Chapter 7
Integrated Pest Management of Okra in India

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Abstract Okra (*Abelmoschus esculentus* (Malavaceae), a major contributor to global vegetable production, is an excellent resource for overcoming global malnutrition and rural poverty. Globally, okra is cultivated on an area of 1.12 mha with a production and productivity of 8.71 mt and 7.8 t/ha respectively. Pests and diseases are major constraints to the quality and quantity of okra produced with total losses of about 35–40 %. Farmers rely on the use of synthetic pesticides for the control of pests thereby endangering environmental and public health. In this context, this chapter describes the biology and etiology of the key pests and diseases of okra and describes the development of components that are integrated into a package of practices as alternatives to the use of pesticides. The Integrated Pest Management (IPM) approach termed the "okra IPM package" registered significantly lower populations of aphids, whiteflies, leafhoppers, leaf miners, nematodes, fruit borer damage and incidence of *Yellow vein mosaic virus* and powdery mildew coupled with an increase in shoot and root growth and natural enemy populations as compared to the farmer's practice which consisted of the use of conventional pesticides. The yield increase in the IPM plots was 12.43–45.54 % above the farmers practice. The benefit:cost ratio was 2.53–3.23:1 in the IPM plots as compared to 1.23–1.52 in the farmer's practices plots. In addition, the IPM approach was environmentally safe and provided residue-free produce for the consumers.

Keywords Insect pests • Mites • Nematodes • Fungal and viral diseases • IPM package for okra

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Introduction

Vegetables are one of the best resources for overcoming malnutrition problems and provide considerable revenue to farmers in a short time span. Okra (*Abelmoschus esculentus* (Malavaceae), one of the important malvaceous vegetables also called as bhendi or lady's finger in India, is a major contributor to the total global vegetable production. It is believed to have originated from Ethiopia (Joshi and Hardas 1976). It is one of the important vegetable crops grown extensively in the tropical, subtropical and warm temperate zones of the world (Charrier 1984; Thompson and Kelley 1957). Okra is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia and the Southern United States (Anon. 2010) and warmer parts of Temperate Asia, Southern Europe and Northern Africa (Oyelade et al. 2003). Globally it is cultivated on an area of 1.12 mha with a production and productivity of 8.71 mt and 7.8 t/ha respectively. Okra is an important vegetable crop for Indian agriculture and is grown extensively throughout the year in all parts of the country with an area of 0.53 million hectares, annual production of 6.35 mt and a productivity of 11.9 t/ha (Indian Horticulture 2014). India is ranked first in production of okra and contributes for 73 % of global production and is second in the total okra cultivable area (Singh et al. 2015). The global climate scenario is having a significant impact on vegetable cultivation including okra.

One of the major constraints to the quality and quantity of okra produced is the increasing incidence of insect pests, diseases and nematodes. Due to their tender and supple nature and their cultivation under high moisture and input regimes, okra is susceptible to pest attack yielding total losses of about 35–40 % (Sardana et al. 2006). In India, Rai (2015) reported that the yield loss of okra is due to major pests (Table 7.1) and their incidence on okra varies across the globe.

In many areas in India, okra is grown adjacent to cotton which is another malvaceous crop. Most of the pests that attack cotton also attack okra. The important insect pests include fruit and shoot borer (*Earias vittella* and *E. insulana*), tomato fruit borer (*Helicoverpa armigera*), cotton leaf roller (*Sylepta derogata*), leafhopper (*Amrasca biguttula biguttula*), leafminer (*Liriomyza* spp.) whitefly

Table 7.1 Yield loss due to major pest damage in okra in India (Rai 2015)

Insect pest/disease	Yield loss (%)
Fruit and shoot borer (*Earias vittella*)	23–54
Tomato fruit borer (*Helicoverpa armigera*)	22
Whitefly (*Bemisia tabaci*)	54
Jassids (*Amrasca biguttula biguttula*)	54–66
Bhendi yellow vein mosaic virus	50–90
Leaf curl disease	30–70
Cercospora blight	44

