



EMERGING INSECT PESTS MENACE IN VEGETABLES AND THEIR SUSTAINABLE MANAGEMENT: A REVIEW

A. B. RAI AND JAYDEEP HALDER

ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh-221305, India

Email: abraiiivr@gmail.com

Unsustainable agricultural production systems, together with unsustainable biotic stresses, have been responsible for several of the recent crop failures. With the changes in cropping system, climate, and introduction of highly input intensive high yielding varieties/hybrids on a global level is the root cause for a shift in insect pest status in time and space resulting in enhanced damage caused by them. Many of them also act as vectors for several viral diseases aggravating the problem still further. In India, yield loss due to major insect pests is reported to vary from 30 to 40%. To control the pest, the farmer still uses chemical pesticides as first choice because of their quick action and easy availability. However many fold problems of indiscriminate usage of chemicals cannot be overlooked. Presently vegetables consume around 13-14% of the total pesticide consumption in India of which insecticides account for two-thirds of total pesticides used in vegetables. The green pods and fruits harvested at shorter intervals and used as vegetables are more prone to retain pesticide residue. Many pests have adapted new hosts, developed resistance to pesticide and often there are secondary outbreaks. Among major biotic constraints in vegetable production in India, tomato fruit borer (*Helicoverpa armigera*, *Spodoptera litura*), brinjal shoot and fruit borer (*Leucinodes orbonalis*), chilli thrips (*Scirtothrips dorsalis*) and mite (*Polyphagotarsonemus latus*), fruit and shoot borer (*Earias* spp.) on okra, diamondback moth (*Plutella xylostella*) on cole crops, fruit fly (*Bactrocera cucurbitae*) on cucurbits are important ones. Some of the new pests that have emerged are of great concern to sustainable vegetable production. Insect pests like serpentine tomato leaf miner (*Liriomyza trifolii*), Spiraling whiteflies (*Aleurodicus macfarlanei*), brinjal gall midge (*Asphondylia capparidis*), okra stem fly (*Ophiomyia phaseoli*) and bitter gourd leafhopper (*Empoasca mottii*) are gradually attaining the major pest status in different regions of the country and more recently pinworm (*Tuta absoluta*) on tomato, mealy bug (*Phenacoccus solenopsis*) on several vegetable crops, Hadda beetle (*Henosepilachna vigintioctopunctata* and *Epilachna dodecastigma*) on cowpea and bitter gourd, Plume moth (*Sphenaeches caffer*) on bottle gourd; Spotted pod borer (*Maruca vitrata*) on cowpea and field bean, melon weevil

(*Acythopius curvovistris citrulli*) on sponge and ridge gourds, mirid bug (*Nesidocoris cruentatus*) on bottle gourd, phytophagous mites (*Tetranychus neocaledonicus*, *T. urticae*, *T. cinnabarinus* and *Polyphagotarsonemus latus*) have intensified the severity of occurrence. In this context, Integrated Pest Management (IPM) system involving use of bioagents and biopesticides along with cultural, physical measures possesses in depth promise in pest management and needs to be brought to the fore aggressively. Public-private partnership in production, distribution and quality control of various components of IPM such as resistant varieties, natural plant products, biopesticides, natural enemies, etc., is imperative, otherwise we will continue to talk of alternative methods of control for several years to come.

Insect pests are the major biotic constraints to vegetables production. Apart from causing direct damage many of them also act as vectors for several viral diseases. The crop losses to the tune of 30-40 per cent have been reported in vegetable crops (Rai *et al.*, 2014b). Insect pests of much significance to vegetable crops and yield loss are given. In recent past, with changes in the cropping pattern, ecosystems and habitat, climate, and introduction of input intensive high yielding varieties/hybrids, a shift in pest status has been realized in time and space. Most of the plant protection recommendations in vegetables so far indicated the calendar based application of insecticides. This has become a common practice over the years by most of the farmers, growing vegetables in the country. Many pests have adapted new hosts, developed resistance to pesticide and often there are secondary out breaks.

