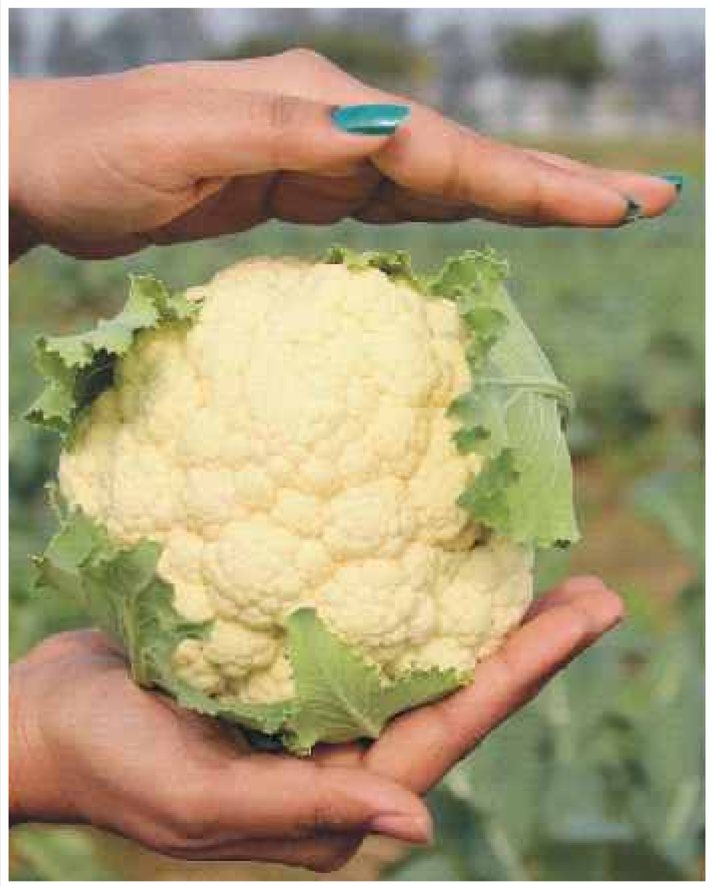
Technical Bulletin No. 53

Eco-friendly Approaches for Sustainable Management of Vegetable Pests



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Varanasi - 221 305, Uttar Pradesh

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Eco-friendly Approaches for Sustainable Management of Vegetable Pests

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FOREWARD

Vegetables play a major role in Indian agriculture as they ensure the food and nutritional security of the country apart from enhancing per capita income of the farmers. Globally, India ranks second in vegetable production and contributes 16.7% to global vegetable area and 15.4% to production. On a global scale, insect pests and diseases are the primary constrains to vegetable production. Borers, sucking pests, fruit flies, root knot nematodes, blight, mildews and viruses are the most important ones causing huge economic losses in the country. In recent past due to climate change coupled with intensification in agriculture, there has been a paradigm shift in infestation of pests in time and space. Management of these biotic stresses needs a comprehensive approach by integrating all ecologically benign methods in vegetable protection. Due to paucity of information, farmers tend to apply chemical pesticides indiscriminately to manage the pests. Finally this venture leads to several concerns regarding environment pollution, residual toxicity in the harvested produce, development of resistance/resurgence in pests, emergence of new pests, food safety and increased cost of production.

The bulletin on "Eco-friendly Approaches for Sustainable Management of Vegetable Pests" is timely and appropriate effort to educate farming community on eco-friendly management of vegetable pests. I believe the description of the vegetable pests, their prevalence, sustainable measures for their management and chronology of the measures (what to do, when to do, why to do, what not to do and why not to do) described in this bulletin will be highly useful to the farmers, extension workers, state officials, academicians and students to plan appropriate management strategies for vegetable pests.

The efforts made by the scientists of the Indian Institute of Vegetable Research, Varanasi deserve appreciation in bringing out such a useful publication.

Date : January 27, 2014

(Dr. N. K. Krishna Kumar)

Place : New Delhi

PREFACE

Vegetables are increasingly becoming important for nutritional and livelihood security due to nutritional richness, economic viability and ability to generate on-farm and off-farm employment. Globally India ranks second with a production of 156.33 million tons of vegetables. However, the current level of productivity of 17.4 t/ha is quite low in comparison with the other leading vegetable producing countries. One of the major constraints of low productivity in vegetable production is the losses associated with the vegetable pests. At present, various pests cause losses in the range of 10-30 per cent depending upon the infestation severity in time and space. Farmers use pesticides as first line of defense and frequently resort to indiscriminate and non-judicious use of pesticides. However these measures lead to several problems such as environmental pollution, pesticide residue in the harvested products, development of resistance/resurgence in pests, emergence of new pests, destruction of natural enemies and pollinators, and increased cost of production. In the background of this, a paradigm shift in pest management approaches is urgently required. This can be effectively achieved through rationalization of pesticide use and integration of several eco-friendly approaches to minimize over reliance on pesticides. These approaches, if undertaken will also help growers in producing vegetables in compliance with the international standards for vegetable export.

In this endeavor, useful information has been generated in different vegetables at Indian Institute of Vegetable Research, Varanasi and other national research institutions. However, this information is scattered in various documents and not readily available in a single publication. In view of this, efforts have been made here to compile available information in a systemic manner and present in the form of a bulletin entitled ***"Eco-friendly Approaches for Sustainable Management of Vegetable Pests".*** The information is presented with series of appropriate chapters that contain illustrations and descriptions of many of the economically important pests. The sustainable measures comprising cultural practices, resistant/tolerant varieties/hybrids/genotypes, bio-control agents, botanicals, chemical pesticides with appropriate dose, and time of application have been presented for the management of different pests. Importantly, we have focused on the chronology of the measures (*what to do, when to do, why to do, what not to do* and *why not to do*) critical for decision making in pest management.

The authors express deep sense of gratitude to Dr. N. K. Krishna Kumar, Deputy Director General (Horticulture) for his constant inspiration, valuable suggestions and encouragement to bring out this publication. The help rendered by the scientists of crop protection division in the preparation of this manuscript is thankfully acknowledged. We hope that this bulletin will be highly useful to the farmers, extension workers, state officials, academicians, students and researchers.

Authors

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TABLES

1. MAJOR INSECT PESTS AND DISEASES OF VEGETABLES IN INDIA

Insect pests and diseases are the major biotic constraints to vegetable production. The crop losses in the country due to various pests range on an average from10-30 per cent (table-1). Apart from causing direct damage, many of them also act as vectors for several viral diseases which have aggravated the problem still further. In recent past, with changes in the cropping pattern, ecosystems and habitat, climate and wider use of high input intensive vegetable varieties/hybrids, a shift in status of pests and diseases has been realized in time and space. Most of the plant protection recommendations in vegetables so far indicated the calendar based application of pesticides. This has become a common practice over the years by most of the farmers growing vegetables in the country. Chemical method of management has its own demerits like ill effects on environment and human and animal healths. Many pests have adapted new hosts, developed resistance to pesticides and often there are secondary out breaks. Insect pests like serpentine leaf miner (*Liriomyza trifolii*) on tomato and cucurbitaceous crops, gall midge on brinjal, chilli and capsicum; stem fly on okra, leafhopper (*Empoasca motti*) on bitter gourd; head borer (*Hellula undalis*) on cabbage, red spider mite (*Tetranychus* spp.) on okra, brinjal, cowpea and Indian bean; yellow mite (*Polyphagotarsonemus latus*) on chilli and more recently mealy bug (*Pheonacoccus solenopsis*) on okra, chilli, brinjal and tomato specially in protected conditions have intensified the severity of occurrence in different parts of the country. Similarly, many soil borne aggressive pathogens such as *Rhizoctonia*, *Sclerotium*, *Pythium* and plant parasitic nematodes are noted to threat the vegetable production system. Apart from these, the aerial pathogens such as fungal (*Alternaria*, *Cercospora*, *Colletotrichum* and mildews), bacterial (*Xanthomonas*, *Corynebacteria*, *Pseudomonaes* and *Ralstonia*) and different viruses (leaf curls, yellow mosaic) are noted to be major limiting factors for vegetable production in India.

Table 1: Yield losses due to major insect pests and diseases in major vegetables in India.