(*Bemisia tabaci*), aphid (*Aphis gossypii*), cotton mealybug (*Phenacoccus solenopsis*), dusky cotton bug (*Oxycarenus hyalinipennis*), red cotton bug (*Dysdercus koenigii*), red spider mite (*Tetranychus urticae*) and root-knot nematode (*Meloidogyne incognita*) (Aziz et al. 2011; Karuppusamy 2012; Kedar et al. 2014). Of these, the *Earias* spp. are the most important (Aziz et al. 2011). The other pests attacking okra are semilooper *Anomis flava* and Bihar hairy caterpillar (*Diacrisia obliqua*) (Azad Thakur et al. 2012). Similarly, the important devastating diseases are *Yellow vein clearing mosaic virus*, *Leaf curl virus*, powdery mildew (*Leveilula taurica*) and leaf spot (Ahmed 2000).

Farmers rely on the use of synthetic pesticides for the control of these pests thereby endangering environmental and public health. In this context, IPM for okra serves well for reducing the usage of toxic pesticides.

Description and Biology of Okra Insect Pests

Fruit and Shoot Borers (Spotted Caterpillars), *Earias vittella* and *E. insulana* (Lepidoptera: Noctuidae)

These are oligophagous pests that also attack cotton, *Hibiscus*, hollyhock and other malvaceous plants (Anon. 2011). Larvae bore into tender terminal shoots at the vegetative stage resulting in withering and drying of shoots and dropping of leaves. At the plant reproductive stage it bores into flower buds, flowers, young fruits and the boreholes are plugged with excreta. The infested fruits are deformed and become unfit for consumption (Anon. 2011).

The adult females oviposit sculptured and sky blue colored eggs individually on leaves, floral buds and on tender fruits (Anon. 2014). The egg period ranges from 3 to 5 days and each female lays up to 400 eggs (Anon. 2011). The emerging small, brown, neonate larvae either bore into the top shoots or fruits. Pupation takes place on the outside of fruit or on the plant or crop debris or on the top layer of soil in an inverted boat shaped cocoon. After 6–10 days the adult emerges. The total life cycle is completed within 3–5 weeks (Justo 2005). The adult moth is yellowish-brown. The fore wings of *E. vittella* are pale white, with a broad wedge shaped horizontal green band in the middle, while in *E. insulana* they are uniformly green. Hind wings are white in both the species (Anon. 2010, 2011).

Tomato Fruit Borer, *Helicoverpa armigera* (Lepidoptera: Noctuidae)

It is a cosmopolitan, polyphagous pest, widely distributed in the tropics and subtropics and attacks several vegetable, fruit and cereal crops (Chandurkar et al. 2005; Rai et al. 2005). Among vegetable hosts, okra is the second most important and the most preferred host crop for feeding and oviposition next to tomato (Rai et al. 2005).

Larvae attack the flower buds and fruits and make circular boreholes inside the fruit. The larvae bore the fruits with their bodies protruding from the fruit (Kedar et al. 2014). External symptoms appear in the form of irregular bore holes, plugged with excreta, on fruits.

Spherical, yellowish eggs are laid singly on tender parts and buds of plants and the egg duration is 2–5 days. A single adult female can lay 300–500 eggs in 4–7 days (Kedar et al. 2014). Among the vegetable hosts, survival of neonates is comparatively less on okra due to the presence of mucilaginous substances that is exuded from the fruits (Latheef and Ortiz 1983). The larval period lasts for 18–25 days. The fully-grown caterpillar pupates in the soil in an earthen cell and emerges in 10–21 days (Anon. 2014). Adult moths are medium sized, olive green to brown colored with V shaped marks on the forewings and a conspicuous black spot in the center. Hind wings are light and dull-colored with a black border.

Jassids, *Amrasca biguttula biguttula* (Hemiptera: Cicadellidae)

Jassids (leafhoppers) primarily attack the crop in the early growth stages. Nymphs and adults suck sap from the under surface of the leaves and inject toxins causing marginal leaf curl, downward leaf cupping and browning of leaves known as 'Hopper Burn'. Ultimately stunting and death of plants take place. Jassid populations are favored by the onset of cloudy weather and adversely affected by heavy rainfall (Fakhri and Jamal 2012).

