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Pest complex of Cucurbits and their management: A review

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Abstract
Cucurbits, belong to family Cucurbitaceae, commonly known as guard family has been reported to be adversely affected by a range of biotic constraints, out of which, insect-pests are important. There is a need for effective and economic pest control/management which requires the use of cultural, mechanical, biological, and chemical methods. The combination of these different methods is necessary for achieving good management of pests. Pest management can be achieved only by a long-term assurance to integrated pest management practices (IPM). IPM involves the strategic use of resistant varieties, cultural measures, crop rotations, biological control, and selective pesticides. IPM requires an under-standing of the interaction between pests, plants, and the environment. IPM must ensure optimal use of chemical pesticides and minimum environmental contamination to maintain crop production. In this regard, there is a need to implement eco-friendly pest management practices by proper identification of the pest.

Keywords: Cucurbits, eco-friendly, integrated pest management practices (IPM)

Introduction
Cucurbits consist of wide range of vegetables belong to family Cucurbitaceae, commonly known as guard family. Cucurbitaceae family has about 110 genera and between 650 to 850 species distributed throughout the world [1]. Cucurbits exclusively include various species viz. *Cucumis* (cucumber, muskmelon), *Cucurbita* (pumpkin, gourd, squash), *Lagenaria* (bottle gourd), *Luffa* (sponge gourd) and *Momordica* (bitter gourd) [2]. The fruits of cucurbits are beneficial for human health which help in purification of blood, improve digestion, boost energy level in the body and remove constipation [3]. Apart from that, member of Cucurbitaceae family like *Benincasa hispida* contains volatile oils, flavonoids, glycosides, carotenes, ß-sitosterin and uronic acid which are of pharmaceutical importance [4]. The major elements present as phytochemical in cucurbits are most commonly the terpenoid substance called Cucurbitacins [5]. In present scenario, there are a group of abiotic and biotic constraints affecting the production and productivity of the crop [6] thus, adversely affecting the qualitative and quantitative yield of the crop. Among the biotic constraints, cucurbits are attacked by different insect and non-insect pests during different growth stages. Various attacks done to the crops are in the form of defoliation of leaves, damage to roots and flowers, reduction in quality of crop stand and ultimately decrease in commercial yield of the crop. In cucurbits, although, the pest complex does not directly attack the commercial part of the plant that is the fruit, they severely damage the crop stand which indirectly reduces the potential yield of the crop. It has been estimated that a single insect pest fauna of fruit fly, *Batocera cucurbitae* can cause a broad range of crop loss in cucurbits which is from 20-39 per cent crop loss in cucumber to about 76-100 per cent crop loss in musk melon [7]. From this emergency, the study related to the pest complex of cucurbits is worth to be learnt along with their possible managements.

Different pest complex of Cucurbits
A wide ranges of pest complex have been noticed infesting the cucurbits which can be broadly categorized into 2 types viz. Sap suckers and Leaf feeders.

Sap suckers and Leaf feeders of cucurbits

S.No.	Common Name	Scientific Names	Family	Order
Sap Suckers				
1	Melon Fruit fly	*Batocera cucurbitae / Batocera dorsalis / Batocera ciliates*	Tephriridae	Diptera
2	Aphids	*Aphis gossypii / Aphis malvae / Myzus persicae*	Aphididae	Hemiptera
3	Stink bug	*Aspongopus janus*	Pentatomidae	
Leaf Feeders				
4	Pumpkin beetle	*Raphidopalpa foveicolli / Aulacophora cincta / Aulacophora intermedia*	Gelerucidae	Coleoptera
5	Spotted beetle	*Epilachna vigintioctopunctata*	Coccinellidae	
6	Stem boring grey beetle	*Apomecyna saltator*	Cerambycidae	
7	Blister beetle (flower feeder)	*Mylabris pustulata*	Meloidae	
8	Plume moth	*Sphenarches caffer*	Pterophoridae	Lepidoptera
9	Snake guard semilooper	*Anadevidia peponis*	Noctuidae	
10	Pumpkin leaf caterpillar	*Diaphania indica*	Pyralidae	
11	Stem borer /clear winged moth	*Melittia eurytion / Melittia cucurbitae*	Aegeriidae	
12	Leaf miner	*Liriomyza trifolii*	Agromyzidae	Diptera
13	Stem gall fly	*Neolasioptera falcata*	Cecidomyiidae	