Crop/Pest	Yield loss (%)	Crop/Pest	Yield loss (%)
Tomato		Brinjal	
Fruit borer (*Helicoverpa armigera*)	24-65	Fruit and shoot borer (*Leucinodes orbonalis*)	11-93
Early blight (*Alternaria solani)*	Up to 78	Blight (*Phomopsis vexans)*	30-50
Wilt (*Fusarium oxysporum* f. sp. *Lycopersici)*	10 to 60	Root knot nematode (*M. incognita, M. javanica*)	16.62
Wilt (*Verticillium dehalie)*	20-30	Cabbage	
Begomoviruses	100	Diamond back moth (*Plutella xylostella*)	17-99
Root knot nematode (*Meloidogyne* spp)	27.2	Caterpillar (*Pieris brassicae*)	69
Chilli		Leaf webber (*Crocidolomia binotalis*)	28-51
Thrips (*Scirtothrips dorsalis*)	12-90	Cabbage borer (*Hellula undalis*)	30-58
Mites (*Polyphagotarsonemus latus*)	34	Black rot (*Xanthomonas campestris* pv. *campestris)*	50
Anthracnose (*Colletotrichum* spp.)	30-80	Cucurbits	
Viral disease due CMV and PVY	66.7-74	Fruit fly (*Bactrocera cucurbitae*) Bitter gourd	60-80
Root knot nematode (*M. incognita*, *M. javanica*)	12.85	Cucumber	20-39
Okra		Ivy gourd	63
Fruit borer (*H. armigera*)	22	Musk melon	76-100
Leafhopper (*Amrasca biguttula biguttula*)	54-66	Snake gourd	63
Whitefly (*Bemisia tabaci*)	54	Sponge gourd	50
Shoot and fruit borer (*Earias vittella*)	23-54		
Bud rot (*Choanephora cucurbitarium)*	5-50		

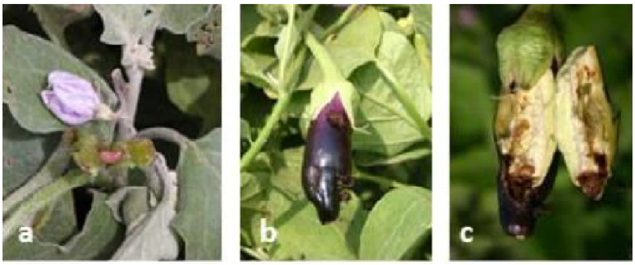
Success of management of insect pests/diseases highly depends on correct identification and selection of appropriate control measures. Among the various methods of pest control, chemical method still enjoys first choice because of its quick action and easy availability. Consequently, vegetables consume about 13-14 per cent of the total pesticide consumption in India. Presently, the maximum pesticide usage is in chilli (5.13 kg a.i. /ha) followed by brinjal (4.60 kg a.i. /ha), cole crops (3.73 kg a.i. /ha) and okra (2-3 kg a.i. /ha). Unlike cereals, the green pods and fruits harvested at shorter intervals and used as vegetables are prone to retain pesticide residue.The residue problem becomes more severe when the Good Agricultural Practices (GAPs) are not followed. In the present context of food and environmental safety, biological and non-chemical approaches for the management of pests/ diseases are being emphasized in developing bio-intensive IPM/IDM technologies to reduce the toxic residues in the produce and cost of inputs. However, field efficacy of bio-control agents in many cases has failed to combat the pests/disease due to evolution of new biotypes/stains/pathotypes/ races in the insect/pathogen system. Hence, it is imperative to develop, validate and implement multipronged approaches consisting of biological, host plant resistance/tolerance, cultural practices, etc. to manage the pests and diseases. In the last couple of decades, researches on vegetable pest and disease management have been reoriented in this direction that has resulted in the generation of extensive information on these aspects. An attempt has been made in this bulletin to compile all the information on eco-friendly management of pests for sustainable vegetable production.

2. IMPORTANT INSECT PESTS OF VEGETABLES

Among major biotic constrains in vegetable production in India, tomato fruit borer (*Helicoverpa armigera*), brinjal shoot and fruit borer (*Leucinodes orbonalis*), chilli thrips (*Scirtothrips dorsalis*) and mite (*Polyphagotarsonemus latus*), fruit and shoot borer (*Earias* spp.) on okra, diamond back moth (*Plutella xylostella*) on cole crops, fruit fly (*Bactrocera cucurbitae*) on cucurbits are important ones. Insect pests like serpentine tomato leaf miner, gall midge, okra stem fly and bitter gourd leafhopper and mites are gradually attaining the major pest status in different regions of the country. Earlier gall midge known to be a minor pest is gradually becoming a regular problem in chilli, Capsicum and brinjal in the states of Andhra Pradesh, Karnataka and in brinjal in Chhattisgarh, whereas *Hellula undalis* on cabbage and red spider mite on okra, brinjal, cowpea, Indian bean, etc. and more recently mealy bug, *Phenococus solenopsis* on several vegetable crops, have intensified the severity of occurrence.On an average the extent of crop losses in vegetables due to insect pest infestation is 40 per cent that varies with the plant type, agro climatic conditions, damage potential of the pest involved and cropping season prevailing in different parts of the country.

2.1 BRINJAL

2.1.1 Shoot and fruit borer (*Leucinodes orbonalis* Guenee)



a. Shoot damage by larva, b. Exit holes plugged with excreta and c. Damaged fruits with larvae inside.

It is one of the most destructive pests of brinjal causing 11-93 per cent damage in the country. There are five larval instars completing in 9-28 days depending upon the weather conditions. The larvae bore into tender shoots, petiole and midribs of large leaves and cause wilting and "dead heart". In the later stage, they also bore into the flower buds and fruits resulting dropping of flower buds at early stage. The fruit is damaged considerably and the entry hole is plugged with excreta. A single caterpillar may destroy as many as 4-6 fruits. The infested fruits become unfit for consumption and marketing.

Young larvae are creamy white in colour while full-grown larvae are light pinkish and measure about 17-23 mm in length. The moth can be recognized by white wings having characteristic triangular brown and red markings on the fore wings. Gravid female moth lays 8-120 creamy white eggs mostly singly or sometime in batches of 2-4 on the underside of leaves, tender shoots, flower buds or calyces of fruits. The incubation period varies from 3-6 days. Pupation takes place in hood-shaped fallen leaves or in soil by making a tough gray cocoon. The pupal period lasts for 5-15 days.

2.1.2 Stem borer (*Euzophera perticella* Rag.)

Euzophera larva feeding on brinjal stem

Wilting of brinjal plant

This is a minor pest of brinjal but occasionally it attains serious status. Infestation is more pronounced during the late stage of the crop. The insect is active from March to October and hibernates as larva in the stem of old plant from November to March. The moth emerges sometimes in March and soon after mating adult female lays eggs singly on the stem and larvae enter the stem and feed exclusively in the main stem by making a longitudinal tunnel. Infested plant becomes either stunted with yellowing of leaves or whole plant gets wilted.

Gravid females lay eggs singly or in batches in tender leaves, shoots or buds. Incubation period lasts for 4-8 days. Full grown caterpillars are creamy white in colour and measure about 20-23 mm in length. Pupation takes place in the feeding galleries inside the stems or in cracks and crevices in the soil. Moth is small having pale straw yellow forewings and whitish hind wings and emerges in 6-8 days. The insect completes its lifecycle within 35-75 days.

2.1.3 Red spider mite (*Tetranychus cinnabarinus*(Boisduval), *T. urticae* Koch.)


Mites feeding on under surface of leaf


Webbing of the red spider mites over the foliage

It is a polyphagous non-insect pest feeding on more than 150 host plants including vegetables like brinjal, ladies finger, cowpea, cucurbits, beans etc. These mites normally inhabit the under surface of leaves and spin the webs. The plants often remain covered with dense webs under which both the developing stages and adults damage the crops by sucking the cell sap. Besides, dust particles get adhered to webs and retard normal physiological activities of the plant leading to reduction in plant growth and yield. The affected leaves turn yellow, dry up and finally wither away giving an unhealthy appearance. Generally, spider mites are found numerous during summer months, multiply quickly and pass through a several generations in a very short period of time like aphids.

These mites are soft bodied red in colour and colony forming. Larva is six legged while nymphs and adults are eight legged like spider. Size varies from 0.5-0.6 mm. Spider mite completes its life cycle within 9-14 days during active period.

2.2 TOMATO

2.2.1 Fruit borer (*Helicoverpa armigera* Hubner)

It is a highly polyphagous and polymorphous pest infesting more than 400 agricultural and horticultural crops. Several vegetable crops like tomato, cabbage, cauliflower, ladies finger, cowpea, pea, field bean, chillies, brinjal, potato, etc. have been found


Larvae of H. armigera feeding on tomato


Adult moth of Helicoverpa armigera

to be infested by this pest. In tomato its infestation appears from flowering stage. The neonate larvae initially feed on the foliage and later bore into the yellowish green fruits. Damaged fruits are unfit for consumption and also invite secondary infection by other organisms lead to rotting. During the feeding, larvae characteristically thrust its head into the fruit leaving the rest of its body outside.

Adult female lays around 240-750 spherical eggs during its life cycle on the flower buds, flowers, tender fruits and growing shoots. Incubation period varies from 3-7 days. Larvae are greenish to variable colours with dark broken grey lines. Pupation takes place in an earthen cell. The total developmental period ranges from 25-40 days depending upon the temperature and the host.

2.2.2 Leaf miner (*Liriomyza trifolii* (Burgress))

It is one of the polyphagous agromyzids causing serious damage on several crops including okra, onion, cucurbits, beans, cowpea, potato, brinjal and crucifers. Damage by the pest occurs due to mining into leaves and petiole by the larvae. The photosynthetic activity of the plants is often greatly reduced. Severely infested leaves may dry and fall.

Serpentine leaf mines with maggots inside.

Eggs are inserted singly below the leaf surface and hatching takes place within 2-5 days. After hatching, the larvae start mining into the leaves in a zig-zag fashion. Pupation occurs in the soil beneath the plant. Adult emergence takes place 7-15 days after pupation. Life cycle completes in 12-15 days.

