Chapter

Integrated Pest Management for Cucurbits in Cucumber (*Cucumis sativus* L.)

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Abstract

The vegetables belonging to family cucurbitaceae are known as cucurbits. These vegetables are attacked by various insect pests right from seeding to harvest. A lot of money, time, and natural resources are invested to cultivate these vegetables. Sustainable pest management practices can save this investment by avoiding losses. Successful cultivation of cucurbits especially cucumber requires an effective and economical control of insect pests. Commercial vegetable growers must produce quality vegetables that are attractive and safe to the consumer at a minimum cost. Insect pest infestations in cucurbits cause heavy economic losses to farmers through reduction in yield, increased cost of production and lowered quality of produce. Effective and economic and sustainable pest management requires the use of cultural, mechanical, biological, and chemical methods. The integration of these different methods is necessary for achieving good management of pests. In case of cucurbits especially for cucumber 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, monitoring of pest incidence, cultural methods, mechanical removal of pest, biological control, and need based use of selective pesticides. Integrated pest management (IPM) is the alternative to insecticide and facilitates sustainable environment management.

Keywords: Cucurbits, Pest Management, Insect Pests, Whiteflies, Aphids

1. Introduction

Crops belonging to the family Cucurbitaceae are commonly called cucurbits, which include more than 120 genera and 1000 species distributed in tropical and subtropical areas. Cucurbits are tropical in origin and grown mostly in Africa, tropical America, and Asia, mainly Southeast Asia. Cucurbits are a large group that include cucumber, bitter gourd, squash, bottle gourd, ridge gourd, snake gourd, watermelon, muskmelon and pumpkin. Most of the gourds and squashes are commonly used for cooking while cucumber is used for salads and pickles. Watermelon and muskmelon are taken as fruits and wax gourd is prepared as biscuits and jam. The cucurbits are beneficial for human health as their fruits help in purification of blood, boost energy level, improve digestion in the body and remove constipation. *Benincasa hispida* a member of cucurbitaceae family contains volatile oils, uronic acid, carotenes, flavonoids, ß-sitosterin and glycosides which are of pharmaceutical importance [1]. The major phytochemical present in cucurbits is a terpenoid substance known as Cucurbitacins.

Most cucurbit species is believed to have an African origin. However, cucumber have originated from the foothills of the Himalayas. There the closely related wild species *C. hardwickii Royle* still exists. In India, the cucumber was already being cultivated 3000 years ago, in the 6th century, cucumber was cultivated in China and now it is cultivated worldwide. Immature fruits of cucumber are used as salad vegetable and for pickles. Cucumber and other cucurbit fruits are generally fat-free and low in sodium content. Cucumber is an annual crop and a climbing herb. Its growth development duration can last 12–13 months in favourable conditions.

In present scenario, a significant constraint in the sustainable production and productivity of cucurbits is mainly due to attack of various insect-pests which are responsible for adversely affecting the qualitative and qualitative yield. A wide range of pest complex has been noticed infesting the cucurbits. This chapter joins all the information and provide overall review about the major insect pest of cucumber and other cucurbits, and different IPM measures like monitoring, cultural methods, host resistance, biological control method, use of botanicals as biopesticide and at last use of less hazardous chemical control methods recommended for management of this pest.

1.1 Melon fruit fly, *Bactrocera cucurbitae* (coquillett)

Bactrocera cucurbitae is a yellowish brown coloured dipteran fly and commonly known as melon fruit fly. It is native to India and is wildly distributed in tropical, subtropical and temperate region of the world [2]. Melon fruit fly attacks about 125 species of plants, mainly cucurbits, viz. gourds, cucumber, pumpkin, squash and other vegetables like tomato, green beans, egg plants etc. The female adult with the help of its sharp and hard ovipositor, punctures the soft and tender fruits and lays eggs just below the fruits's epidermis. After hatching, the maggots start feeding inside the pulp of fruits. A water soaked appearance of fruits develops as a result of larval feeding, these punctures and feeding tunnels provide entry points for various bacteria and fungi and result of this, the infested fruit start rotting, distorted and malformed fruits from plants pre-maturely. About 1000 white colour eggs in the batches of 1–40 slender (2 mm long) are laid by a single female. Dirty white coloured apodous maggots are cylindrical, elongate (7-12 cm). The maggot developmental period is 3 to 21 days depending on the temperature and host. Pupation occurs in the soil at the depth of 0.5 to 15 cm, pupal period is about 7–13 days depending on host and temperature. Adults are long lived about 150 days [3]. Melon fruit fly can cause devastating fruit damage up to 100% in all cucurbits [4].