Sap suckers infesting cucurbits

1. Melon Fruit fly

Life cycle: The melon fruit fly remains active throughout the year however, they hide and huddle together under dried leaves of bushes and trees during the severe winter months. During the hot and dry season, the flies feed on honeydew of aphids infesting the fruit trees [8]. Generally, the females prefer to lay the eggs in soft tender tissues on the fruit surface by piercing with the ovipositor. Sometimes, the eggs are also laid into unopened flowers [8-10]. The eggs are laid shiny to creamy white, slightly curved, nearly 1.3 mm in length, oblong, bananas shaped and tapering at one end while rounded at the other end [9, 11]. The eggs are fixed vertically or slightly at an angle and touching each other. The eggs are laid singly or in clusters of into flowers or tender fruits [9]. The egg incubation period on pumpkin, bitter gourd and squash gourd has been found to be longer (4.0 to 4.2 days) [13] than on cucumber and sponge gourd (1.1 to 1.8 days) [14]. The maggots, after hatching of eggs, bore into the pulp tissue and make the feeding galleries. The full-grown maggot comes out of the fruit by making one or two exit holes, hops out of the fruit to pupate in the soil at a depth of 0.5 to 15 cm. The depth up to which the larvae move in the soil for pupation, and survival depend on soil texture and moisture [15, 16]. In general, it has been observed that the pupal period lasts for 6 to 9 days during the rainy season and 15 days during the winter [11]. After the stipulated time period, the adults come out from the soil. The males mate with females for 10 or more hours, and sperm transfer increases with the increase in copulation time. It has been observed that egg hatchability is not influenced by mating duration [17]. It has been reported that the males and females survived for 65 to 249 days and 27.5 to 133.5 days respectively [18].

Stage of Infestation: Starting from the hatching of eggs, the first instar maggot infests the fruit by entering at its soft tissues. The oviposition puncture by the female, lead to rotting of fruit, thus, deteriorating the quality of fruit. The four stages of maggot actively feed inside the fruit and develops quickly by passing three instars [9].

Damage Symptoms and Extent of Loss: Young maggot move to healthy tissue of the fruit, where they often introduce various pathogens, secondary infections and initiate decomposition. One of the most prominent scavengers, the vinegar fly, *Drosophilla melanogaster* has also been observed to lay eggs on the fruits infested by melon fly [12]. As a result of this type of infestation, premature drop of fruits and decay of fruits occur due to the bacterial infections. Depending on the cucurbit species and season of infestation, the extent of losses varies between 30 to 100%. Fruit infestation by melon fruit fly in bitter gourd has been reported to vary from 41 to 89% [8, 11, 19-22]. It has been reported that melon fruit fly causes 31.27% damage on bitter gourd and 28.55% on watermelon in India [8, 23].

Management: Melon fruit fly is a serious internal feeder of all the cucurbits. So, the more application of insecticide does not seem to be fruitful against them. A proper integrated pest management strategy needs to be followed. Local area management practices like bagging of fruits, field sanitation, protein baits and cue-lure traps, host plant resistance, biological control and soft insecticides can be employed to keep the pest population below economic threshold in a particular crop over a period of time to avoid the crop losses which is the immediate concern of the farmers [8]. Bagging of whole trees or fruits can be done with mosquito netting, shade-cloth or nylon fly screen. Large nets will need to be supported by a frame. Furthermore, individual fruits or branches can be protected by making bags or sleeves out of cloth such as gauze curtain material, muslin or mosquito netting. Bagging of fruit is an environmentally safe method for the management of this pest. In cucumber, the beg kept for 3 days for anthesis should be retained for 5 more days in order to control the fruit fly effectively [24]. Field sanitation and burying damaged fruits 0.46 m deep in the soil prevents emergence of adult fly and reduces population increase [25]. The biological agents like *Opius fletcheri*, *Fopius arisanus*, *Steinernema carpocapsae*, *Rhizoctonia solani* have been tested as effective against melon fruit fly but their effective parasitization potential under field condition yet to be proved [26-29].