2.2.3 Whitefly (*Bemisia tabaci* Gennadius)

Whiteflies are cosmopolitan and polyphagous insects. Other than tomato, they also feed on brinjal, ladies finger, cowpea, cucumber, pumpkin, chillies, etc. There are 11 to 15 generations in a year. Both the nymphs and adults suck the sap and also secrets the honeydew on which black sooty moulds develops that reduce the photosynthesis of the plants. Apart from direct feeding damage, it also act as vector of a wide range of important plant viruses *viz.*, *Tomato leaf curl virus* (TLCV), *Bean golden mosaic virus* (BGMV), *Bhendi yellow vein mosaic virus* (BYMV) etc.

(a) Nymphs and adult whiteflies on undersurface of the leaves, (b) Nymphs and adult whiteflies and (c) Tomato leaf curl virus infected plants

Adults are small, tiny, soft-bodied insects. Entire body is covered with white waxy bloom, hence the name whitefly. Stalked whitish eggs are laid in circular fashion on the undersides of leaves. Hatching occurs after 5-9 days depending on host species, temperature and humidity.

On hatching, the first instar larva (only mobile stage) or crawler moves to a suitable feeding site mostly on the lower leaf surface where it moults and becomes stationary throughout the remaining stages. Nymphs are oval, scale-like and greenish white in colour. The fourth larval stage is called as puparium. Pupation lasts for about 4-6 days. The adult emerges through a 'T'-shaped rupture in the puparium. A female lives upto 60 days while the male lives shorter for 7-19 days.

2.3 CHILLI

2.3.1 Yellow mite or broad mite (*Polyphagotarsonemus latus* Banks.)

a **b** **c**

(a) Stages of mite on under surface of leaf, (b) Downward curling of the chilli leaves due to P. latus and (c) Mite infested fruits.

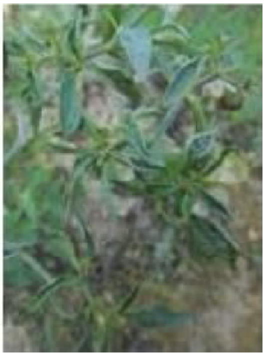
It is a polyphagous, cosmopolitan, white, transparent, very tiny, microscopic mite and observed in large numbers on under surface of the leaves. Mostly mites are congregated towards terminal leaves of the plants. They suck the cell sap and cause typical "down ward curling" of the leaves like inverted boat and petiole elongation in older leaves. Edges of damaged young leaves usually curl downward and the foliage often becomes rigid and appears bronzed or scorched. In severe infestation fruits become brownish with hard skin. Yield is drastically reduced.

They are tiny sized varies from 0.2- 0.25 mm. Each females lay around 20-25 eggs on the underside of leaves, tender stems, flowers and even on fruits. On chilli, the developmental period from egg to adult is 3-4 days. Adult longevity is 10-15 days.

2.3.2 Thrips (*Scirtothrips dorsalis* Hood.)

It is a polyphagous, cosmopolitan, soft-bodied, sap sucking insect occurs throughout the year except the monsoon season and most active during dry weather. As many as 25 overlapping generations occur in a year. The nymphs and adults lacerate the tissues and feed on the oozing sap. The infested leaves become shortened, crumble and curl upwardly and finally shed. The attacked shoots hardly develop and the leaves fall off. Affected fruits show light brown scars and reduced its market value severely.

Nymphs of S. dorsalis



Typical upward curling of leaves

Adults are slender, minute with apically pointed heavily fringed wings and yellowish brown or grey in colour,whereas, the nymphs are similar to adults except wing and smaller in size. A female lays about 40 to 50 eggs over a period of 20-30 days in to the leaf tissues and shoots. Entire life cycle completes in 15-20 days.

2.4 OKRA

2.4.1 Okra shoot and fruit borer (*Earias insulana* (Boisduval) and *E. vittella* Fabricius)

This is an oligophagous pest of malvaceous crops like okra and cotton. It is widely distributed throughout India. Initial stage caterpillars bore into tender shoots and tunnel downwards. Affected shoots wilted and drooped down. During reproductive stage, they bore the fruits and feed inside it. The infested fruits become unsuitable for consumption and marketing.

Wilting of shoots

Infested fruits

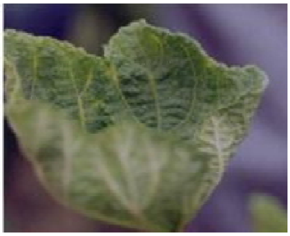
Larva feeding inside fruit

Adults are medium sized moths with 13-15 mm long and hind wings are silver creamy white in colour. Fore wings of *E. vittella* are pale white with a broad wedge shaped horizontal green patch in the middle while *E. insulana* are uniformly green. A female lays on an average 400 eggs singly on buds, flowers, tender shoots and young fruits thorough out its life. Eggs are spherical, about 0.5 mm in diameter, light bluish green in colour, with ridges. The larva is grayish brown with dark brown to black spots on the body. Full-grown caterpillars are stout and spindle shaped measuring 18-24 mm. Pupation takes place on plant debris or in soil with in an inverted boat-shaped silken light brown cocoon (13-16 mm). Incubation, larval and pupal period lasts for 3-9, 9-20 and 8-12 days, respectively.

2.4.2 Leaf hopper (*Amrasca biguttula biguttula* Ishida)

This is polyphagous pest widespread in the Indian subcontinent. Major host plants include okra, potato, brinjal, cotton, castor, beans and cucurbits. Damage caused by both the nymphs and adults by sucking the sap from the underside of the leaves. Affected leaves initially turned yellow and then converted to pinkish red and become brittle and crumple followed by upward curling of leaves. Severely affected plants have stunted growth. Cloudy weather favours its rapid multiplication. Rainfall is a key mortality factor for the nymphs and adults.

a



b

(a) Nymphs of Amrasca feeding on underside of the leaf surface and (b) Typical leafcupping.

Adults are pale green, wedge-shaped and move diagonally. Nymphs are translucent yellowish green in colour. The eggs are yellowish white in colour and inserted on the main veins on the under surface of the leaves. The females lay around 15-38 eggs during its life and the incubation period is 7-11 days. There are five nymphal instars and each instar completes within 3-5 days. The longevity of adults is 11 days.

2.4.3 Solenopsis mealybug (*Phenacoccus solenopsis* Tinsley)

a

b

(a) P. solenopsis on okra and (b) brinjal

It is a polyphagous, invasive, recently introduced pest first reported to attack on cotton and subsequently to a number of crops like food, fibre, fruit, ornamental, plantation, vegetable and weeds. Among the vegetables, its infestation was reported from tomato, ladies finger, brinjal, chillies, pumpkin, etc. Both nymphs and adults cause damage by sucking the sap from the growing points resulting the infested plants loose its vitality and in heavy infestation gradually dried. They also create the black sooty mould which inhibits the photosynthetic activity of the plants.

They often attended by the ants which cause for their rapid spreading. The mean developmental period from immature crawler to adult stage varied from 12-15 days.

2.4.4 Whitefly (*Bemisia tabaci* Gennadius)

Please see 2.2.3 above.

2.5 COLE CROPS (CABBAGE AND CAULIFLOWER)

2.5.1 Diamond back moth (*Plutella xylostella* Linn.)

It is considered as a major insect pest of cruciferous plants particularly, cabbage, cauliflower and sprouting broccoli. There are 8 to 12 overlapping generations in a year. The newly hatched larvae cause serious damage by scrapping the epidermal leaf tissues and later feed the entire foliage render the vegetables unfit for consumption. A severe infestation results in the formation of under-sized curds in cauliflower and in cabbage, leaves are completely drilled with holes and head formation does not take place when the infestation is severe during primordial stage.

Adult moths are small (8-10 mm), grayish brown with distinct whitish spots on the fore wings. When the wings are folded at rest, three white diamond shaped median dorsal patches are seen and hence they named as "diamond back moth". The gravid female lays minute yellowish-white eggs

Cabbage leaves damaged by DBM

DBM pupae on the cabage leaf

DBM adult

singly or in batches of 2-40 mostly on the underside of foliage. The egg hatches in 3-10 days. The neonate larvae move to the under surface of the leaf and mine the leaf tissue. The full-grown larvae are pale yellow-green (8 mm) and feed on the underside of the leaf by making characteristic holes. The larval duration lasts for 9-17 days. Pupation takes place inside a barrel-shaped, loose silken cocoon, normally attached to the leaf surface. The pupal stage completes within 4-5 days. The total life cycle is completed in 4-5 weeks.

2.5.2 Aphids (*Myzus persicae* Sulzer and *Brevicoryne brassicae* Linn.)

Aphids are most widely distributed sucking pest of cole crops with a range of host plants. Mostly appear during November and remain active till April. Cloudy and humid weather favours rapid multiplication of the pest. Under favourable conditions, 11 to 20 overlapping generations are completed in one year. Direct feeding through sucking the plant sap by both the nymph and adult causes stunted growth of the plants and poor head formation. Infested seedlings lose their vitality and distorted.