1.1.1 Management

Cucurbits fruits are picked up at small intervals for marketing and self-consumption for that reason we cannot rely on insecticide for control of this pest but under severe infestation, it is important to use low residual toxic insecticides with short waiting periods. Therefore in keeping view the importance of crop and this pest different strategy should be used for the management of fruit fly as follows.

1.1.1.1 Local area management

Local area management is the minimum scale of pest management over a restricted area l, which has no natural protection against reinvasion. Here the major objective is to suppress the pest, rather than to eradicate it. The strategies includes bagging of fruits, field sanitation, protein baits and cue-lure traps, host plant resistance, biological control, and soft insecticides, can be employed to avoid environmental and health hazard [4].

1.1.1.2 Monitoring and management with cue/pheromone lures

For the monitoring of fruit flies, the sex attractant cue-lure traps are more effective than the food attractant tephritlure traps. and cue-lure and methyl eugenol traps have been used to attract males for monitoring and mass trapping [5, 6]. *Ocimum sanctum* as the border crop sprayed with protein bait containing spinosad as a toxicant found effective in management of this pest [7]. A variety of commercially produced attractants (cuelure ®, Eugelure®, Flycide®) are available in the market and can be used efficiently in management of this pest. For trapping male flies, installation of old used water bottle baited with cue-lure saturated wood blocks (ethanol/ cue-lure/carbaryl in a ratio 8:1:2) at 25 traps/ha prior to flower initiation is quite effective. Use of NSKE 4% as a repellent can enhance trapping and luring in bait spots. Use of neem as a repellent enhanced the catch in parapheromone traps and increased the luring ability of para-pheromone by 52%. Although, along with repellents and bait spray, other operations like removal and destruction of maggots in early infested fruits and field sanitation must be adopted.

1.1.1.3 Cultural methods

Field sanitation is most effective method in melon fruit fly management. It should be done for minimising pest intensity and to break reproduction cycle by removal and destruction of infested fruits daily from the field and bury the damaged fruits 0.46 m deep into the soil [8]. Akhtaruzzaman et al. [9] recommended bagging of cucumber fruits after 3 days of anthesis and bag should be kept for 5 days for effective control. Bagging of 3–4 cm long fruits with two layers of paper bags reduces fruit fly infestation and enhances the net returns by 40–58% [10]. 2–3 rows of maize as a trap crop can be grown between the cucurbits, which can be used as a resting site by the adult fruit fly. Spraying of any contact insecticides can be done on maize during the evening hours to kill adult fruit flies.

1.1.1.4 Biological control

Srinivasan [11] reported *Opius fletcheri* Silv. to be a dominant parasitoid of *B. cucurbitae.* The parasitization of *B. cucurbitae* by *O. flatcheri* has been reported to vary from 0.2 to 1.9% in *M. charantia* [12]. In the IPM program of *B. cucurbitae* at Hawaii, a new parasitoid, *Fopius arisanus* has been included [13]. A nematode, *Steinernema carpocapsae* Weiser *(Neoaplectana carpocapsae),* has been found to cause 0–86% mortality to melon fruit fly after 6 days exposure [14]. The culture filtrate of the fungus, *Rhizoctonia solani* Kuhn, act as an effective bio-agent against maggots [15], and the fungus, *Gliocladium virens* Origen, has been found to be an effective against adult flies [16]. Oviposition and development of *B. cucurbitae* adversely affected by culture filtrates of the fungi *R. solani, Trichoderma viridae* Pers., and *G. virens* [17].

1.1.1.5 Host plant resistance

Host plant resistance is an important element in IPM programs It is an important component in IPM programs. It does not cause any negative impact to the environment. The success in developing high yielding and melon fruit fly-resistant varieties is limited. By using wide hybridization technique the resistance genes from the wild relatives can be transferred in the cultivated genotypes of cucurbits [4]. Some resistant genotypes are IHR 89, Hisar II for bitter gourd, Arka Suryamukhi, IHR 35 for pumpkin, NB29 and Pusa smooth purple long for bottle gourd, Arka Tinda for round melon, *Cucumis callosus* for Wild melon, NS14 for sponge gourd and NR2, NR5, NR7 for ridge gourd.