2. Aphids

Life cycle: Adult females give birth to wingless nymphs which later on become adults after moulting by shedding the skin multiple times within seven days. Their populations can increase rapidly as each adult reproduces numerous nymphs in a short interval of time. The green peach aphid, *Myzus persicae* is slender, dark green to yellow body without any waxy bloom on body surface. They tend to aggregate on soft-succulent parts of plant. Only 10–12 days are required to

complete one generation and about 20 generations or more are produced annually under mild climates [30]. Aphids are small about 3 mm long, soft-bodied, pear-shaped insects. The adults are usually wingless. The winged forms appear when populations are high during spring and autumn season. Most species have a pair of tube-like structures called cornicles projecting outwards from their abdomen. The majority of aphid species reproduce asexually through parthenogenesis. Aphids are considered to be the most important vector for the transmission of viruses throughout the world with equal capability of both nymphs and adults [31].

Stage of Infestation: Both nymphs and adults suck the sap from the succulent plant parts. Nymphs congregate at the lower surface of the leaves, soft growing tips, flower buds and flowers. Later on, adults move to the rest of the plant and infest in the same way. They inject toxins which causes the malformation in leaf and flower growth. The distinct feature of aphid is that they excrete copious amount of honeydew which acts as a substrate for sooty mould (fungi) development on the plant parts. Honeydew also acts as the feed for ants that safeguards the aphids thereby, interferes in the efficient biological control of the aphids [32].

Damage Symptoms and Extent of Loss: Downward curling and crinkling of leaves are the first symptom of the aphid infestation. A variety of symptoms including reduced plant growth and vigour, mottling, yellowing, browning, curling or wilting of leaves, which result in low yields and sometimes death of plants are noticed. Salivary toxins infected by the aphids causes the puckering and curling of leaves that help them to protect themselves from natural enemies and insecticides [32].

Management: Due to their rapid multiplication rate, frequent monitoring i.e. at least twice a week with special attention on the under surface of the leaves should be done. The existing population of aphids can be monitored by installing the yellow sticky traps 2-3 weeks prior to planting. Culturally, the application of reflective mulches (aluminium foils) can repel the aphid population and check virus transmission in young plants [31]. Reflective polyethylene and biodegradable synthetic latex spray mulches are found to be effective for the management of aphids and aphid-borne virus diseases on late-season melons [33]. Organic chemical controls include potassium soap and petroleum oil which can be sprayed on the nymphs. Endosulfan, Dimethoate, Lannate, Fulfill and Actara are recommended for aphid control. Detergent and vegetable oil solution can be sprayed before destroying old crops to avoid winged virus-infected aphids from getting to nearby crops [32].

3. Stink bug

Life cycle: The cucurbit stink bug, *Aspongopus janus* are major pests of cucumber, bitter gourds, water melon, musk melon and other cucurbitaceous gourds. Adults are red to pale- brown bugs. The insect has orange to orange- brown stripes on the edges of the abdomen and underneath body parts. Eggs are pearly white which later on turn cream or pinkish coloured. Early nymphal stages resemble the adults in shape but have various markings and patterns. Nymphal stages have no wings, but develop prominent wing pads during fourth and fifth instar [34].

Stage of Infestation: Both nymphs and adults are injurious to plants. They suck the plant sap from leaves and tender parts of the plant. In the process of feeding, they usually open a path for pathogens to enter inside the plant [35].

Damage Symptoms and Extent of Loss: Both nymphs and adults suck the sap from the soft- proximal parts of the plant thereby, reduces the quality vegetative growth. The plants wither, shows yellowing symptoms and finally devitalizes.

Management: Generally, stink bugs are monitored by sweep net and beat sheet sampling methods in field crops. But cucurbits stink bugs can be monitored using blacklight traps. Blacklight trap catch may be helpful for improving the timing of scouting and management methods for stinkbugs [36]. Most stink bug parasitoids are tachnid flies which usually oviposit on the abdomen of the host. *Trichopoda pennipes* is one of the classical examples [34]. Broad-spectrum insecticides like organophosphates and pyrethroids are the frequently applied insecticides against stinkbug management [37]. Dusting of 4% Carbaryl or spraying of Malathion 50% EC @ 1.5ml/litre water is useful in controlling the pest.