M. persicae on cabbage leaves

Beside these, they also excrete honey dew which favours the development of sooty mould on the foliage thereby reducing the photosynthetic activity of the plants. *M. persicae* is reported to transmit over 100 plant viral diseases.

Minute, soft-bodied, yellowish green, pear shaped nymphs and adults found in colonies under surface of the leaves. A single female produces viviparously 5 to 10 young ones per day during February to May and 2 to 5 per day during July to January. The life cycle is completed in 11 to 18 days during April to March.

2.5.3 Cabbage butterfly (*Pieris brassicae* Linn.)

Larvae of P. brassicae

A sporadic pest of cruciferous crops causes serious damage in northern and eastern parts of India. It passes its winter in plains and migrates to Himalayan hilly regions during summer. The caterpillars feed gregariously and skeletonize the foliage. Newly hatched caterpillars scrape the leaf surface,whereas, mature larvae eat up the leaves from margins, leaving the main vein. Sometimes entire crops may be eaten by this insect.

Adults are medium sized butterflies and they are snow white colour with black markings. The females lay about 100-150 orange-yellow coloured conical eggs in clusters on the upper or lower side of the leaf. The eggs hatch in 10-17 days in winter and 3-8 days in summer months. Neonate larvae are pale yellow and later turn to greenish yellow. Mature larvae (25-48 mm) are velvety bluish green with black dots and yellow dorso-lateral stripes. There are five instars and are full-grown in 2-3 weeks in March-April and in 4-6 weeks during November-February.

2.6 CUCURBITACEOUS VEGETABLES

2.6.1 Fruit fly (*Bactrocera cucurbitae* (Coq.))

a b

(a) Maggots feeding on the bitter gourd fruit and (b) adult fruit fly

It is a major pest of cucurbits particularly in bitter gourd and musk melon. Among the several species of fruit fly, *B. cucurbitae* is most important due its polyphagous nature and cosmopolitan distribution. The female fly makes a cavity with the help of its sharp ovipositor and inserts the white, cigar-shaped, slightly curved eggs singly or in groups into the flowers and tender fruits. The incubation period is 3-9 days. The freshly hatched maggots bore into the fruit pulp by forming serpentine galleries and contaminating them with its frass and providing entry points for saprophytic fungi and bacteria, which cause the rotting of the fruit. Due to feeding on pulp, there is premature dropping of fruits and make them unfit for consumption. The infestation varies from 50-100 per cent in different cucurbitaceous crops.

Adult flies are medium sized (4-5 mm long) with reddish brown and their wings are hyaline with a dark patch on the outer margins. Hind cross veins thickened with brown and grey spots at the apex. The full-grown maggots come out of the fruits and drop to the ground and pupate in the soil. The total life cycle occupies 14-34 days depending on weather conditions. There are several over lapping generations in a year.

2.6.2 Red Pumpkin beetle (*Aulocophora foveicollis* Lucas)

It is a bright orange red coloured medium size (6-8 mm) beetle with black ventral surface found regularly on cucurbitaceous crops like pumpkin, cucumber, ash guard, bottle gourd, bitter gourd and melons. The grubs live in soil feeding on roots, rootlets and under ground stems and sometimes on fruits in contact with the soil. On emergence, the beetles feed on aerial parts of the plants like cotyledons, flowers and foliage and make holes on them. The damage by beetles is more detrimental during the cotyledonous stage of the plants.

Adults of A. foveicollis feeding on the flowers

The female beetle lays 250-300 oval eggs, initially yellowish pink in colour and later changes to orange. The eggs are laid singly or in batches of 8-9 in moist soil, near the base of the plant. The incubation period lasts for 5-15 days. Fully grown grubs are 10-12 mm in length. The pupation takes place in earthen chambers in the soil at a depth of 15-25 cm. It completes its life cycle in 25- 38 days.

2.6.3 Cucumber moth or leaf eating caterpillar (*Diaphania indica* (Saunders))

It is an occasional and sporadic pest of cucumber and also becoming serious on bitter gourd and gherkins. After hatching, caterpillars feed chlorophyllous portion of the leaves by webbing them together. Sometime the flowers and young fruits are also infested. The larvae make characteristic holes on the fruits and feed inside it. The bored fruits become unfit for human consumption.

a **b** **c**

(a) Cucumber leaf damaged by the D. indica, (b) larvae of D. indica and (c) adult D. indica.

The adults are medium sized moths with whitish transparent forewings with big brown patches on the margin. Females have an anal tuft of orange coloured hairs at the caudal end. The caterpillars are elongated, bright green and bear a pair of narrow longitudinal white streaks along the mid-dorsal line. A female can lay up to 350 eggs, mostly singly or sometimes in groups on the lower surface of leaves. The egg, larval and pupal periods last for 3-6, 9-15 and 5-12 days, respectively. The pupation takes place in the silken cocoons formed in the leaf folds. Life cycle is completed in three to five weeks.

2.7 LEGUMINOUS VEGETABLES

2.7.1 Spotted pod borer (*Maruca vitrata* Geyer)

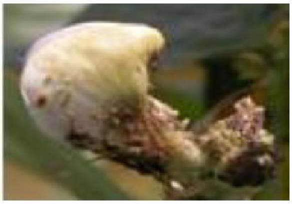
It is a serious pest of leguminous crops and gaining importance due to its wide geographical distribution, extensive host range and its ability to infest the young growing plant tips, stems, flower buds, flowers, pods and seeds. Young larvae feed on the flowers and young pods by scrapping and later stage they bore the pods and feed the internal content of the fruits and make unsuitable for consumption. Infested flowers drop down prematurely. Sometime, they also feed the leaves and shoots by making galleries. In cowpea, damage due to this pest is reported up to 42 per cent.

a **b**

(a) Maruca larva feeding cowpea pod and (b) adult moth of M. vitrata

Moths are medium sized with brownish black fore wings with conspicuous transverse white elongate marking,whereas, hind wings are translucent, pinkish white in colour. Eggs are laid singly on the flowers, flower buds, pods, tender leaves and growing points. The egg hatches within 3-4 days and larval period lasts for 11-16 days.

2.7.2 Black bean aphid (*Aphis craccivora* Koch.)



A. craccivora infesting cowpea leaves and buds

It is soft-bodied, black coloured sucking pest usually found in colonies on the growing points of the plants, tender fruits, flower buds etc. Both the nymphs and adults suck the sap from the plants and cause stunted growth of the plants and seeds shrivelled in the developing pods. They also produce copious amount of honeydew deposited on the plants and develop the sooty mould which hinder the photosynthetic activity of the plants. Beside these, they also transmit the viral diseases like bean yellow mosaic virus, bean common mosaic virus, etc. Reproduction noticed throughout the year by means of parthenogenesis.

They are often attended by the symbiotic ants which favour them for dispersal and protection against natural enemies. Total life cycle completes in 9-13 days depending on the weather conditions.

3. IMPORTANT FUNGAL DISEASES OF VEGETABLES

Two major groups of fungal pathogens are found to attack the vegetables. The genus such as *Sclerotium*, *Pythium*,*Phytophthora*, *Fusarium* and *Verticillium* are known to attack root or collar region of the crop, while *Alternaria*, *Cercospora*, *Colletotrichum*, *Erysiphe*, *Pseudoperonospora* and *Uromyces* infect aerial parts (leaves, stem, fruits, *etc*.) of the plant. The yield loss due the diseases is estimated to the tune of 50-80 per cent from the heavily infected fields. The intensity of disease varies depending on the environmental conditions, virulence of pathogen and degree of resistance present in the host.

3.1. BRINJAL

3.1.1. Wilt or collar rot


a **b**

(a) Wilt/Collar rot disease of brinjal (b) Mycelium and sclerotia produced by the fungus on collar region and root zone

Wilt or collar rot caused by *Sclerotium rolfsii* is a polyphagous and ubiquitous fungus attacking wide range of vegetables including brinjal, tomato, chilli, cucurbits etc. grown in tropical, subtropical and temperate regions. It causes 30-90 per cent seedling mortality which may account for more than 50 per cent yield loss under severe infection. The fungus produces lot of brown colour mustard like sclerotia which permit the fungus survive in the soil for long term. When the next crop is planted the sclerotia start germinating as white colour mycelium and attack the crop. It attacks both collar region and root portion of crop by establishing mycelial network on them and starts decaying the regions hence, the infected plants become wilted.

The fungus survives well in low moisture level (20-40%) and aerobic conditions. The germination of mycelium and sclerotia is favoured by high temperatures (28-30^{0}C) and high relative humidity.

3.1.2. *Phomopsis* rot

The disease is caused by *Phomopsis vexans*. It causes damping off in the nursery. On leaves it produce circular, light brown spots mostly in lower leaves. Later, spots show numerous black colour dots due to formation of pycnidia. The diseased leaves may turn into yellow and falls pre-maturely. On twigs and stem it produces blight or lesions. On fruits, initially pale sunken circular ring like spots are produced, later these spots coalesce to form bigger patches and finally turn into fruit rot. Severely infected fruits show brown rotting both inside and outside the tissues. Finally the infected fruits become shrivel and mummified.