1.1.1.6 Botanicals

The adult longevity reduced from 119.2 to 26.6 days by continuous feeding with extract of *Acorus calamus* (0.15%) mixed with sugar (at 1 mL/g sugar) [18]. Neem oil (1.2%) and neem cake (4%) are found to be effecting in fruit fly management [19].

1.1.1.7 Chemical control

The use of chemical insecticide to manage fruit fly is relatively ineffective. Application of malathion (0.05%) as cover spray to kill the insects on contact is effective or a bait spray by adding 50 g gur + 10 mL malathion in 10 L water that attract and kill the adults is good for its management. For good control of fruit fly spraying of malathion + molasses + water in the ratio of 1:0.1:100 is suggested by Akhtaruzzaman et al. [20]. This method is economical and environmental friendly as there is very low contamination of fruits from insecticides. Gupta and Verma [21] recommended that fenitrothion (0.025%) in combination with protein hydrolysate (0.25%) minimised melon fruit fly infestation to 8.7% compared to 43.3% damage in untreated control. Reddy [22] reported that triazophos is the most effective insecticide to manage this pest on bitter gourd. Diflubenzuron is also found effective in controlling the melon fruit fly [23], and quinalphos (0.2%) successfully manage its population on different cucurbits.

1.1.2 Wide area management

The objective of wide area management is to combine and coordinate different characteristics of an insect eradication program over an entire area within a defensible perimeter. This management program includes a three-tier model, that is, early reduction in population using bait spray, inhibition of reproduction using para-pheromone lure blocks to eradicate males to avert oviposition by females, and intensive survey using traps and fruit inspection until it could be discovered that the pest is entirely eradicated [24]. Male-sterile technique, also incorporated under this program, in this sterile males are released in the fields for mating with the wild females. The transmission of dominant lethal mutations kills the progeny of fruit fly. The females either do not lay eggs or lay sterile eggs. Eventually, the pest population can be eradicated by maintaining a barrier of sterile flies [4]. The spread of the melon fruit fly can be blocked through tight quarantine and treatment of fruits at the import/export ports.

1.2 Red pumpkin beetle (*Raphidopalpa foveico* llis/*Aulacophora foveico* llis)

Red pumpkin beetle is a common and major pest of a wide range of cucurbits, especially sweet gourd, bitter gourd, watermelon, bottle gourd, and muskmelon. It is polyphagous in nature [25]. Both larval and adult stages are voracious feeders of the cucurbit crops and cause severe damage to seedlings and young and tender leaves and flowers [26, 27]. The pest is widely distributed in different parts of the world, especially in Asia, Africa, Australia, and south Europe. In India, it occurs throughout the country but is more common in the north western parts.

The dorsal body of the adult beetle is deep orange in colour, while the ventral side is black. The beetles are about t 5–8 mm in length and 3.5–3.75 mm in width. The posterior part of the abdomen bears soft white hairs. The female lays brown coloured elongated eggs in the moist soil in the clusters of 8–9 that hatch into larvae in 6–15 days. After about 7 days of emergence, beetles starts egg laying and complete its 5 generations from March to October. Larvae are creamy, yellow-coloured and feed on the roots, stems, and fruits touching the ground. Due to infection by the saprophytic fungi rotting of damaged roots and underground stems may be occurred. Leaf lamina of cucurbits is voraciously feed by scrapping off the chlorophyll and making irregular holes on leaves with netlike appearance by beetle. First generation is more injurious than the subsequent generations as the maximum damage is noticed during cotyledon stage. The infested plants may shrivel, and resowing/replanting may become important under severe infestation. The young and smaller fruits of the infested plants may dry up. Sweet gourd was the most susceptible while bitter gourd was found to be the least susceptible host for this pest [28]. Beetles are strong fliers and very active in hot weather, and when disturbed, take fly quickly. If it is not controlled timely the damage by this pest may become severe. The losses due to the pest have been reported up to 30–100% in the field conditions [29].