Current shift in the pest scenario

Some of the insects pests of vegetable crops become major and are gradually attaining the major pest status in different regions of the country due to changes in the ecosystem and habitats are *Helicoverpa armigera* in tomato, whitefly *Bemisia tabaci*, serpentine leaf miner *Liriomyza trifoli* on tomato and cucurbitaceous crops, fruit fly on fruits and vegetables, mealy bugs on several horticultural crops, gall midge on brinjal, okra stem fly and bitter gourd leafhopper, red spider mite on okra,

brinjal, cowpea, Indian bean and nematodes on several vegetable crops. In recent times there were out break of gall midge, which was known to be minor pest and gradually becoming a regular problem in chilli and capsicum and brinjal in the states of A.P. and Karnataka and in brinjal in Chhattisgarh (Rai *et al.*, 2014a). Various species of mealybugs in cotton, vegetables and papaya have intensified their severity of occurrence in different parts of the country and have become indicator insects for the current ecosystems due to slow changes in climate in the last one decade. Several national and international polyphagous pests like termite, white grubs, hairy caterpillars and *Spodoptera litura*. This envisages that there is a need to relook into the cropping systems for reorientation and vegetables should be given importance with adequate insect pest management measures. In this context, Integrated Pest Management (IPM) system was developed out of the need for sustainable crop protection strategy against the background of increasing pesticide use and deleterious effect of residues in the environment.

Melon weevil: Melon weevil (*Acythopeus curvirostris citrulli* (Marshall) (Coleoptera: Curculionidae) is an emerging serious borer pests of gourd crops especially sponge and ridge gourds. The pest was first recorded from Varanasi, India on sponge gourd. About 70-80 per cent fruits and 30 per cent shoots were damaged by this weevil (Halder *et al.*, 2016). Gravid females lay eggs in small batches on the tender fruits just beneath the rind and on hatching, grubs start feeding on the soft, tender fruit pulp and continue till pupation. Due to its feeding, the affected fruits rot and there was no seed formation. Pupation occurs inside the fruits. Cocoons are hard blackish in colour made up of fibrous materials of the fruits and larval excreta. Adults emerge from the dry fruits by making small emerging holes. Affected fruits exhibit characteristic brown gummy encrustations on the fruits which significantly reduce its market value.

Management: Amongst the duo gourd crops, sponge gourd was most preferred by the *A. c. citrulli* than the ridge

gourd. The summer sponge and ridge gourd crops suffered less damage than the rainy season crops. Similarly early sowing crops had lower infestation than the late sown. Halder *et al.*, 2016 observed that significantly lowest fruit damage (43.48%) was recorded in the sponge gourd grown in raised bed system than the trailing system (80.73%). Among the biopesticides, *Lecanicillium lecanii* at recommended dose was found most effective (LT50= 87.84 h) followed by *Metarhizium anisopliae* (LT50= 101.08 h) and they were also found compatible and synergistic in nature with neem oil (1%) (Halder *et al.*, 2016). Amongst the insecticides Quinalphos, Deltamethrin and Thiodicarb were found promising and caused 100% mortality within 24 hours under laboratory conditions.

Bottle gourd mirid bugs: Two mirid bugs species viz., *Nesidiocoris cruentatus* (Ballard) and *Metacanthus pulchellus* Dallas (Hemiptera: Miridae) were been recorded as a serious and emerging pests of bottle gourd from Varanasi, Uttar Pradesh, India. Studies indicated that about 70-80 per cent fruits and 30 per cent shoots were damaged by these bugs. Infested leaves showed a minute puncture spot with yellow hallow. While damage was more prominent on young fruits with typical brown puncture spots often in the form of irregular lines on the rind with sap oozing out from the tender fruits formed the characteristic symptoms of these sucking pests (Halder *et al.*, 2017a). Affected fruits therefore had significantly reduced market value. Studies on species composition of duo mirid bugs revealed that *N. cruentatus* was dominant species contributing overall 68.63% of the mirid bug population infesting bottle gourd followed by *M. pulchellus* (31.37%).

Management: Amongst the different plant parts, highest number of *N. cruentatus* (26.39%) was oriented towards apical buds followed by young leaves (16.67%) and tender fruits (15.28%) so spraying should be done on these following plant parts. Trailing (bower) system of cultivation harbored significantly the highest number of bugs per tender shoot (7.2) than the raised bed system (1.35). Amongst the biopesticides tested, neem oil (1%)

Table 1. Changing pest scenario in vegetable crops in India

Pest	Crops affected
Serpentine leaf miner (<i>Liriomyza trifolii</i>)	Tomato, brinjal, leafy vegetables and cucurbits
Spiralling whiteflies (<i>Aleurodicus macfarlanei</i>)	Bhendi
Mealy bug (<i>Coccidohystrio insolita</i> , <i>Pheococcus solanopsis</i>)	Brinjal, chilli, okra, Pointed gourd
Leafhopper (<i>Empoasca motti</i>)	Bitter gourd
Fruit borer (<i>Helicoverpa armigera</i>)	Peas
Cabbage butterfly (<i>Peiris brassicae</i>)	Cabbage and cauliflower (in plain regions/ nonhilly regions)
Gall midge	Chilli, capsicum and brinjal

was found most promising with lowest median lethal time (LT50) (50.31 h) followed by entomopathogenic fungi, *B. bassiana* (52.26 h) and *L. lecanii* (56.59 h) whereas Flonicamid 50% WG and Spiromesifen 22.9% SC were most promising chemicals under field and laboratory conditions (Halder *et al.*, 2017a).