Adult hoppers lay their eggs singly within leaf veins and on the upper leaf surface and eggs have an incubation period of 4–10 days. The nymphs and adults are wedge shaped, pale green with a black spot on the posterior half of the fore wings and their longevity ranges from 7 to 21 and 35 to 56 days respectively (Fakhri and Jamal 2012).

Whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae)

Nymphs and adults suck leaf sap, usually from the under surface, and excrete honeydew resulting in a sooty mold growth on leaves. The infested leaves become wrinkled and show the characteristic browning symptom. Infested plants become stunted and fail to bear fruits (Shivanna et al. 2009). The whiteflies are vectors for the *Bhendi yellow vein mosaic virus* (Fakhri and Jamal 2012).

Cotton Aphid, *Aphis gossypii* (Hemiptera: Aphididae)

It is a polyphagous pest (Ahmed 2000). Both nymphs and adults suck the plant sap mostly from the tender plant parts. Severe infestation results in leaf curling, stunted growth, gradual drying and death of plants. Black sooty mold develops on the leaves. Dry conditions favor an increase in pest population and young plants are more susceptible (Kedar et al. 2014).

Cotton Leaf Roller, *Sylepta derogata* (Lepidoptera: Pyralidae)

The larvae within folded leaves feed from the leaf edge towards the mid-rib. In severe cases, complete defoliation occurs. Female moths lay about 200–300 eggs, singly, on the underside of the leaves. The incubation period is 2–6 days. Larvae are green with spots on the body and pupate within 15–35 days. Pupation, which occurs over a 6–12 day period, occurs either on the plant inside the rolled leaves, or on the plant debris in the soil. The total life cycle is completed in 23–53 days. Adult moths, which live for about a week, are yellowish-white, with black and brown spots on the head and thorax and wings with a series of dark brown wavy lines.

Blister Beetles, *Mylabris pustulata* and *M. phalerata* (Coleoptera: Meloidae)

Only the adult stage is destructive and feeds on floral parts of the plant causing significant yield loss. Each female lays about 100–2000 eggs depending on the quality of the food they ingest. The eggs are usually laid in the soil. Upon hatching, the grub feeds on soil-dwelling insects, including pests, and do not cause any damage to the crop. The grubs have several instars, with two or more different forms of larvae. During later instars, it becomes less active, and then pupates.

Red Spider Mites, *Tetranychus urticae* and *T. telarius* (Acari: Tetranychidae)

The nymphs and adults are red in color. Mite infestation is severe in dry and hot environmental conditions. The nymphs and adults suck the cell sap from under surface of the leaf resulting in whitish grey patches appearing on leaves followed by mottling and bronzing and ultimately defoliation. Lall and Dutta (1959) reported 36.8 to 83.2 per cent loss in okra yield due to spider mites. The egg stage lasts for 3–5 days and the egg is 0.13 mm in diameter, globular and translucent. Each female can lay an average of 90–110 eggs during a lifetime of about 30 days; therefore numbers of mites can increase very rapidly during the summer, or under glass or plastic. The larval/nymph stages last 4–5 days. The larva is pale green and has six legs. The nymphs are pale green with darker markings and have eight legs. The adult female is 0.6 mm long, pale green or greenish-yellow with two darker patches on the body, which is oval with quite long hairs on the dorsal side. The male has a smaller, narrower, more pointed body than the female. The total life cycle takes only 8–12 days.

Root-Knot Nematode, *Meloidogyne* spp.

Okra is highly susceptible to root-knot nematodes, *Meloidogyne* species. The above ground symptoms are similar to those described for root rot and wilt diseases. The infected roots are enlarged and distorted. The root-knot nematode has a wide host range. It has a short life cycle of 6–8 weeks. In susceptible hosts, the nematode population builds up to a maximum, usually, as the crop reaches maturity (Shurtleff and Averre 2000) and in some cases the plants die even before maturity (Singh and Khurma 2007).

Important Okra Diseases

Damping Off (*Pythium* sp., *Rhizoctonia* sp.)

Damping off is caused by a fungus and it usually occurs in small patches at various places in the seedbeds or field. The disease spots often increase from day to day until the seedlings harden. Seedlings are extremely susceptible for about 2 weeks after emergence. Infection before seedling emergence (pre-emergence damping off) results in poor germination which is attributed to poor quality of seeds and results in a poor crop stand. Infection on seedlings (post-emergence damping off) causes death or damping-off of the plants which are small and tender. The roots are first killed and then the plant dies.