Leaf feeders infesting cucurbits

4. Pumpkin beetle

Life cycle: It is a major pest of almost all the cucurbits and is polyphagous in nature. The female lays eggs in the moist soil near fallen dead leaves or at the base of the host plant in clusters of 8–9 that hatch into larvae in 6–15 days. The eggs are brown and elongated in shape. Generally, beetle starts laying after 7 days of emergence and complete about 5 generations before October. The grubs are 10-12 mm long, possess creamy-white body with conspicuous brown heads which feed on the basal part of the host touching the soil. Adult beetles are deep orange with black coloured back. It is oblong with oblong about 5–8 mm length, 3.5–3.75 mm width and bears soft white hairs on the posterior part of the abdomen [32].

Stage of Infestation: Both grub and adult are voracious feeders of cucurbits. They actively feed on all parts of the plant starting from root to the leaves.

Damage Symptoms and Extent of Loss: The grub feeds on the roots, stems, and fruits touching the soil [38]. The damage done by the grub may attract rot infection by the saprophytic fungi in the under-ground root and stem of the plant. Adult beetles cause the net like appearance on the leaves by feeding voraciously on the leaf lamina and by scrapping off the chlorophyll. They attack the plant mostly at the cotyledon stage. The beetles may kill seedlings and sometimes the farmer has to resow the crop for 3-4 times more than the normal [39]. As a result of such attack, the young and smaller fruits of the infested plants may dry up and the bigger and mature fruits become unfit for human consumption. They are so serious pest that their damage may reach up to a loss of 35-75% at seedling stage [40] and 30-40 % at the field condition [41]. Sweet gourd was the most suitable and bitter gourd was the least suitable host for red pumpkin beetles [42].

Management: The pest should be monitored at least twice a week to check their infestation at the seedling stage. During the initial period of the pest infestation, hand picking of the beetle is advisable. If defoliation is severe, preventive

measures like burning of old plants, ploughing, and harrowing of field after harvest of the crops are followed in order to control the pest population. Early plantation of cucurbits should be done in order to escape the cotyledon stage of the plant from the active stage of the beetles. Use of botanicals and entomopathogenic fungi *Beuveria bassiana* against the beetle control the pest population and simultaneously gives better yield in bottle gourd [43]. Extract of weed species like *Parthenium* spp. also found to be effective against red beetle population [44]. Chemical controls like synthetic pyrethroids are found to manage the beetle population efficiently.

5. Spotted beetle

Life cycle: It is an occasional pest of cucurbits but, attacks seriously on bitter gourd, pumpkin and squash. The females lay eggs up to 300-400 in number in clusters on the under-surface of the leaves that hatch into yellowish larvae. The larva is of 7–9 mm long. Full-grown larvae pupate below the leaf or at the base of the stems by hanging from the leaf. Pupa is yellow in colour and lacks spines. The adult beetles are yellowish-brown, medium-sized (6–8 mm long) and globular. Adults bear 12–28 black spots on the elytra [32].

Stage of Infestation: Both grub and adult attack various stages of the cucurbits. It has been observed that grubs feed only on the underside of the leaves while the adult feed on both side of the leaves and also on the soft rind of the fruit. Adults overwinter under the leaf litter or loose tree bark near the edge of the plant [45].

Damage Symptoms and Extent of Loss: The grubs scrap the epidermis of the leaves while the adults cut the leaves in a semi-circular manner. Young plants are vulnerable to the damage as compared to the older plants. They also cause the spiral shaped scars on the fruits which reduces the market value of the crop [45].