1.2.1 Management

1.2.1.1 Monitoring and cultural methods

Monitoring of seedling should be done twice a week to check the infestation of red pumpkin beetle. The older plant parts should be monitored regularly and should be treated if severe defoliation is noticed. In the initial stage of infestation collection and destruction of beetles is good practice, otherwise the alternative practices can be employed for the management of this pest. Preventive measures such as burning of old plant parts, ploughing, and harrowing of field after harvesting of the crops should be followed for the destruction of all the stages of this pest. Early planting of cucurbits than the normal planting time could also be effective in management as the plants pass the cotyledonary stage by the time the beetles become active.

1.2.1.2 Host plant resistance

Khan [29] reported the preferred cucurbit host plants for this beetles and categorised bitter gourd, ribbed gourd, sponge gourd, and snake gourd as non-preferred hosts (resistant), while cucumber, muskmelon, and sweet gourd were the most preferred hosts (susceptible) and bottle gourd and ash gourd were moderately preferred hosts (moderately susceptible).

1.2.1.3 Botanicals and biopesticides

Application of neem oil cake in the soil is effective in killing grubs. Treatment of bottle gourd plants with entomopathogenic fungi *B. bassiana* resulted in maximum reduction of beetle infestation along with the highest fruit yield [30]. Khan and Wasim [31] reported maximum repellence against pumpkin beetles in treatment comprising of neem extracts mixed with benzene. *Parthenium spp*. extract was found to be effective in management of the red pumpkin beetle [32].

1.2.1.4 Chemical control

Generally, this pest attacks the crop at the cotyledonary stage when adults skeletonize the young leaves. At the time of initial infestation, applications of malathion (0.5%) or carbaryl (0.1%) minimise the damage successfully [33]. Dusting with permethrin (0.5%) alone and ash + permethrin dust (2000:1 *a.i.* w/w) provide good control against this beetles on the cucumber crop, with no phytotoxicity symptoms on the plant [34]. Synthetic pyrethroids (cypermethrin 0.012%, deltamethrin 0.004%, and fenvalerate 0.01%) were effective in suppressing the beetle population for about a week [35].

1.3 Hadda beetle (*Epilachna implicate, E. viginitioctopunctata and E. borealis*)

This is an occasional pest on cucurbit. It is a serious pest of squash, bitter gourd, and pumpkin. Grub only feed on the underside of the leaf, whereas adults may be found to feed on both the leaf surfaces or even on the fruit rind, leaving spiral-shaped scars and deteriorating fruit quality [36]. Both grub and adult feed voraciously by scrapping the chlorophyll of the leaves which cause characteristic skeletonization of leaf lamina and leaving a fine net of veins on leaves. The affected leaves gradually dry and fallen down. The young plants are killed overnight in case of severe infestation. The yellowish-brown coloured adult beetles are globular in shaped and 6–8 mm long, bearing 12–28 black spots on the elytra. The female lays about 300–400 eggs in clusters on the under surface of the leaves. Eggs on hatching turns into yellowish larvae (grub) with branched black spines covering the body. Full-grown larvae about 7-9 cm long pupate below the leaf or at the base of the stems. The pupa is yellow in colour, and lacks spines and hangs from the leaf. The development period comprises of 4–6 weeks under optimal conditions. Adults make semicircular cuts in rows, while Scrapping of the epidermis indicates the feeding manner of the grubs. Young plants can be totally destroyed, but older plants can tolerate considerable leaf damage. Overwintering sites for adults are under loose tree bark or under leaf litter near the edge of fields.

1.3.1 Management

1.3.1.1 Cultural methods

The best time of day for the inspection of hadda beetles on cucurbits is around noon. As they are not strong fliers, so crop rotation to distant fields tends to limit population and colonisation [36]. On the small scale like kitchen garden handpicking is recommended for the management of this pest because both the larvae and adults are not very aggressive defoliators. Harrowing and destroying vines and larvae after harvesting early cucurbits is recommended to suppress pest population. Row covers can be used to protect cucurbit from the beetles.