Phomopsis blight on brinjal fruit

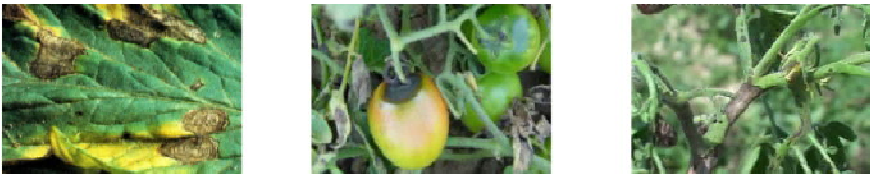
The fungus survives on the infected plant debris, in and on the seeds. It can survive in the soil for more than a year. The disease is spread by splashing water. The disease is favoured by warm and wet weather conditions.

3.2. TOMATO

3.2.1 Early blight

The disease is mainly caused by *Alternaria alternata* and *A. solani*. Yield losses due to this have been reported up to 79 per cent from different part of world including India, Canada, the United States and Nigeria. Apart from early blight symptom, this pathogen also causes collar rot which has been reported to account for seedling losses of 20-40 per cent in the infected field.

Initially the infected leaves show small dark spots, which enlarge into



a **b** **c**

Early blight disease of tomato; (a) Target board symptom on leaf, (b) Sunken ring like rotting on fruit; (c) Lesion on the stem circular lesions with concentric blackish yellow rings that is called target board symptom. Later all the spots coalesce and become irregular blight. On the infected stem and petioles, elliptical concentric lesions appear which may gradually weaken the plant. On ripe-fruits, it shows large, dark, leathery, sunken areas bordered by concentric rings

The disease is favoured by warm temperature and extended periods of leaf wetness from frequent rain, overhead irrigation or dews. The disease is polycyclic and produce numerous conidia during its life cycle. These spores may germinate under favourable conditions and infect the plants. Early blight is more prevalent on old transplants and the transplants lacking vigour or stressed by wilting. The fungal spores are disseminated by wind and rain, running water, insects, workers, farm tools and implements. The pathogen can be seed-borne and it also persists in the soil, on diseased tomato debris and volunteer tomato plants or solanaceous weeds. The spores can resist and survive under hot and dry conditions.

3.2.2. Late blight disease

Late blight in tomato is caused by *Phytophthora infestans* (Mont.) de Bary. It is a most important disease of tomato and it can cause 100 per cent yield loss in severely infected field. It also affects other solanaceous crops like potato and weeds.

Initially it produce small water soaked lesions with irregular border on leaves and later these lesions turn pale green to black. In advance stage, the lesion joined together and produce blight symptoms. Under surface of the leaves shows white mycelial growth in between blight area and healthy tissue.

Late blight symptoms on leaves

Late blight symptom on tomato plant

Weather factors like cool temperature and humid favoure the disease development as zoospores are produced from sporangia in high RH (91-100%) and optimum temperature (64-72°F). More preciously, it infects fast in 60-70°F day temperature and 50-60°F night temperatures with 100 per cent RH. The disease can spread fast and destroy the crop quickly as the pathogen produce 300,000 sporangia per day from single lesion. It can spread through wind or rain or infected seeds, or movement of human or tool in infected field. It also can produce thick wall oospores which can survive in soil for long time and acts as propagule for next season crop.

3.2.3. Fusarial wilt

Fusarium oxysporum f. sp. *lycopersici* (Sacc.) W.C. Snyder and H.N. Hans, a soil-borne plant pathogen causes wilt in tomato. It can cause up to 90 per cent yield loss from severely infected field.

Tomato plant showing yellowing due to Fusarium wilt

Browning of vascular tissue

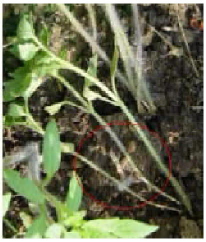
The first indication of this disease is yellowing and drooping of the lower leaves. This symptom often develops at one side of the plant or on one shoot. Successive leaves become yellow, wilt and die, often before the plant reaches maturity. As the disease progresses, the plant growth is typically stunted, and little or no fruit develops. If the main stem is cut open, dark brown streaks running all along the vascular system of the stem will be seen. Browning of the vascular system is the characteristic of infection by fusarial wilt and therefore, can be used for preliminary diagnosis of this disease.

Generally, the pathogens which cause wilt diseases are soil inhabitant and the main mode of infection is via infected soil. Fusarial wilt occurs in high temperature (78-90°F) and poorly drained soil.

3.2.4. Damping off

Disease is mainly caused by *Pythium aphanidermatum* and *Rhizoctonia solani*. It can cause up to 70 per cent seedling loss in vegetable crops. Two types of symptoms are commonly noticed, (i) Pre-emergence damping-off, where the damping-off occur in seed and seedling stage before they emerge out from the soil, which may lead to poor seed germination and seedling emergence in the nursery, and (ii) Post-emergence damping-off, where the damping-off phase is characterized by infection of the young, juvenile tissues at the collar region. In such cases, the infected tissues become soft and water soaked. The collar portion rots, ultimately the seedlings collapse and die, this is called toppling over symptom in the nursery. Damping off caused by *Pythium* is more prevalent in the nursery with high soil moisture and moderate temperature along with high humidity. Whereas damping off by *Rhizoctonia* spp. is more in dry conditions.

Tomato nursery suffering from damping off disease

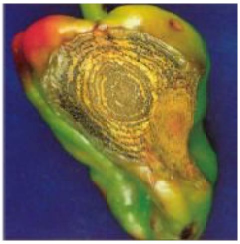


Toppling of seedlings due to infection on collar region

3.3 CHILIES

3.3.1. Anthracnose

Infected plants showing anthracnose symptoms on fruits



Capsicum fruit infected with anthracnose

Anthracnose pathogen infecting chilli has been reported with five different species: *Colletotrichum capsici, C. acutatum, C. gloeosporioides, C. coccodes* and *C. dematium*. Among the five species, *C. gloeosporioides* and *C. capsici* are the most predominant species infecting chilli in India. *C. gloeosporioides* is having wide host range which comprises of avocado, guava, apple, almond, mango and strawberry, and plantation crop, arabica coffee whereas, *C. capsici* reported only in the crop genus *Capsicum* spp.

Normally the symptom is produced on all plant parts including leaf, stem and fruit. On plant, it produces typical die back symptom where the tip of twig or branch become necrotic or dry and extend the process from top or tip to bottom. On fruits, circular spots are produced initially and later the spots become enlarge to form a circular or elongated circular grey colour spots with black dots inside which indicates formation of acervuli. In chilli cultivation, anthracnose is reported as one of the most destructive diseases worldwide including Asian countries. Crop loss due to the disease is estimated as 30-80 per cent even to 90 per cent under severe conditions.

In general, optimum temperature around 27°C and 80 per cent relative humidity (RH) are required for fast development of the disease. It is spread though infected seeds and crop debris. Secondary spread is through conidia dispersed by wind and rain splash.

3.4 OKRA

3.4.1 *Cercospora* leaf spots

Three species *viz.*, *Cercospora abelmoschi*, *C. malayensis* and C. *hibisci* are reported to cause the leaf spot disease. All the stages of the crop are susceptible to this disease and it is one of the notable diseases in okra. In India *C. abelmoschi* is the most prevalent species and it produces gray colour spores on the lower surface of the leaves which later become sooty black patches and corresponding upper surface yellowish to dark green colour or purplish red irregular spots are produced. The other two species *C. malayensis* and *C. hibisci* produces small, round, necrotic spots surrounded by purple halo and later the centre portion become grey colour and in advance stages, it may produce shot hole symptoms.

Symptoms on upper surface

Symptoms on lower surface

Infected plant debris serves as primary inoculum. The spores are dispersed by wind from one plant to other. High temperature coupled with high level humidity favours fast spread of the disease. Heavy moisture followed by high temperature coinciding with vegetative phase of the crop may favour the disease development.

3.4.2 Wet/Bud rot

Wet/Bud rot is caused by *Choanephora cucurbitarium* L. It is reported to be a severe problem in okra and other vegetables. The yield loss due to the disease has been estimated as 5-50 per cent in tropic and subtropical countries. The fungus enters into the fruits from blossom end and develops feathery mass of black spores. It also produces wet rot on leaves and stem. The affected parts will have silky hair like structures and in severe cases it cause heavy defoliation.

Bud rot symptom on okra

Main predisposing factor for the disease is injuries on plant parts. Warm and moist weather favours the disease. The disease is severe in rainy season because of fast spread from one plant to another and within the plant from one part to another.

3.4.3 Powdery mildew

Powdery mildew on okra leaves

Powdery mildew is caused by *Erysiphe cichoracearum* Dc. Ex Mérat and it is one the important fungal diseases of okra. Infected plant initially shows greyish white powdery spots and later it produces whitish powdery appearance on both surfaces of the leaves. The powdery mass comprises of conidiophore, conidia and mycelium.

Hot and dry weather favours the disease. It spread from one plant to other by wind borne conidia. Normally the problem is more in dry season whereas less severe in rainy season because the conidia adhering on the plant surface are washed by rain water. Dry weather coupled with appearance of greyish white patches on leaves is observable symptom of powdery mildew.