South American tomato pinworm: South American tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a key oligophagous pest of tomato originating from South America and recently introduced to India. It causes reductions in yield and fruit quality, to a tune of 50–100% loss in either greenhouses or fields. Plants are damaged by direct feeding on leaves, stems, buds, calyces, young and ripe fruits and by caterpillars and the invasion of secondary pathogens which enter through the wounds made by the pest (EPPO 2005).

In India, its infestation was first recorded from Pune, Maharashtra and subsequently spread to other tomato growing states viz., Karnataka, Tamil Nadu, Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Gujarat, Uttar Pradesh and Kerala. Larvae feed on the mesophyll tissues of the leaves, leaving only the epidermis intact. They often cause conspicuous irregular leaf blotches which later turned to necrotic. Tomato plants, from seedlings to mature stage, attacked by this pest. On fruits, small minute pin sized hole is often visible. Damaged fruits with frassy galleries accompanied by an open areas acts as entry paths for invasion by secondary pathogens, leading to fruit rot is the common symptom of this nefarious pest (Halder *et al.*, 2017b).

Management: *Tuta absoluta* has a strong affinity towards solanaceous plants. Apart from tomato (*Solanum lycopersicum*), it can also attack potato (*Solanum tuberosum*), Chillies (*Capsicum annum*), eggplant (*Solanum melongena*) and black nightshade (*S. nigrum*). Amongst the different biopesticides, *Bacillus thuringiensis* var *Kurstaki* was found most promising causing 66.7 and 73.37% mortalities at 48 and 72 h after the treatment followed by *Bacillus subtilis*-2 and the corresponding values were 53.36 and 66.70%, respectively, under laboratory conditions (Halder *et al.*, 2017b). The egg parasitoid, *Trichogramma achaeae* Nagaraja and Nagarkatti (Hymenoptera: Trichogrammatidae) has been recommended for the control of new invasive pest, South American pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in tomato in Azores Islands (Oliveira *et al.*, 2017).

White plume moth: White plume moth, *Sphenarches caffer* (Zeller) (Pterophoridae: Lepidoptera), is a serious pest of lablab, beans etc. (Nair, 1995, Sujithra *et al.* 2010). Recently, it attained its pest status as an apical bud and foliage feeder in bottle gourd as they damaged the leaves and buds of bottle gourd by scrapping the chlorophyll

portion thereby reducing the photosynthetic activity of the plants in and around Varanasi region. However, damage is more severe when they feed on the emerging buds resulting in restricted growth of the buds with characteristic black excreta inside it (Halder *et al.* 2014). During the peak summer months of May-June when atmospheric temperature was around 45°C in Varanasi its incidence was also observed and from mid-October onwards when *rabi* season bottle gourd was in its vegetative stage there was no incidence of this plume moth. Sujithra *et al.* (2010) from Tirupati, Andhra Pradesh reported *S. caffer* as one of the major pod borer of field bean. However, in Varanasi region incidence of this plume moth is restricted to bottle gourd.

Management: Hand collection and destruction of the larvae is beneficial. Conservation of solitary, larval, endoparasitoid *Apanteles paludicole* (Braconidae: Hymenoptera) (maximum parasitization 40.91%) (Halder *et al.* 2014) and chalcid pupal parasitoid, *Tropimeris monodon* are beneficial. Need based application of *Bacillus thuringiensis* @ 1 kg/ha is able to control this pest.