1.3.1.2 Botanicals

The application of seed extracts of *Annona squamosa* (3 mL/L of water) helps in minimising population build up to the extent of 76% which is followed by 64% and 57% through NeemAzal (5 mL/L of water) and petroleum ether rhizome extracts of *A. calamus* (2 mL/L of water), respectively [37]. Aqueous neem kernel extracts foliar spray at concentrations of 25, 50, and 100 g/L once in a week and neem oil spray with an ultralow-volume sprayer at 10 and 20 L/ha significantly was found effective in reducing feeding by *Epilachna* beetles in cucumber and squash [38]. Tephrosia leaf extract (20 g/100 mL water) provide highest yield and good control of *Epilachna* beetle by killing adults and inhibition of pupae formation and this is an environment friendly pest control method [39]. Swaminathan et al. [40] have observed the antifeedant and lethal effects of *Azadirachta indica*, *Madhuca latifolia* and *P. glabra,* on this pest. Islam et al. [41] performed larvicidal bioassays with crude aqueous leaf extracts of *plants viz., Ricinus communis, Datura metel* and *Calotropis procera* and these extracts showed considerable toxicity against the Hadda beetles by adversely affecting both oviposition and egg hatching besides prolonged larval duration, pupae formation, and adult emergence.

1.3.1.3 Chemical control

Foliar applications of some synthetic pesticides like parathion, malathion, lambda-cyhalothrin, pyrethrin and spinosad are found to be effective in control of severe infestation of this pest.

1.4 Aphid (*Myzus persicae and Aphis gossypii*)

Many aphid species including melon aphid (*Aphis gossypii*) and green peach aphid found to feed on cucurbits and cause similar devastating damage. They pierce the tender plant part with their slender mouthpart and suck plant fluids from it. Aphids are small about 3 mm long, pear-shaped soft bodied insects with long legs and antennae. They are yellow, pale green, red, brown or black in colour. Some aphid secretes a waxy grey or white material that covers their body and it gives them a waxy or woolly appearance. The adults are usually wingless but when populations are high especially during spring and autumn season winged forms can also be seen. A pair of tube-like structures known as cornicles projecting rearwards from their abdomen is present in most of the aphid species. Aphids can disperse long distances with the help of wind flow. Asexual reproduction is a common phenomenon in majority of aphid species. Adult females give birth to wingless nymphs which become adults after moulting and shedding the skin multiple times within a week. Each adult reproduces numerous nymphs in a short span of time therefore, aphid population increase rapidly. The green peach aphid (*Myzus persicae*) is slender, dark green to yellow in colour, and it has no waxy bloom. They tend to cluster on succulent plant parts and within 10–12 days one generation completes and there are about over 20 generations annually under mild climates [42]. This aphid (both nymph and adult) is known as the most important vector for the transmission of viruses throughout the world [43]. Aphids' infestation causes a variety of symptoms, including reduced plant growth and vigour, yellowing, mottling, browning, curling and wilting of leaves, Ultimately result in low economic yields and sometimes death of plant. The downward curling and crinkling of the leaves is the first sign of aphid infestation. Malformed flowers or fruits are developed due to feeding of aphid on flower buds and fruits. Honeydew excreted by aphids also act as a growth substrate for sooty moulds (fungi) on leaves and other plant parts, which ultimately hinders photosynthesis by blocking light. Aphids also transmit several viruses that affect all cucurbits causing a high rate of crop failure and great economic losses. These viruses are cucumber mosaic virus, zucchini yellow mosaic virus, watermelon mosaic virus and papaya ring spot virus. Mottling, yellowing, or curling of leaves and stunted plant growth are some usual symptoms of viral infection.

1.4.1 Management

1.4.1.1 Monitoring

Aphids multiply at a very fast rate, and this must be considered while monitoring this pest. Plants should be inspected at least two times a week especially at the under surface of the leaves. Severe infestation is noticed during end of growing season. Yellow sticky traps should be used for detecting aphids 2–3 weeks prior to planting.

1.4.1.2 Cultural method

Floating row covers or reflective mulches may be effective to exclude or repel this pest [43]. On early crop stage, aluminium foil mulches can be used to repel the invading aphid and check transmission of viruses. Reflective mulches can increase temperature beyond optimum for cucurbits in very hot and arid regions therefore, not recommended for these areas. Reflective mulches repels aphids from plants and consistently suppress aphid population and also help in delaying symptoms of watermelon mosaic and cucumber mosaic cucumo virus and zucchini yellow mosaic potyviruses by 3–6 weeks. Biodegradable synthetic latex spray mulches and reflective polyethylene and provide good control of aphids and aphid-borne virus diseases on late-season melons [44]. Living mulches minimise the contrast between the plant foliage and bare land, subsequently, the aphids do not detect their host and these mulches around main crop provide additional feeding sites for viruliferous aphids (aphids carrying virus) and hence minimise aphid-borne non -persistently transmitted viruses incidence and spread [45].

