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DK Rana
Department of Plant Protection, SMS, Krishi Vigyan Kendra, New Delhi, India

Jai Parkash
Department of Animal Husbandry, SMS, Krishi Vigyan Kendra, New Delhi, India

Anant Kumar
Department of Horticulture, SMS, Krishi Vigyan Kendra, Ghaziabad, Uttar radish, India

Virender Pal Gangwar
Department of Horticulture, SMS, Krishi Vigyan Kendra, Hapur, Uttar Pradesh, India

Corresponding Author:
DK Rana
Department of Plant Protection, SMS, Krishi Vigyan Kendra, New Delhi, India

Integrated pest management in cucurbits crops and colony organization in honey bees (Api species) with mites' association: A review

DK Rana, Jai Parkash, Anant Kumar and Virender Pal Gangwar

Abstract
When a pesticide application is considered, review the Pesticide Application Checklist for information on how to minimize the risks of pesticide use to water and air quality. Water quality can be impaired when pesticides drift into waterways or when they move off-site. Air quality can be impaired when pesticide applications release volatile organic compounds (VOCs) into the atmosphere. Pest control measures by using any alternate host of pests on the surroundings of your crops before planting, destroying cucurbit weeds will prevent reproduction of pests such as the melon worm, and the melon fruit fly, and diseases such as downy mildew, powdery mildew, gummy stem blight, and bacteria. Use live barriers around your crop to prevent the direct entry of virus vectors, like aphids and white flies, to maintain natural enemies and to selectively kill armyworms that are attracted to the barriers. Use botanical pesticides whenever necessary. Promote the maintenance of ladybugs and other natural enemies by maintaining plant diversity and flowering plants in home gardens and commercial fields. Rotate botanical pesticides with detergent (3 grams per liter) plus vegetable oil (1 ml per liter) to maintain aphid, spider mite, thrip and whitefly populations low. Even though leaf miners are relatively common in cucurbit crops, they are not listed as pests in this bulletin because they normally do not cause economic damage, except in conditions where pesticide abuse is common. In nature, leaf miners are controlled by natural enemies and normally do not require human intervention.

Keywords: Aphids, thrips, melon worm, sex pheromones

Introduction
Cucurbits are vegetable crops belonging to family Cucurbitaceae, which primarily comprised species consumed as food worldwide Cucurbits are consumed in various forms *i.e*., salad (cucumber, gherkins, long melon), sweet (ash gourd, pointed gourd), pickles (gherkins), deserts (melons) and culinary purpose. Some of them e.g. bitter gourd) are well known for their unique medicinal properties. In India, a number of major and minor cucurbits are cultivated in several commercial cropping systems and also as popular kitchen garden crops. Production of vegetables is estimated to be around 168.6 million tonnes 2016-17. Cucurbits share a larger portion of the total vegetable production of India to provide food and nutritional security at individual level and, being a large group of vegetable, cucurbits provide better scope to enhance overall productivity and production. A fundamental aspect of IPM affecting growers, government regulators, and consumers alike is the concept of risk. An important risk to growers that rely heavily on pesticides is the development of resistance to pesticides that can greatly affect production economics and pesticide use patterns. There are also the real and perceived risks to human health. These include potential chronic health effects from pesticides in diet, exposure to acute toxicity by agricultural workers and handlers that deal with pesticides, and indirect exposure through feeding of treated plant material to livestock. Risks to environmental quality can include non-target effects of pesticides, effects of pesticides on the severity of other pests, reduction in the abundance of fungal parasites of the invertebrate pest (e.g., EBDC fungicides increasing aphids), toxicity to aquatic vertebrates, and contamination of groundwater (soil-mobile fungicides, e.g., metalaxyl). A basic assumption of the proponents of IPM is that IPM can reduce these risks.

General pest control measures are listed below
1. Remove any alternate host of pests on the surroundings of your crops before planting. Destroying cucurbit weeds will prevent reproduction of pests such as the melon worm, and the melon fruit fly, and diseases such as downy mildew, powdery mildew, gummy

2. stem blight, and bacteria.
3. Use live barriers around your crop to prevent the direct entry of virus vectors, like aphids and white flies, to maintain natural enemies and to selectively kill armyworms that are attracted to the barriers.
4. Use botanical pesticides whenever necessary.
5. Promote the maintenance of ladybugs and other natural enemies by maintaining plant diversity and flowering plants in home gardens and commercial fields.
6. Rotate botanical pesticides with detergent (3 grams per liter) plus vegetable oil (1 ml per liter) to maintain aphid, spider mite, thrip and whitefly populations low.

The important insect pests of cucurbits are:

Aphids: Aphids are pear shaped, soft bodied, small in size and have two small horns at the end of the abdomen. They are sucking insects, vectors of non-persistent viruses.