Serpentine leaf miner: The American serpentine leaf miner, *Liriomyza trifolii* Burgess which is a native of Southern United States of America and Central America has spread to other countries in seventies along with *Chrysanthemum* flowers. It is suspected that this species has entered in Karnataka along with plant materials during 1990-91 (Viraktamath *et al.*, 1993) and then spread in many other parts of the country like Andhra Pradesh, Maharashtra, Gujarat, Tamil Nadu, Uttar Pradesh, West Bengal, Delhi, Haryana and Madhya Pradesh. Srinivasan *et al.*, (1995) reported 78 host plants covering pulses, fibre, vegetables, ornamental and flowers, green manuring, fodder crops, narcotics and weeds belonging to 16 families. In vegetables, three species of this pest are reported and they were found in infesting tomato, French bean, cow pea, cluster bean, summer squash, cucumber, melons etc. The losses to the extent of 15-70 % in French bean, 41% in cucumber and 35% in tomato have been reported by Kumar (1998) from Karnataka. The pest can be managed by using yellow sticky traps in the field for monitoring the presence and mass trapping of adults and exploiting the natural enemies. Recently, a new parasitoid *Neochrysocharis farmosa* (Eulophidae: Hymenoptera) has been reported from this leaf miner. During February-March the per cent parasitization was 37.5 at Varanasi region, Uttar Pradesh, India (Halder *et al.*, 2018). In Hawaii, Gyaana and Senegal this pest was controlled by inundative release of parasitoids viz., *Hemiptarsenus*, *Chrysocharis* and *Chrysonomyia* sp. (Puri and Mote, 2004). In another study it was also revealed that marigold (*Tagetes erecta*) plant serve as an attractant for this leafminer besides it also attract large number of parasitoids *N. farmosa*.

Management: It has been observed that higher dose of

nitrogen favours the populations build up of this pest. There by judicious nitrogen application reduces pest build up in endemic areas. Periodically infested leaves should be removed and destroyed. Application of NSKE 4% with a sticker found to be effective to deter the leaf miner. In case of severe infestation, spraying of imidacloprid 17.8 SL @ 0.3 ml/lit. of water during early stages of crop growth before flowering is effective. Kumar et al., 2010 reported that seed treatment with Imidacloprid 70 WS @ 3 g/kg seeds or foliar applications of neem seed extract (NSKE) 5 per cent on 10 days after germination gives better result in controlling the serpentine leaf miner.

Phytophagous mites: The predominant mite species associated with vegetables are *Tetranychus neocaledonicus*, *T. urticae*, *T. cinnabarinus* and *Polyphagotarsonemus latus*. *T. urticae* Koch also called as two spotted mite is one of the most common and destructive species of mite which is cosmopolitan in distribution and is highly polyphagous in nature. It is commonly associated with plants like ladies finger, brinjal, beans and cucurbits (Singh, 2004). *T. cinnabarinus* though mainly feeds on cucurbits like pointed gourd, cucumber, melons, gourds but also found on a number of other crops including brinjal, beans, onion, peas, cole crops, tomato, sweet potato and various ornamental crops (Butani and Jotwani, 1984). *Polyphagotarsonemus latus* or yellow mite has also been identified as serious pest on chilli and beans. Due to infestation of this mite in chilli the underside of the leaves turns reddish and plants become rosetted. The Murda disease of chilli is due to infestation of this mite. During recent years major bottle neck of chilli growers in Varanasi region, Uttar Pradesh is heavy infestation of this mite which needs immediate attention.

Management: During initial stage of infestation destruction of severely attacked plant part mechanically reduces mite population. Conservation and release of native predatory mites if available also can minimize the mite populations from the field. Using botanicals like *Kochea* and *Duranta* leaf extract showed strong acaricidal action under field conditions (Rai et al., 2007). In case of severe infestation, spraying of Dicofol @ 2.5 ml/lit or Propargite @ 3 ml/lit (Singh and Singh, 2004) or Fenazaquin @ 1.5 ml or Spiromesifen @ 0.75 ml/lit or Chlorfenapyr 10 SC @ 1.5-2 ml/lit of water should be done at 10 days interval at the initiation of symptoms (Halder et al., 2015).

Fruit flies: It has been estimated that in India fruit flies alone cause 35 to 40% losses in gourds. Kapoor and Agarwal, 1980 and Kapoor, 1993 reported 159 host plants of various species of fruit flies from India. Among these *Bactrocera dorsalis*, *B. cucurbitae*, *B. zonata* were recorded on different vegetable crops. If uncontrolled these pests are capable of causing substantial losses, which can not be tolerated. Beside these, this pest is very

important in export point of view. Therefore, successive cultivation and export are highly relying on sound pest management system.

Management: Infected and damage fruits are often serve as source of infestation. So all the infested fruits should be collected and destroyed. Earthing up of the soil around the vine helps in exposing the pupae for desiccation and predation by predatory birds. Ploughing the infested field after the crop is harvested can help in killing the pupae. Apply the bait spray containing 20 ml Malathion 50 EC + 10 g protein hydrolysate+ 500g of molasses/jaggery in 20 lit of water per acre. When the attack is serious, it should be repeated at weekly intervals. Male annihilation techniques (MAT) of adult flies through plastic bottle trap with ethanol, any insecticide (Carbaryl / DDVP / Malathion), cuelure (6:1:2) coated in wooden block. Installation of such trap @ 25-30 traps / ha is advisable (Rai et al., 2014a).