Management: Hand picking of grubs, crop rotation, harrowing and destroying of vines and grubs after the harvest of the crop are some of the cultural methods to minimize the pest population. Weekly foliar spray of aqueous NSKE at different concentrations (25-100gm/lt.) of or ultra-low volume spray of neem oil (10-20 lt/ ha.) help in controlling the feeding activity of *Epilachna* beetle in cucumber and squash [46]. The leaf extract of *Tephrosia* is found to be efficient in killing the *Epilachna* adult and prevent the pupae formation, when applied at a dose of 20gm per 100 ml. of water [47]. If the infestation is severe, chemical control comes to action. Chemically, the beetles may be controlled through foliar applications of synthetic pesticides like parathion, malathion, pyrethrin, spinosad, rotenone etc.

6. Stem boring grey beetle

Life cycle: These cerambycid members are infrequent feeders of cucumbers, pumpkins, squashes, watermelons, and gourds. Adult female lays whitish-yellow, oval eggs in the holes at the nodal joints of vines [48]. The grubs are cream coloured and about half an inch long when full grown which, pupate within a fibrous cocoon within the stem. The slate-grey adult beetle is about a half an inch long with several white spots arranged in three evenly shaped V-markings across the wing covers [49]. The adult has a very long antennae about two-thirds the length of the body like other beetles belonging to the Cerambycidae family.

Stage of Infestation: The grub usually feeds on the stem by boring into it.

Damage Symptoms and Extent of Loss: Soon after the grubs boring into the stem, sap often oozes out from these holes and closes up the opening which later on swell and split open the squash vines. The feeding tunnel is usually directed towards nodes and is filled with glutinous waste material. Under very severe infestations young plants may die, but older plants often live to produce fruit at reduced yields [49]. The grubs also cause gall formation and withering of the vines in snake gourd [50].

Management: In order to reduce the chance of planting infested material, seedling should be carefully examined for presence of grubs and adults in the roots and shoots. The plant residues of harvested material should be destroyed immediately after harvest to prevent grub and pupae before starting new crop. In maximum cases, studies suggest that endosulfan, chlorpyrifos and fenvalerate used to give 70 - 85 per cent control. Malathion and Carbaryl provide lower rates of control [51].

7. Blister beetle

Life cycle: The common blister beetle (a flower feeder), *Mylabris pustulata* is a common pest of leguminous plants but, it has been observed that it has a wide range of host including the members of Solanaceae, Malvaceae and Cucurbitaceae family [52]. Among the cucurbits, they particularly attack on pumpkin, ribbed gourd, bottle gourd etc. Mostly they feed on yellow and white coloured flowers, hence called flower feeders [53]. The members of sub-family Meloinae lay their egg in the soil while the blister beetle of sub-family Tetraonycini and in Nemognathinae are laid under flowers and bracts or in their host nests. Most meloid larvae are predaceous and feed on grasshopper egg pods [54]. In the typical form of blister beetles, hyper-metamorphosis occurs where the larva passes through four distinct phases before entering the pupal stage, such as triungulin, first grub, coarctate and second grub stage. The pupal stage is relatively short lived compared to the coarctate stage [55]. At last, the adult emerges out from the pupae.

Stage of infestation: Adults extensively feed on the floral parts of the cucurbit vines. They prefer the yellow and white coloured flowers of the plants.

Damage Symptoms and Extent of Loss: The attack on the floral parts of the plants possess a great threat for the fruit set. The insect directly affects the fruit set by damaging the pollen and flower stand of the plant. One single adult has a potential of damaging 16.8-19.4 flowers in major pulses [56].

Management: Beetles can be collected through hand nets and then destroyed. Light traps are good source of management against the beetles as they are highly phototrophic. Dusting of Carbaryl and Endosulfan @ 10-15 kg/ ha is effective. The adult beetles can be killed by putting them in kerosinised water.

8. Plume moth

Life cycle: It belongs to family Pterophoridae of order Lepidoptera. The members of Pterophoridae family has flattened, smooth, minutely pitted eggs laid singly on the

tender parts of the plants. Upon hatching, the larvae are active and have 10 prolegs throughout the body. They conceal themselves inside the rolled leaves, buds or broken stems. The pupae are exposed and without any outer cocoon. Pupation takes place near the entrance hole of the pod. Adults are slender, long-bodied, crepuscular or nocturnal. Adult wings are partially opened or with the forewings rolled around the hindwings, the pairs borne horizontally at an angle (or at right angles) to the body which serve as a distinguishable identified characteristics of plume moth. Their forewing has a tibial epiphysis. The adult moth is having deeply fissured wings with frilled edges to look like plumes [57, 58].