1.4.1.3 Biological control

Beneficial insects like predators, parasitoids, and pathogens are attracted to plants with moderate to heavy aphid infestations. These natural enemies may attack large numbers of aphids but as the reproductive potential of aphids is very high hence, the impact of the these natural enemies may not be enough to keep the aphids population below economic threshold levels. Lady bird beetles and their larvae *(Hippodamia convergens, Harmonia axyridis, Coleomegilla maculata)* [46], larvae of the syrphid fly [47], minute pirate bug *(Orius tristicolor* and *O. insidiosus)* and green lacewing larvae (*Chrysoperla carnea, Chrysopa spp*.) and brown lacewing larvae *(Hemerobius spp.)* and larvae of the aphid midge *(Aphidoletes aphidimyza*) [48] are common predators of aphid and help in natural control of this pest. Parasitoids comprises important place among natural enemies of aphid [49]. Some commonly found aphid parasitoids are *Aphidius matricariae, Aphidius colemani*, *Binodoxys angelicae and Lysiphlebus fabarum* [50]. Under humid conditions, Some fungi infect and provide biological control of aphid population, the most common entomopathogenic fungi are *B. bassiana, M. anisopliae, Verticillium lecanii* [51], and *B. bassiana* must be applied three times at an interval of 5–7 days for good control. Entomopathogenic fungus could be more effective than insecticides for controlling large populations of aphids if utilised properly.

1.4.1.4 Chemical control

Potassium soap and petroleum oil or Actara are recommended for the management of this pest. Killing of aphid population should be done before destroying old crops to avoid winged virus-infected aphids from getting to nearby crops by using a detergent and vegetable oil solution. Acetamiprid (0.01%) or Cypermethrin (0.01%) or malathion (0.05%) can be used to control aphids.

1.5 Whitefly (*Bemisia tabaci, B. argentifolii and Trialeurodes vapurariorus*)

Cucurbits are attacked by several species of whiteflies. Of these, silverleaf whitefly *(Bemisia argentifolii),* tobacco whitefly *(Bemisia tabaci),* and greenhouse whitefly *(Trialeurodes vaporariorum)* are the most devastating. Whiteflies are small in size about 1–1.5 mm long and the body and wings of adult are covered with fine whitish powdery wax. Adults and eggs are commonly found on younger leaves while nymphs are present on older leaves. A female lays around 300 eggs [52]; eggs are oval in shape and are laid by making a slit in the leaf. Initially the eggs are white, changing to brown colour, and are hatched within 8–10 days. The first instar is known as called crawler is the only mobile instar that moves to look for feeding sites, while the other instars are sessile and complete its life cycle on the same feeding site [53]. One generation of whitefly completes in about 3–4 weeks. The silverleaf whitefly gets injects a toxin into the plant that causes whitening of the under surface of newly emerging leaves. Severe damage may be occur on younger plants compared to older plants. Whitefly directly affects the cucurbits by its feeding and by acting as a vector of viruses. Cucurbit yellow stunting disorder virus, Cucurbit chlorotic yellow virus, beet pseudo yellow virus, and lettuce infectious yellows virus, are exclusively transmitted by whiteflies in both field and greenhouse-grown cucurbits [54]. Whiteflies also excrete honeydew which promotes the growth of sooty mould on leaves and economic plant parts.

1.5.1 Management

1.5.1.1 Monitoring

For early detection and monitoring the activity of whiteflies in the field, yellow sticky traps can be used. These traps are very important step for their management of whitefly. Traps should be placed just above the canopy at every 100 m^2 distance of the crop as whiteflies are most attracted toward young foliage [55].

1.5.1.2 Cultural methods

Crop rotation, mulching, floating row covers, non-infested transplants, cover crops, and good field sanitation are some common cultural practises to prevent the build-up of whiteflies. Delayed planting or host-free periods may reduces severity of infestation as temperature and rainfall influence whitefly population dynamics [56, 57]. Soil ground covers such as living or synthetic mulches have been found to suppress whitefly infestation [52, 58]. UV-reflective plastic mulch provide good management of silverleaf whitefly by repelling the adults flies, which minimize their colonisation and nymph population on zucchini squash and pumpkin [59]. Field sanitations an important practice to control whiteflies infestation, whitefly-transmitted virus incidence, and insecticide resistance. Crop residues that shelter whiteflies should be destroyed immediately after final harvesting to reduce their population and sources of plant viruses [60]. Weeds should be eradicated regularly from the crop as they can support large populations of whiteflies.