1. Use yellow sticky traps to detect incoming aphids from the surroundings two to three weeks before planting.
2. Kill aphids using a detergent and vegetable oil solution before destroying old crops to avoid winged virus infected aphids from getting to nearby crops.
3. Destroy early infected virotic plants to avoid aphids from being infected and spreading the disease within the crop. If aphids are present on infected plants spray the plants before destroying them.
4. Use systemic pesticides in rotation with botanical pesticides and with detergent and vegetable oil in commercial crops whenever necessary. Use the drip irrigation system to apply the systemic insecticide to prevent the killing of natural enemies and pollinators. 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 [5. This aphid (both nymph and adult) is known as the most important vector for the transmission of viruses throughout the world [6].

Melon Worm and Armyworms: The melon worm is green in color and has 2 white stripes on its back. It likes to feed on growing tips and fruit. The butterfly has white wings with brown borders and is more active at night. Armyworms are not specific pests to cucurbits, but may attack many other crops and weeds. The adults are nocturnal moths, light brown in color, dull and unattractive, and lay eggs in masses. Larvae are voracious, and vary in color and size depending on the species.


1. Hand pick and kill armyworm egg masses, melon and armyworms and melon worm pupae in home gardens. If the worms are parasitized, do not destroy them but leave them in the field.
2. Use *Bacillus thuringiensis* insecticides to kill worms without affecting pollinators or beneficial insects.

Thrips: Thrips are small, elongated insects, yellowish when young, and light brown when adult. They are commonly found inside flowers and on the underside of the leaves.



1. Use yellow sticky traps.
2. Apply ashes or limestone on plastic mulch or on the surface of the naked soil to kill any pupating thrips that drop to the ground.
3. Maintain sunflower plants near thrip affected crops to allow the minute pirate bug, an efficient thrip predator, to establish and reproduce through time.

Spider and Broad Mites: Spider mites are normally red in color, and look like small ticks. Broad mites are whitish and smaller than spider mites. Broad mites normally occur on the underside of leaves.

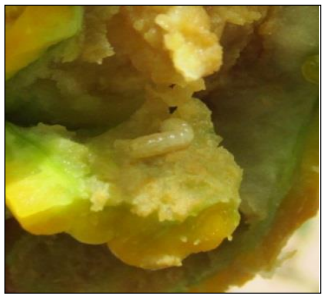

Spider mites' Broad mites

1. Avoid dusty roads near crops.
2. Plant live barriers and if possible water dusty roads several times a day to prevent dust in crops. Dust helps transport spider mites and protects them from predators.

White Flies: White flies are tiny white insects, triangular in shape, soft bodied and with wings that look like a two-sided roof. They are sucking insects that may be vectors of persistent viruses, especially in watermelons. In another cucurbit crops they may be unimportant. A female lays around 300 eggs [7]; 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 [8]. One generation of whitefly completes in about 3–4 weeks. The silver leaf whitefly gets injects a toxin into the plant that causes whitening of the under surface of newly emerging leaves.

1. Use yellow sticky traps.
2. Maintain crop surroundings free of broad leaf weeds at all times because these plants allow the reproduction of white flies and may maintain white fly transmitted viruses as well.

Melon Fruit Flies: Melon fruit flies have a strong built body. They are light brown in color and females have a pointed abdomen.



1. Use sex pheromones to prevent mating and reproduction.
2. Cover bitter gourd fruit with paper bags or other local material envelopes to prevent female fruit flies from ovi-positing and damaging fruits.
3. Collect and destroy all fruit fly infected fruit to prevent new adults from emerging.

Cultural control

- Early maturing varieties are less affected than later ones.
- Changing of sowing dates.
- Collection and destruction of infested fruits
- Slight raking of soil during fruiting time and after the harvest to expose pupae from the soil.
- Use methyl eugenol (0.1%) based trap

Biological control

- Conserve parasitoids such as *Opiusfletcheri*(pupal)
- Spray NSKE 5%

Red pumpkin beetles

These insects infest bitter gourd, snake gourd, melons, pumpkin, coccinia etc.

Hadda beetle

Spotted beetles are distributed from East Asia to South Asia and Australia. They are polyphagous and feed predominantly on cucurbits, cucurbits, potato, and kidney beans as well as eggplant. These beetles are considered to be one of the most serious groups of pests damaging eggplant. In addition, they also feed on other Solanaceous plants such as *S. nigrum*, *S. xanthocarpum*, *S. torvum*, *Datura*sp, *Physalis*sp and *Withaniasomnifera*. 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 [9].

The genus *Apis* includes seven recognized species of honey bees of which four are major species and the other three are presently considered as minor. The major species include two domesticated/hive bees, *Apis mellifera* Linn. and *Apis cerana* F. and two well-known wild species, *Apis dorsata* F. and *Apis florea* F. The other honey bee species are *A. koschevnikovi*, *A.* andreniformis, *A. laboriosa*. India is a country where all the four major species are present. Honey bees are highly social insect which live in a well-organized colony. They are capable of multiplying their colonies and establishing new nests; providing a high degree of brood care, communicating among themselves about the distance, direction and potential of a flora and presence of queen bee etc; producing different castes which perform different duties on the basis of division of labour [3]. Different castes are dependent upon each other and bees work for the benefit of the colony as a whole. The

worker bees, in the act of stinging even die, sacrifices for the defence of the colony. A colony of honey bees is composed of three castes. The queen, a few hundred drones and thousands of worker bees, which may be recognized by their morphological differences (Table 1).