Stage of infestation: Larval stage of the pest is harmful to the crop.

Damage Symptoms and Extent of Loss: The recent study found that plume moth larvae extensively damage to the foliage in bottle gourd. It causes damage to the leaves and buds by scrapping the chlorophyll content of the leaf portion thereby reducing its photosynthetic activity of the plants. They also cause severe damage to the emerging buds which result in stunted growth [59].

Management: The pest can be biologically controlled by larval endo-parasitoid, *Apanteles paludicole* with maximum parasitization rate of 40.91 per cent. Pupa are managed by chalcid pupal parasitoid, *Tropimeris monodon* [59, 60]. During the flowering period, Bt var. *Kurstaki* @ 1 kg/ ha can be applied three times at fortnight interval to reduce the pest attack [50, 59]. Chemically, the pest can be controlled through the spray application of Azadirachtin 0.03% WSP, Deltamethrin 2.8% EC, Quinalphos 25% EC and 1.5% DP.

9. Snake gourd semi looper

Life cycle: It is a member of family Noctuidae of Lepidoptera order. It is a pest of cucurbits such as snake gourd, pumpkin, cucumber etc. Sometimes, it is treated as a specific pest of snake gourd [50]. The eggs are white or pale green in colour and laid singly under the leaves. The early instar caterpillar is greenish in colour with black spikes which moves like loopers due to the absence of some prolegs. Generally, pupation takes place in dry leaves or in a sparse cocoon. The moth is having a uniform dark brown body with a golden sheen to its wings [61].

Stage of infestation: Caterpillar of snake gourd semi-looper feeds on the cucurbits and causes huge loss.

Damage Symptoms and Extent of Loss: The caterpillar feed on the tender leaves in the early stages of the crops. Later on, it feed on matured leaves too during the late instars. As a result of this, complete defoliation occurs. The caterpillar is found underside of the leaves. The leaves are found lightly folded.

Management: Hand picking of feeding larvae and pupal stages can be done manually. Biologically, the larvae can be controlled by *Apanteles plusiae.* Methyl Parathion 0.05% can be applied as spray application to control the pest [50].

10. Pumpkin leaf caterpillar

Life history: The leaf caterpillar is a potential pest of different cucurbits viz. muskmelon, cucumber, bottle gourd, bitter gourd, snake gourd etc. causing 14% – 30% yield loss [62][63]. Eggs are laid on the buds, flowers and other actively growing portions of the plant. It undergoes five larval instars before pupation [64]. The adult moths are of medium size, white winged with brown border. The abdomen of the adult bears a tuft of orange hairs at tip [50].

Stage of infestation: The larvae of the pest causes heavy infestation.

Damage Symptoms and Extent of Loss: The larvae feed on various growing plant parts like leaves and fruits. It feeds on the leaves by folding the leaves and scrapping the chlorophyll content. It results in the drying of the leaves. In severe infestation, ovaries of the flower and young developing fruits has been seen being infested by the larvae [50, 64].

Management: The larvae are parasitized by the *Apanteles taragamae, Goniozus sensorius, Elasmus brevicornis.* It has been found that the combination of *Trichogramma chilonis* and *Dolichogenidea stantoni* is effective in controlling the pest effectively [65]. The predators like common mynah, *Acridotheres tristis* and cattle egret, *Bubulcus ibis* are effective in controlling the larvae [50]. Foliar sprays with Quinalphos 2 ml/l or Endosulfan 2 ml/l are effective.

11. Stem borer /clear winged moth

Life cycle: It is an important pest of summer squash and some winter squashes, pumpkins, and gourds that have large and hollow stems but does not attack melons and cucumber [66]. The eggs are flat, brown and laid individually on the stalks of leaves and vines. A larva feeds for about 30 days in the exiting the stem and then pupate in the soil [67]. Adult moths are stout- dark grey coloured with orange abdomen. Unlike the other moths, the active period of the adult moth is during the day time. It appears like a paper wasp [70].