Fusarium Wilt (*Fusarium oxysporum* f. sp. *vasinfectum*)

The fungus enters the plants through its roots and is mainly transmitted by infected seeds, contaminated farm equipment or through human movement. Warm temperatures increase the prevalence of the disease. The young infected plants exhibit wilting of cotyledons and seedling leaves. Chlorotic spots then appear on the edges of the cotyledon and it then becomes necrotic. Old plants show symptoms of chlorosis and wilting and eventually, the plants die.

Powdery Mildew (*Erysiphe cichoracearum*)

Powdery mildew is very severe disease on okra. Warm and dry weather followed by cool nights that result in dew formation increase the prevalence of this disease and the fungus over-winters in plant debris and or alternate hosts. The symptoms are characterized as appearance of small white spots that lead to formation of white powdery growth on the upper surface due to coalescence of the spots. Heavily infested leaves show curling and appear scorched. The disease later spreads to the entire plant causing a severe reduction in fruit yield.

Bhendi Yellow Vein Mosaic Virus (BYVMV)

Among the various vegetable diseases, *bhendi yellow vein mosaic virus* is the most severe affecting the quantity and quality of the fruits (Uppal et al. 1940). The virus infects all stages of crop growth. The characteristic symptoms of the disease are a homogenous interwoven network of yellow veins enclosing patches of green tissues in the leaf blade (vein clearing). Additional symptoms include vein swelling, slight downward curling of leaf margins, twisting of petioles, dwarfing and retardation of growth (Capoor and Varma 1950). Serious infection of this virus restricts flowering and fruiting (Anon. 2010). The causative virus is transmitted by the whitefly *Bemisia tabaci*.

Okra Enation Leaf Curl Virus (OELCuV)

The pathogen is transmitted through whiteflies The disease symptoms appear predominantly on the lower surface of the leaf as small, pin head enations and later become warty and rough textured followed by twisting of the main stem and lateral branches along with enations (scaly leaf like structures, differing from leaves in their lack of vascular tissue).

Integrated Management of Okra Pests

The okra IPM package, in all three trials conducted at the Tamil Nadu Agricultural University, registered a significantly lower populations of aphids, whiteflies, leafhoppers, leaf miners, nematodes, fruit borer damage, *Yellow vein mosaic virus* and powdery mildew coupled with an increase in shoot and root growth and natural enemy populations as compared to the farmer's practice. The pest population was significantly lower in the different IPM options tested compared with farmers who used conventional pesticides for the control of insect pests. The IPM components include seed treatment with *Trichoderma viride* (4 g/kg) and *Pseudomonas* (10 g/kg), soil application of *Pseudomonas* (2.5 kg/ha), soil application with neem cake @250 kg/ha, maize as border crop against movement of whiteflies and leafminer, use of yellow sticky traps, pheromone traps for monitoring *Helicoverpa* and *Earias*, *Trichogramma* release after each brood emergence of *Helicoverpa* and *Earias*, application of neem oil formulations (2 %), neem seed kernel extract (5 %) and need-based application of new generation safer pesticides.

The pest population was comparatively low in the neem-based treatment compared with farmer's practices as recorded in previous studies (Praveen and Dhandapani 2001; Shabozoi et al. 2011). The yield increase was 12.43–45.54 % above the farmers' practice in the IPM plots. The benefit: cost ratio was 2.53–3.23:1 as compared to 1.23–1.52 in farmer's practice.