1.5.1.3 Biological control

Natural enemies of whitefly such as *Encarsia formosa*, *E. luteola,* and *Eretmocerus californicus* have been found quite effective in the greenhouse conditions [61]. Entomopathogenic fungi based products namely, *V. lecanii*, *B. bassiana* and *Paecilomyces fumosoroseus* are very useful to suppress whiteflies in both field and greenhouse crops [62]. The important predators affecting whiteflies are true bugs (Miridae, Anthocoridae), beetles (Coccinellidae), lacewings (Chrysopidae, Coniopterygidae), spiders (Araneae) and mites (Phytoseiidae), [63]. *Conwentzia africana* (dusky lacewing) has been considered one of the most important predators of *B. tabaci* [64].

1.5.1.4 Botanicals

Azadirachtin containing neem-based pesticide formulations like NeemAzal and Azatin have been found to control young nymphs and inhibit growth and development of older nymphs, and suppress egg laying by adult flies. Soap and certain oil sprays can be used in an organically certified crop. The efficacy of neem-based pesticides can be increased by adding 0.1%–0.5% soft soap in it.

1.5.1.5 Chemical control

The adults at immature stage reside on the underside of leaves, therefore whiteflies are usually difficult to control by using chemicals. Neonicotinoid insecticide like imidacloprid or thiamethoxam applied in soil at the time of planting effectively controls whiteflies. Foliar spray with neonicotinoid insecticide such as acetamiprid can be done at early stages of growth before flower initiation. Spiromesifen is effective against immature stages of the whitefly [60]. Consecutive applications of the same insecticide should be avoided. Soil application of any neonicotinoid with a foliar application of another neonicotinoid never be followed.

1.6 Squash bug (*Anasa tristis)*

The pest has been reported to attack nearly all cucurbits but most preferred cucurbits for oviposition and high rates of reproduction and survival are squash and pumpkin. It damages the crop severely by secreting highly toxic saliva into the cucurbit. Foliage is the primary site of that wilts, becomes blackened, and dies upon feeding. The fruits are also infested. The intensity of damage is directly proportional to the population density of pest. The adults emit a strong odour when crushed.

1.6.1 Management

1.6.1.1 Cultural methods

Plastic and spun bounded material can be used a row cover at the time of planting. Straw mulch is found effective in controlling squash bugs by providing cover [65]. As this pest prefers squash over other cucurbits, squash planting can be used as a trap crop around other cucurbits. Trap crop squash can be treated with insecticide to control the infestation.

1.6.1.2 Biological control

Several natural enemies are known to parasitize squash bug, especially Hymenoptera parasitoids belonging to family Encyrtidae and Scelionidae. A important tachinid fly parasitoid *T. pennipes*, attacks nymphs and adults of this pest [66], and 100% parasitisation in certain fields in particular years was observed [67].

1.6.1.3 Botanicals

Certain plant derived oils such as neem oil are helpful in the management of squash bug.

1.6.1.4 Chemical control

For the successful squash bug control timing of application is the key. Systemic insecticides are effective in suppression of these bugs up to 3 weeks. Foliar sprays targeting newly hatched nymphs are more effective than sprays used against older stages. Multiple foliar sprays are often needed for long periods of control. Soil application of dinotefuran and pyrethrin in foliar application are recommended for management of this pest [68].

2. Conclusion

The attacks made by the insect pests in cucurbits cause severe yield and quality losses in cucurbits. Cucurbitaceous crop are an important part of the fresh market vegetable crops. The current pest management still relies mainly on chemical pesticides and excessive dependence on chemicals leads to environmental pollution, pest resurgence, pest resistance and disturbance in balance between pest and their natural enemies. There are also the real and important risks to human health and environment as insecticide residue persist in these vegetables for longer times. Therefore, an integrated approach including monitoring of pests; cultural methods, like field rotation, use of mulches and trap crops and shifting planting dates; resistant cultivars; biological control; botanicals and biopesticides; and judicious use of chemicals can minimise these associated risk with chemical pesticides. An effective integrated programme for pest management is necessary for the management of these pest problems in cucurbits. By giving focused attention through adopting IPM techniques, sustainable production of cucurbits can be achieved.

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