3.5 COLE CROPS (Cabbage and Cauliflower)

3.5.1 Clubroot

Clubroot disease of crucifers is caused by *Plasmodiophora brassicae* Woron. The pathogen is an obligate soil borne fungal pathogen and reported to cause huge yield losses especially under monoculture. The pathogen attacks the crop from seedling stage onwards and it produce club root symptom. In the main field, the club root affected crucifers, show pale yellowing on the leaves and plants wilt on hot sunny days and eventually the plants produce irregular galls on their roots, which later become spindle shaped.

a **b** **c**

Clubroot (a) Cabbage seedling root shows club root symptom, (b) Wilting symptom of cabbage and up rooted plant showing club root symptom as insert, (c) Cabbage root fully converted into club root

The pathogen survives in soil as resting spores or in crop debris. Formation of club shaped tumour like growth on both taps and lateral roots and rarely on the base of the stem in affected plants is the diagnostic symptoms of *P. brassicae* in cabbage and cauliflower.

3.5.2 Head rot

Head rot or bud rot or white mould disease incited by *Sclerotinia sclerotiorum* (Lib.) de Bary. It is reported as one of the major diseases in field crops and vegetables including crucifers. In cabbage, the infected plants show typical white superficial cottony mycelium as white compact bodies and at later stage outer layers of compact structures become black sclerotial bodies.

Head rot disease of cabbage

Sclerotia of *Sclerotinia* spp. are found to survive in soil for long periods under adverse conditions. This pathogen is usually a problem in relatively cool and moist areas. It is known to infect more than 400 plant species and it can survive in the soil in the form of sclerotia for more than four years. All vegetables including tomato, eggplant, potato, cabbage, cauliflower, brussels sprouts, carrot, green beans, lettuce, squash, melon and other cucurbits, are susceptible to *Sclerotia* rot. Sclertotia in the soil utilize available moisture and germinate to produce mycelium sclerotial bodies. Development disease/sclerotial bodies is very fast in saturated moisture in the soil and temperature at 10-20ºC.

3.5.3 Leaf spot

This disease is caused by two species *viz.*, *Alternaria brassicae* and *A. brassicicola*. Plants at all stages of growth including seedlings are affected. This pathogen is seed borne and the conidia are dispersed by wind.

Alternaria leaf spot on cabbage

Numerous spots on the cauliflower leaf

Infection at early seedling growth causes damping off and stunting of plants. It produces leaf spots as small as pin points to some with diameter of 5 cm. In advanced stage of infection *A. brassicae* exhibits distinct spots with concentric rings on the lower leaves with a sign of dark dusty fungus growth on these spots during moist periods. Brown discoloration of cauliflower heads is also caused by these fungi. Black irregular spots on pods, shriveling of the grains and premature spilling of pods occur in severe cases. *A. brassicicola* produce dark spots on the leaves as well as pods which turn black later. Pre-mature ripening of the pods leading to shedding of seeds and shrunken seeds with low viability in infected pods are some additional signs of the disease.

3.6 CUCURBITS

3.6.1 Downy mildew

The disease is common in cucurbits and is caused by *Pseudoperonospora cubensis*. Identification symptoms are angular and chlorotic lesions on the upper surface of the leaves and corresponding lower surface with gray-brown to purplish-black downy growth. Severe causes, lesions turn into necrotic patches. Humid and night temperature (55 and 75°F) favours the sporangia formation. Spread of sporangia is normally by wind and splashing water.

Downy mildew disease on sponge gourd

3.6.2 Powdery mildew

a

b

Powdery mildew disease on (a) pumpkin and (b) bitter gourd

The disease is caused by *Erysiphe cichoracearum* on cucurbits. The disease will appear first on older leaves and spread to the upper leaves. On the upper surface of the leaves, white powdery fungal growth with bright yellowish spots develops and later coalesces together. The centers of the spots may turn brown and the fungal growth may appear on the lower leaf surface in advance condition. The entire leaf blades may turn brown and dry-up under heavy infection. Blades seldom drop from the plant and fruits are not infected. Disease is favoured by high RH (80-95%) and temperature (75-85^{0}F). Dry weather and absence of rainfall spread the disease fast.

3.7 LEGUMINOUS VEGETABLES

3.7.1 Powdery mildew

The disease is caused by *Erysiphe pisi* in pea. White powdery coating on leaves, twigs, tendrils and pods is typical symptom of the disease. Under severe cases the powdery patches coalesce and cover entire foliage. Huge loss is occurred due to formation of partially filled and small pods. The disease is favored by warm days and cool nights

Powdery mildew disease on pea

where the dew forms. Disease epidemic in plains appears every year in the pod development stage during January to March.

3.7.2 Rust

It is caused by *Uromyces fabae* and *U. pisi* in pea and it accounts for 30-50 per cent yield loss. On under surface of leaves yellowish rusty raised pustules are seen. Normally this fungus produce two kinds of pustules. Initial one is yellowish due to formation of uredospores and later one is reddish brown teleospores. The disease is favored by humid weather with heavy dew and low temperature (21-27^{0}C).

Rusts on pea

4. IMPORTANT VIRAL DISEASES OF VEGETABLES

About 130 vegetable crops used by man (excluding potato, sweet potato, cassava, and legumes) are infected with nearly 200 viruses. Of these, more than 90 viruses have been found in the most cultivated vegetables (tomatoes, watermelons, cabbages, onions, cucumbers and eggplants). Vegetables escape virus infections, for a number of reasons, including resistance, human selection. Important viruses infecting vegetables crops in India are Begomovirus, Cucumovirus, Potyvirus, Tobamovirus and Tospoviruses. Among them Begomoviruses and Tospoviruses are most important. An average of 70 to 80 per cent of vegetable production is lost due to the infections of different viruses.

4.1 BEGOMOVIRUSES

Begomovirus are circular single stranded DNA viruses and their genomes encapsidated into small twinned icosahedral virions, belongs to the family Geminiviridae. The family Geminiviridae is divided into four generas (Mastrevirus, Topocuvirus, Curtovirus and Begomovirus) based on their genome structure, the host plants they infect and the type of insect vector involved in transmission. Among these, begomoviruses are major limiting factor in the production of vegetables and other crops in the tropics and subtropics worldwide. They are mono- or bipartite single-stranded DNA plant viruses are transmitted by whiteflies in circulative non-propagative manner. The important diseases caused by begomviruses are leaf curl in solanaceous vegetables, yellow vein mosaic in okra, yellow mosaic in grain legumes, and yellow mottle in cucurbits. The disease incidence in all the cases ranges from 90- 100 per cent during the dry season and losses may exceed 60 per cent.

4.1.1 Bitter gourd mosaic

Bitter gourd mosaic

Bitter gourd mosaic diseases caused by mono- or bi-partite single-stranded DNA begomoviruses and are transmitted by whitefly in circulative persistent manner. The virus produces varying degree of symptoms like mosaic, mottling and distortion of leaves, flowers and fruits. The disease incidence in all the cases ranges from 90-100 per cent during the dry season and losses may exceed 65 per cent.

4.1.2 Chilli leaf curl diseases


Chilli leaf curl

Chilli leaf curl diseases caused by mono- or bi-partite single-stranded DNA begomoviruses (*Chill leaf curl virus, Pepper leaf curl Bangladesh virus*) and are transmitted by whitefly in circulative persistent manner. The virus produces different type of symptoms like curling, mottling and distortion of leaves, flowers and fruits. The disease incidence in all the cases ranges from 90-100 per cent during the dry season and losses may exceed 60 per cent.

4.1.3 Radish enation leaf curl disease

Radish enation and leaf curl disease caused by bi-partite single-stranded DNA begomoviruses (*Radish leaf curl virus* and *Radish enation virus*) and is transmitted by whitefly in circulative persistent manner. The virus produces different type of symptoms like leaf curl, enation and distortion of leaves, flowers and fruits. The disease does not affect the root quality, but the seed production may be affected by more than 50 per cent. The disease incidence is ranged from 85-90 per cent.


Radish enation

4.1.4 Bottle gourd mosaic


Bottle gourd mosaic

Bottle gourd mosaic disease caused by bi-partite single-stranded DNA begomovirus (*Tomato leaf curl New Delhi virus*) and is transmitted by whitefly. The virus causes different type of symptoms such aschlorotic, mosaic, mottle, leaf curling, leaf distortion and acute stunting. The symptoms are most severe in plants infected at an early stage of growth. These plants develop small chlorotic leaves with upward curling and severe stunting symptoms.The disease incidence is ranged from 25-50 per cent during the dry season.

4.1.5 Pumpkin yellow mosaic disease

Pumpkin yellow mosaic

Pumpkin yellow mosaic disease caused by three bi-partite single-stranded DNA begomoviruses (*Tomato leaf curl New Delhi virus, Tomato leaf curl Palampur virus* and *Squash leaf curl China virus*) and is also transmitted by whitefly. In pumpkin, variable symptoms like general yellowing of young leaves, curling, thickening of tender stem as well as erect and hard secondary branches and severe to mild mosaic are observed. But general yellowing and mosaic in the younger most leaves are predominantly observed. The disease incidence in all the cases ranges from 90-100 per cent and losses may exceed 50 per cent.