The other practices included in IPM of Okra are:

1. The non synchronized sowing of seeds (Rai and Satpathy 1999; Mandal et al. 2007; Gautam et al. 2013)
2. Growing resistant varieties/ hybrids (Table 7.2)
3. Application of NSKE (5 %) or Azadirachtin (5 %) and need based application of safe insecticides if needed.
4. Seed treatment with *Trichoderma viride*
5. Removal of the alternate hosts
6. Installation of yellow sticky traps for monitoring
7. Roguing YVMV affected plants, if any, from time to time
8. Removal and destruction of borer affected shoots and fruits
9. Sprinkler irrigation to reduce the whitefly population
10. Application of botanical insecticides
11. Inundative release of natural enemies such as *Trichogramma brasiliensis* against *Earias vittella* and *H. armigera* and *Chrysoperla zastrowi sillemi* for sap feeders

Table 7.2 Disease tolerant okra varieties in India

Character	Open pollinated varieties	Hybrid varieties
Resistance to *A. gossypii*	Pusa A-4 and Gujarat Anand – Okra-5	–
Resistance to *Amrasca biguttula biguttula*	IC-7194, IC-13999, New selection, Punjab padmini	–
Yellow vein clearing mosaic tolerance	Kashi satdhari, Shitla lila, Parbhani kranti, Arka Abhey, Arka anamika, Varsha uphar, Hissar unnat, Hisar Naveen, Pusa A-4, Punjab-8	Shitla jyoti, Makhmali, tulsi, Anupama-1 and Sun-40
Leaf curl tolerance	Kashi Mohini	Shitla Uphar
Yellow vein clearing mosaic and leaf curl tolerance	Kashi vibhuti, Kashi pragati, Kashi kranti, Punjab padmini and CO(O)- 2 and 3	Lam hybrid selection-1, HBH-142, SOH-152 and Makhmali

Sardana et al. (2006), Anon. (2014), and Rai (2015)

12. Application of bio-agents such as *Bacillus thuringiensis* var. *kurstaki*, HaNPV and entomopathogenic nematode, *Steinernema feltiae* against lepidopteran pests
13. Installation of sex pheromone traps to attract the adult males of *H. armigera* and *E. vittella*
14. Encouraging predators e.g. anthocorid bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis*), predatory mites (*Amblyseius* spp.) and predatory coccinellids (*Stethorus punctillum*) against red spider mites
15. Application of wettable sulphur (0.2 %) to control powdery mildew and spider mites.
16. *Cercospora* leaf spot control by spraying with copper oxychloride

The impact of IPM on okra pests including insects, diseases and nematodes is listed in Table 7.3.

Table 7.3 Impact of IPM on pests (insects, diseases and nematodes) and natural enemies

Details of observations	Experiment 1		Experiment 2		Experiment 3	
	% reduction over farmer's practice		% reduction over farmer's practice		%reduction over farmer's practice	
Aphid population (% leaf damage)	54.0		62.8		66.7	
Whitefly population (number per leaf)	70.8		93.3		75.8	
Leafhopper population (number per leaf)	64.2		–		65.8	
Serpentine leaf minor damage (% leaf damage)	45.3		52.6		59.2	
Fruit borer damage (% damage in fruits)	62.8		–		65.8	
Yellow vein mosaic (% infested plants)	74.40		65.2		58.7	
Powdery mildew (% leaf damage)	32.7		–		47.3	
Root rot (% infested plants)	–		91.6		52.6	
M. incognita population (population/250 ml soil)	56.16		60.88		61.94	
Nematode gall index	60.00		60.00		80.00	
Percent increase in natural enemies (coccinellid beetles, spiders, syrphids, and leafminer parasitoids)	21.56		14.32		22.21	
	IPM	Farmer's practice	IPM	Farmers' practice[a]	IPM	Farmer's practice
Yield (t/ha)	20.90	17.00	19.63	–	17.00	15.12
B: C ratio	2.86:1	1.52:1	3.23:1	–	2.53:1	1.23:1

[a]Due to severe root incidence caused by *Macrophomina*, the crop was abandoned

Summary and Conclusion

In okra production, after the introduction of high yielding hybrids, there is increasing incidence of insect pests, diseases and nematodes which results in substantial yield losses. To mitigate the losses due to these pests, large quantities of pesticides are used in okra and it is observed that okra growers spray 10–12 times in a season. Therefore, the fruits that are harvested at short intervals are likely to have pesticide residues that are highly hazardous to consumers. Since the okra produce is harvested at short intervals and also consumed fresh in some cases, the adoption of IPM is essential to avoid the pesticide residues. It was proven that adoption of IPM benefited the farmers in both economically and environmentally sustainable ways.

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