Stage of infestation: The larvae feeds on the stem portion of the vines.

Damage Symptoms and Extent of Loss: The larvae block the flow of water to different parts of the plant by entering and feeding in the stems of cucurbit vines. It causes wilting of plants and finally mortality [68]. Sawdust-like frass near the base of the plant is the best evidence of stem borer activity. The primary feature for distinguishing stem borer from Bacterial wilt and *Fusarium* wilt is frass accumulating at the entrance to the larval tunnel [69].

Management: Traps like wire cone traps, unitrap bucket and nylon mesh *Heliothis* traps, are found most successful for monitoring stem borer [71]. Cultural practices like early planting, floating row covers placed over the crops prevent the egg deposition by the moth. If observed at the early stage, the larvae can be discarded from the vine by slitting the stem longitudinally near the entrance hole with a fine blade. The slit part can be covered with soil to promote new growth [72]. Insecticides like Acetamiprid, Carbaryl and Bifenthrin can be applied twice at a weekly interval to effectively control the early larval stage of stem borer.

12. Leaf miner

Life cycle: It is one of the minor pests of cucurbits which mines the leaf. The whitish, translucent eggs are deposited on

the after making the tubular punctures with the help of ovipositors. Female generally lays eggs with in days 4 to 10 of adult life. The larvae are cylindrical, maggot like, has 4 instars. The fourth instar occurs between the interval of puparium formation and pupation. The larvae usually pupate in the semi circular slit in the leaf surface usually near the end of the mine after making the puparium. The slit may be observed on the upper or lower surface of the leaves. Adults generally emerge from the anterior end of the puparium. Males emerge prior to the females [73, 74].

Stage of infestation: Leaf miner usually harmful to crops at the maggot stage when the they actively feed by making feeding punctures.

Damage Symptoms and Extent of Loss: The active feeding is done by the maggots. They make feeding punctures with the help of their ovipositor and suck the sap oozing out from the punctures. They also mine the mesophyll of leaf and feed on the sap. Eventually, the photosynthetic activity of the leaf decreases and affect the fruit-setting. They are also responsible for transmitting plant pathogens during oviposition [75, 76].

Management: Maggots are parasitized by the braconids and eulophids. Chemically, they can be managed through foliar spray of methyl demeton @ 2ml/ lt or dimethoate @ 2ml/ lt. However, it has been noticed that chemical control of leaf miner lasts for very short period of time. They have developed a high level of resistance to broad range of insecticides [77, 78].

13. Stem gall fly

Life cycle: It is a minor pest of cucurbits. The eggs are deposited inside the tender leaves or tender shoots in patches of five by the females. The eggs are elongate and yellow in colour. Upon eclosion, the maggots are observed to be 11 segmented with abdominal Y-shaped 'sternal spatula'. It forms larval cavity and remain inside. After the active period of feeding, pupation takes place inside the larval cavity itself. The adults emerge from the puparium leaving the pupal semi atrophied on the gall shoots. The adult is a mosquito like fly. The total life cycle period from egg to adult was observed to be 21.5 days [79].

Stage of infestation: Maggots cause considerable amount of loss to cucurbits, particularly to bitter gourd.

Damage Symptoms and Extent of Loss: The maggots generally bore into the soft part of stem and elongated thickenings on bitter gourd [50, 79, 80].

Management: Biological agents like *Aprostocetus diplosidis* and *Bracon* spp. are helpful in managing the pest population [79]. If severe infestation is noticed, chemical application of Malathion 50 EC @ 500 ml, Dimethoate 30 EC 500 ml and Methyl demeton 25 EC @ 500 ml/ ha can be done to control the damage to the crop [80].

Conclusion

Considering the importance of the diverse sap sucking insects and leaf feeders, there is a need to develop and adopt eco-friendly management practices, which can ensure proper control of the pest, below the Economic Injury Level (EIL). In this regard, proper identification of the pest, understanding the life cycle and damaging stage of the insect and managing it at the right time becomes crucial for the crop to achieve qualitative and quantitative yield.

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