4.1.6 Squash yellow mosaic disease

Squash yellow mosaic

Squash yellow mosaic disease caused by bi-partite single-stranded DNA begomovirus (*Squash leaf curl China virus*) and is transmitted by whitefly in circulative persistent manner. The virus induces diverse symptoms as yellowing of young leaves, curling, thickening of tender stem as well as erect and hard secondary branches, and severe to mild mosaic. The disease incidence in all the cases ranges from 90-100 per cent and losses may exceed 70 per cent.

4.1.7 Ridge gourd mosaic disease

Ridge gourd mosaic

Ridge gourd mosaic disease caused by bi-partite single-stranded DNA begomovirus (*Tomato leaf curl New Delhi virus*) and the vectored by whitefly. The virus will produce diverse symptoms such as mosaic, leaf curl and leaf distortion. The disease incidence is ranged from 90-100 per cent and losses may exceed 50 per cent.

4.1.8 Tomato leaf curl disease

Tomato leaf curl

Tomato leaf curl disease caused by mono and bi-partite single-stranded DNA begomoviruses (*Tomato leaf curl New Delhi virus, Tomato leaf curl Gujarat virus, Tomato leaf curl Palampur virus* and *Tomato leaf curl Bangalore virus*) and is transmitted by whitefly. The virus produces diverse symptoms as leaf curling, leaf puckering, mottle and leaf distortion. The disease incidence in all the cases ranges from 90-100 per cent during the dry season and losses may exceed 70 per cent.

4.1.9 Bhendi yellow vein mosaic disease

Bhendi yellow vein mosaic disease caused by mono and bi-partite single-stranded DNA begomoviruses (*Bhendi yellow vein mosaic virus, Bhendi yellow vein Delhi virus*) and is transmitted by whitefly in circulative persistent manner. The affected plant show yellow mosaic symptoms. The disease incidence in all the cases ranges from 90-100 per cent during the dry season and losses may exceed 50 per cent.

Bhendi yellow vein mosaic

4.1.10 Okra enation leaf curl disease

Okra enation leaf curl

Okra enation leaf curls disease caused by monopartite single-stranded DNA begomovirus (*Okra enation leaf curl virus*) and is transmitted by whitefly. The disease initially causes small pin-head enations on the under surface of the leaves. This is followed by a warty and rough texture of leaves, later leaves curl upwards. Affected plants show a twisting of the stem and lateral branches with leaves becoming thick and leathery. The disease incidence is ranged from 30-50 per cent.

4.1.11 Cowpea golden mosaic disease

Cowpea golden mosaic disease caused by bi-partite single-stranded DNA begomovirus (*Mungbean yellow mosaic virus, Mungbean yellow mosaic India virus*) and is transmitted by whitefly in circulative persistent manner. The virus produces golden yellow mosaic symptom on infected plant. The disease incidence ranges from 25-60 per cent.

Cowpea golden mosaic

4.1.12 Dolichos yellow mosaic disease

Dolichos yellow mosaic

Dolichos yellow mosaic disease caused by bi-partite single-stranded DNA begomovirus (*Dolichos yellow mosaic virus*) and is transmitted by whitefly in circulative persistent manner. The virus will produce faint chlorotic specks on leaf lamina, which later develop into bright yellow mosaic patches with small islands of green tissue. The leaves are seldom deformed, but yields are reduced significantly. The disease incidence ranges from 70-90 per cent.

4.2 CUCUMOVIRUS

Cucumber mosaic virus (CMV) is a small group of plant virus, belongs to the family Bromoviridae that include *Tomato aspermy virus* (TAV) and *Peanutstunt virus* (PSV). CMV is known to occur worldwide in both temperate and tropical climates, affecting many agricultural and horticultural crops. It causes a systemic infection in most host plants, but may remain symptomless in some crops like alfalfa. Almost all cucurbits are susceptible

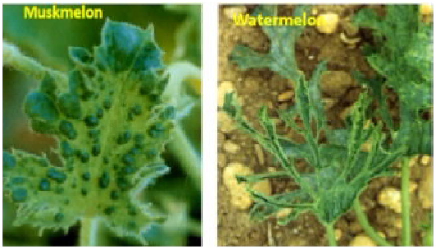
Mosaic symptoms on cucumber and bitter gourd to CMV, with symptoms varying in severity.Among the most important vegetables affected by *Cucumber mosaic virus* are cucumbers, melons, squash, peppers, spinach, tomatoes, celery, beets, beans, and crucifers. It produces varying degree of symptoms like mottling or discoloration and distortion of leaves, flowers and fruits.

The viruses are isometric, about 29 nanometers in diameter. The genome consists of three single-stranded RNAs and each existing in a separate but identical particle. A fourth RNA, which codes for the coat protein of the virus, is generated from the smallest of the three RNAs.

The virus is transmitted by more than 80 aphid species including *Myzus persicae* and *Aphis gossypii* which are capable of transmitting the virus in a non-persistent and stylet-borne manner. The virus also transmitted by mechanical as well as seed borne in some crop plants. The disease incidence in all the cases ranged from 6-50 per cent on different vegetable crops.

4.3 POTYVIRUS

The potyvirus is the largest group of plant virus belongs to family potyviridae. It is characterized as monoparticle, positive-sense, single stranded RNA genome encapsidated in flexuous rod shape particles. Viral RNA consists of about 9600 nucleotides with a 5' viral protein genome linked (VPG) and a poly (A) tail. The typical feature of all potyviruses is the induction of characteristic pinwheel or scroll-shaped inclusion bodies in the cytoplasm of the infected cells. Members of this group are responsible for important virus diseases affecting all types of vegetables, forage, fruit, ornamental and field crops causing significant yield loss. The infected plants show an overall lighter color along with mosaic patterns (alternating light and dark green areas) on at least some leaves, especially on the younger leaves. Plants will often show stunting, leaf curling and fruit distortion along with the mosaic pattern on leaves. All potyviruses are transmitted by aphids in a non-persistent and stylet-borne manner. The



Mosaic symptoms on muskmelon and watermelon different potyviruses that are infecting the vegetable in India are *Bean common mosaic virus* (BCMV), *Bean yellow mosaic virus* (BYMV), *Papaya ring spot virus* (PRSV), *Pepper mottle virus* (PepMV) *Watermelon mosaic virus* (WMV1 and WMV2), *Zucchini yellow mosaic virus* (ZYMV). These viruses can also spread through mechanically through sap. The disease incidence in all the cases ranged from 20- 95 per cent on different vegetable crops.

4.4 TOSPOVIRUS

Tomato spotted wilt virus (TSWV) belongs to the genus *Tospovirus* in the family *Bunyaviridae*. The tospoviruses are near pleiomorphic, about 80-120 nm in diameter. The genome consists of three RNAs referred to as Large (L), Medium (M) and Small (S). There are four tospoviruses infecting different vegetables are *Peanut bud necrosis virus* (PBNV), *Watermelon bud necrosis virus* (WBNV), *Capsicum chlorosis virus* (CaCV) and *Melon chlorotic spot virus*. Diseases caused by tospoviruses are emerging as a significant limiting factor for the sustainable production of vegetables in India. Among the different tospoviruses, PBNV has become a major constraint for the production of vegetables in India. Its severity ranges from 25-100 per cent on different vegetable crops. In nature, these tospoviruses are transmitted by several species of thrips (*Franklienella occidentalis, F. schultzei, F. Intonosa, F. bispiosa, F. fusca, Thrips setosus, and T. tabaci)* in a propagative manner. TSWV produces a wide range of foliar symptoms includes, bronzing, curling, necrotic streaks and spots on the leaves. Dark-brown streaks also appear on leaf, petioles, stems and growing tips. The infected plants become small and stunted as compared with healthy plants. The ripe fruit shows pale red or yellow areas on the skin. Sometimes, affected

a

b

(a) Watermelon bud necrosis and (b) chilli necrotic spots

plants are killed by severe necrosis. These symptoms vary depending on the strain, host species and genotype and is also influenced by environmental factors especially temperature.

4.5 TOBAMOVIRUS

Tobacco mosaic virus on chilli

The genus tobamoviruses includes three viruses namely, *Tobacco mosaic virus, Tomato mosaic virus* and *Pepper mild mottle virus*. These viruses produce various degrees of symptoms on the infected plants include mottling, chlorosis, curling, distortion, and dwarfing of leaves. In some plants, necrotic areas develop on the leaves and leaflets may become long and pointed and sometimes shoe-string like. The viruses are easily transmitted mechanically and in nature they are spread by incidental contact and wounding. The viruses can be carried on seed. The viruses survive in crop debris, including roots in soil and on contaminated equipment and clothing. They do not seem to be transmitted by any vectors. Tobamoviruses are very stable in the environment and can survive on implements, trellis wires, stakes, containers and contaminated clothing for many months in the absence of any plant material. The viruses can also survive in crop (leaves, stems) and root debris on the soil surface for at least several months and can infect a new crop planted into a contaminated site. The genome consists of one positive single-stranded RNA [(+) ssRNA] of approximately 6,400 nucleotides (6.4 kb).