Mealy bug: Polyphagous, soft bodied this insect previously known as a minor pest in vegetables but now possess a new threat to most of the cultivated crop plants. Presently, they feed more than 400 host plants covering cereals, pulses, oil seeds, fruits, vegetables, ornamental crops as well as many weeds including *Parthenium*. Amongst vegetable crops, they were found to attack on variety of plants belonging to malvaceae (ladies finger), solanaceae (tomato, brinjal, potato, chilly), leguminosae (cow pea, filed bean), cucurbitaceae (pointed gourd, cucumber, melons and gourds). Besides sucking the sap, they also secrete the copious amounts of honey dew which is deposited on the plants and create black sooty mould and there by reducing the photosynthetic activity of the plants.

Management: It is a polyphagous pest so proper management practices should be taken.

Removal of alternate hosts and weeds like *Parthenium hysterophorus* from the field will help to

reduce the pest incidence. Ants also help in transmitting the mealybug beside they give protection to mealybugs against its natural enemies. So, destruction of the ants' colonies during land preparation is recommended. Uprooting and burning the affected plants reduce the pests load from the field. Spraying of fish oil resin soap (FORS) @ 20 g/lit of water or entomopathogenic fungi *Verticillium lecanii* (2 x 10⁸ cfu/ml) @ 5 g/lit of water give better control. Recently, Patel et al., 2010 reported that Buprofezin @ 625 g ai/ha is effective in controlling this pest.

Giant African snail: Giant African snail, *Achatina fulica* is a polyphagous and one of the world's most damaging land snails. It is originated in mid Africa and now spread all over the world mainly the countries have tropical climates with warm, mild year-round temperatures and high

humidity. Being polyphagy, it voraciously feed many vegetable like colocasia, elephant foot yam, cucumber, cow pea, field bean, pea, ladies finger, tomato etc. Its sporadic outbreak noticed in about 300 ha in Sapur during 1998 and in 150 ha area of Nashik of Maharashtra and causing havoc damage to the crops like bitter gourd, beans, bottle gourd, chilli, tomato and cauliflower (Puri and Mote, 2004).

Management: Clean cultivation and establishment of physical barriers like wrapping of tree trunks with copper foils around the trees etc. that restrict the movement of snails has long been practiced. Beside this, Metaldehyde bait (2.5%) is recommended to control this pest.

Critical issues in and their management

Melon weevil

- Being an internal feeder it is difficult to control with insecticides
- Search for suitable biocontrol agents including microbials are need of the hour
- Over lapping generations and short life-cycle
- Need ecofriendly IPM strategy

Bottle gourd mirid bugs

- Microbial pesticides and botanicals need to be tested
- Round the year bottle gourd cultivation helps them quick multiplication
- Regular monitoring of the pest for early damage

Tomato pin worm

- Wide host range and oligophagy nature made it difficult to control
- Damage symptoms on leaves often resembles with serpentine leaf miner
- Lack of awareness and knowledge about this exotic pest to the farmers
- Need domestic quarantine for interstate transport if transported from pest endemic state

White plume moth

- Soft and delicate insect, so, emphasis should be given on biopesticides during its management
- Conservation of its endoparasitoid *Apanteles paludicole*

Serpentine leaf miner

- Being an internal feeder it is difficult to control with insecticides
- It can survive even in weeds, wide host range make

them difficult to control

- Need regular monitoring using yellow sticky traps
- More emphasis should be given on trap crop, Mary gold

Fruit flies

- Pupation takes place in soil, so difficult to control until soil treatment is done
- Hence internal feeder difficult to identify at early stage of infestation
- Export point of view, needs pest risk analysis
- More emphasis should be given on behavioral management.

Mites

- Tiny and microscopic creature, difficult to observe
- Cultivation of vegetables throughout the years
- Excessive use of insecticides with higher doses
- Most of the time acaricides are applied on the upper surface of the leaves
- They can transmit from one place to another by means of air current *i.e.*, ballooning
- Biological control agents like predatory mites will give long term control

Mealy bugs

- Protective waxy coating over the body
- Insecticides are not much effective and they also cause residue problem
- Honey dew attracts the ants which give them protection against natural enemies
- Ants also held responsible for physical movement of this pest
- Biological control with Australian lady bird beetle, *Cryptolaemus montrouzeiri* and biopesticides like whit halo fungus, *Verticillium lecanii* may be encouraged

Giant African snail

- It thrives in high humid areas
- It spread through egg or juvenile stages
- Management required community based approach
- Very less number of known natural enemies

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