Tablet 1: Morphological Differentiation in Different Castes of *A. mellifera*

Character	Queen	Worker	Drone
Body	Largest and broader than worker	Smallest of three castes	Longer than worker but shorter than queen bee. Stoutly built and broadest of all castes.
Wings	Do not cover the abdomen fully.	Cover the abdomen fully	Cover the abdomen fully
Head	Small in proportion to the body size.	Large in proportion to the body size	Large in proportion to the body size
Abdomen	Shining brown in colour and gradually tapering	Abdomen with slight golden and black stripes. Tip of the abdomen conical	Tip of the abdomen blunt/round and hairy
Compound eyes	Medium sized and well apart	Medium sized and well apart	Large, black, kidney shaped meeting with each other at the top of the head
Proboscis	Not well developed	Well developed	Not well developed
Pollen collecting legs	Absent	Present	Absent
Sting	Curved with very small barbs used for stinging only the rival queen	Well-developed sting with barbs, used for colony defence. Sting cannot be retracted after use	Absent

Department of Entomology CCS Haryana Agricultural University, Hisar

Table 2: Mite associated with honeybees (Apis spp.)

Sr. No.	Mite species	Hosts (*Apis*)	Nature of mite	Habitat
1	*Acarapis woodi*	*A. cerana, A. mellifera*	Endoparasite	Trachea of adult bee
2	*A. externus*	*A. mellifera*	Ectoparasite	Thorax region of adult bee
3	A. dorsalis	*A. mellifera*	Ectoparasite	Neck region of adult bee
4	*Acaropsis sollers*	*A. mellifera, A. dorsata*	Predatory	Pollen storage cells
5	*Aceria litchi*	*A. mellifera*	Phoretic	Adult bee
6	*Afrocypholaelaps africana*	*A. mellifera*	Phoretic	Adult bee
7	*Allodinychus flagellifer*	*A. dorsata*	Phoretic	Adult bee
8	*Aleuroglyphus robustus*	*A. mellifera*	Phoretic	Adult bee
9	*Dermatophagoides* sp	*A. mellifera*	Phoretic	Adult bee
10	*Euvarroa haryanensis*	*A. florea, A. mellifera*	Ectoparasite	Brood cell, adult bee
11	*E. sinhai*	*A. florea, A. mellifera*	Ectoparasite	Brood cell, adult bee
12	*E. wongsirii.*	*A andreniformis*	Ectoparasite	Brood cell, adult bee
13	*Forcellinia gallariella*	*A. mellifera*	Phoretic	Adult bee
14	*Leptus* sp.	*A. mellifera*	Ectoparasite	Adult bee
15	*Macrocheles glaber*	*A. mellifera*	Predatory	Pollen storage cells
16	*M. muscaedomesticae*	*A. mellifera*	Predatory	Pollen storage cells
17	*Melittiphis alvearius*	*A. mellifera*	Predatory	Pollen storage cells
18	*Neocypholaelaps apicola*	*A. cerana, A. mellifera*	Phoretic	Adult bee
19	*N. indica*	*A. cerana, A. dorsata, A. florea, A. mellifera*	Phoretic	Adult bee
20	*N. favus*	*A. mellifera*	Phoretic	Adult bee
21	*Pseudacarapis indoapis*	*A. cerana*	Phoretic	Adult bee
22	*Pyemotes herfsi*	*A. cerana*	Ectoparasite	Adult bee
23	*P. tritici*	*A. mellifera*	Ectoparasite	Adult bee
24	*Sennertia* sp.	*A. mellifera*	Phoretic	Adult bee
25	*Suidasia pontifica*	*A. cerana, A. florea*	Phoretic	Adult bee
26	*Tarsonemus apis*	*A. cerana*	Phoretic	Adult bee
27	*Tropilaelaps clareae*	*A. dorsata, A. mellifera, A. laboriosa, A. cerana A. florea*	Ectoparasite	Brood cell, adult bee
28	*T. koenigerum*	*A. dorsata, A. laboriosa, A. cerana A. mellifera*	Ectoparasite	Brood cell, adult bee
29	*T. stimulis*	*A. dorsata*	Ectoparasite	Brood cell, adult bee
30	*Tyrophagus longior*	*A. mellifera, A. florea, A. dorsata, A. cerana*	Phoretic	Adult bee
31	*Varroa destruuctor*	*A. cerana, A. mellifera*	Ectoparasite	Brood cell, adult bee
32	*V. jacobsoni*	*A. cerana, A. mellifera*	Ectoparasite	Brood cell, adult bee
33	*V. underwoodi*	*A. cerana*	Ectoparasite	Brood cell, adult bee

Directorate of Research, CCS Haryana Agricultural University, Hisar

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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