5. IMPORTANT NEMATODE PESTS OF VEGETABLES

Plant parasitic nematodes are also called as hidden enemies of crop plants. They are economically important yield limiting factors in vegetable cultivation. They can infect almost all types of vegetables which are grown in tropical, subtropical and temperate regions and cause economic loss up to 12.3 per cent. They are capable to thrive well in a wide range of temperature ranging from 15 to 35°C (optimum temperature required is 30°C). Plant parasitic nematodes can cause damage to the host by their own apart from that they also pave the way for several other pathogens to invade easily in vegetables.

5.1 ROOT KNOT NEMATODES (*Meloidogyne incognita, M. javanica, M. arenaria and M. hapla*)

Root knot nematode is known to infect approximately 2000 plant hosts and causes 5 per cent loss to the crops globally. Vegetables like tomato, carrot, brinjal, okra, cucurbits, *etc*. are frequently affected by this nematode.

Tomato wilting caused by root knot nematode, M. incognita

Tomato roots with galls

Root galls caused by M. incognita on okra

Development of symptoms on plants above ground level is observed only when high nematode population and damage accompanied with environmental stress. The injuries to the roots reduce the ability of plants to absorb water and nutrients from the soil solution. The major symtoms are yellowing (chlorosis), day wilting, stunted growth and patchy appearance in field. The symptom often resembles the nutrient deficiency or drought stress.

Below ground the nematode produces small galls in chilli, bigger galls in cucurbits, heavy galls in most of vegetables like tomato and okra, and small galls and forking symptom in carrot and radish. In severe infestations,

Stunting and yellowing symptoms in radish field infected by M. incognita

Forking and decay symptoms caused by Meloidogyne spp. in radish

heavily galled roots may rot, leaving a poor root system with a few large galls. Second and later generation nematodes are responsible for formation of massive galls (ranging from 1 to 10 mm in diameter) all over the roots.

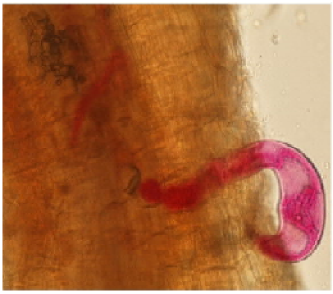
These nematodes are soil inhabiting in nature which damage the root system by feeding. Thus, soil moisture conditions that are optimum for plant growth are also ideal for the development of root-knot nematode. Root knot nematodes have 6 stages in life cycle *i.e.,* egg, 4 juvenile stages and adult. Mature adult lays 350-500 eggs on surface of the root in gelatinous matrix and they hatch on getting favorable environmental conditions like sufficient moisture, optimum temperature and susceptible plant host. The second stage juvenile hatches from eggs, move through the soil and invade roots near the root tip. Occasionally they develop into males due to prevailing high temperature and insufficient amount of food materials in soil.

The length of the life cycle depends on temperature which varies from 28-30 days at 30°C in summer and 50 days in winter. Hence, nematode multiplication and the degree of damage are maximum in crops grown from March to October.

5.2 RENIFORM NEMATODES (*Rotylenchulus reniformis)*

Reniform nematodes are semi-endoparasites which are known to infect more than 314 plant species and distributed in tropical, subtropical and warm temperate zones of the country. Among 10 *Rotylenchulus* species, *R. reniformis* is the only species that causes major economic loss in crops.

The vegetables such as cowpea, okra, cabbage, cucumber, tomato, pumpkin, squash, radish, eggplant, melon *etc*. are the most affected ones. *R.*



Reniform nematode infecting brinjal root (stained root)

Lesions and dark colour symptoms appear on brinjal roots

reniformis can produce symptoms resembling those of moisture and nutrient deficiencies on plant parts above the ground. Major symptoms are stunting, chlorotic leaves and wilting. Generally root growth is reduced with limited secondary roots. In severe infection, it can produce root necrosis. Root decay symptoms can also be seen due to secondary infection by fungi.

The life cycle is completed in six stages *viz*., eggs, 4 juveniles and adult. Mature adult is kidney shaped hence called 'reniform nematode'. This lays 60 to 200 eggs in gelatinous matrix on surface of the root. Second stage juveniles hatch out from eggs and do not infect the plant. They grow into young female adult after three moults without feeding the plant. After that the females infect the plant at cortex region of the root and penetrate the epidermis and cortical parenchyma of the host root. Only the anterior part of nematode body is embedded in root tissue. The penetration is stopped when lips reach the endodermis and forms a trophic site.The nematode sucks nutrients from root at particular point thought out life cycle, hence, it is known as sedentary endoparasites.

The nematode takes 25 days to complete its life cycle at 30^0C. Males are not able to infect the plant, but they are important for reproduction. Damage from *R. reniformis* is directly related to the number of nematodes present in a cropping period. Economic loss to the crop occurs if the nematode population density exceeds two nematodes/cm^3 soil.

6. IMPORTANT APPROACHES FOR PEST MANAGEMENT

Insect pests, diseases and nematodes are major constraints in achieving full yield potential in vegetables. The losses due to these biotic stresses are around 40 per cent and if we add about 15-20 per cent post-harvest losses, the situation becomes more alarming. Indiscriminate use of chemical pesticides has resulted in emergence of more aggressive pests due to resistance development; residual problems in food and drinking water and ecological imbalance due to elimination of beneficial microorganisms and insects. Therefore, for sustainability of vegetable crops, these biotic stresses need to be managed through eco-friendly measures supported by need based and judicious use of chemicals to achieve high economic returns without disturbing environmental balance and serenity. Integrated pest management (IPM) is one of the economically viable and environmentally safe key technologies to increase vegetable productivity in the country. Some of the important components of IPM practices in vegetables are given below.

- Use of resistant varieties/hybrids/genotypes (host plant resistance).
- Use of healthy seeds obtained from a reliable source.
- Crop rotations, intercropping, trap/barrier crops *etc*.
- Optimum dates for planting and harvesting.
- Use of biocontrol agents, biofumigants, botanicals *etc*.
- Need based application of safer and label claim chemical pesticides.

In fact a typical eco-friendly approach for sustainable management of vegetable pests involves biological control including deployment of host resistance, best cultural practices and need based use of chemical pesticides (figure 1). Such plant protection measures are also in harmony with international food safety and environmental protection protocols.

6.1 HOST PLANT RESISTANCE

Keeping in mind the diversity and intensity of pests in particular place, selection of resistant/less susceptible varieties/hybrids/genotypes holds well in pest management. Being completely safe, host plant resistance fits well

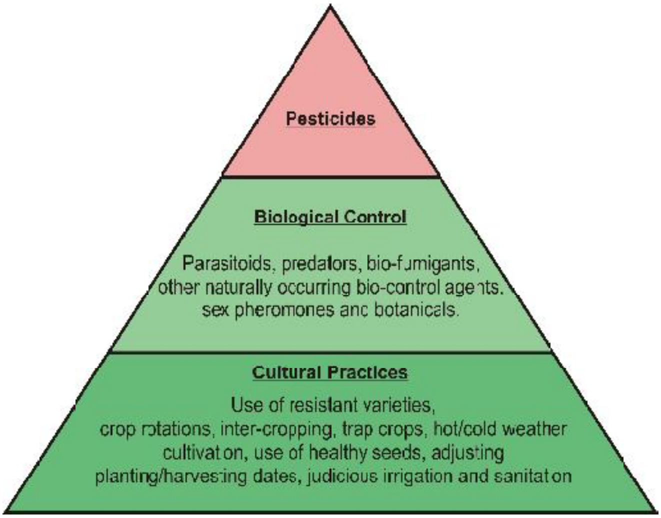


Figure 1: Eco-friendly approaches for pest management in vegetables.

with all other components. Unlike cereals, in vegetables very less number of resistant / less susceptible genotypes have been developed for insect pest management (Table 2). Pests of sucking nature can be combated to a greater extent with the adaption of resistant varieties/genotypes. Similarly, some genotypes have also been identified for the management of diseases in vegetables in India (Table 3).

Table 2: Tolerant genotypes of some vegetable crops against major insect pests

Crop	Pest(s)	Genotype(s)
Tomato	Fruit borer (*H. armigera*)	Arka Vikash, Pusa Gaurav, Pusa Early Dwarf, Punjab Keshri, Punjab Chhuhara, Pant Bahar, Azad, BT 1, T 32, T 27
Brinjal	Shoot and fruit borer (*L. orbonalis*)	SM 17-4, PBr 129-5 Punjab Barsati, ARV 2-C, Pusa Purple Round, Punjab Neelam, Kalyanpur-2, Narendra Hybrid Brinjal-2
	Jassid (*Amrasca biguttula biguttula*)	Chaklasi Doli, Doli 5, Pusa Purple
	Whitefly (*Bemisia tabaci*)	Pusa Purple
Chilli	Yellow mite or broad mite	Japani Longi, GKC-29, Kashi Gaurav, VR-339

Table 2: Contd...

Crop	Pest(s)	Genotype(s)
Cabbage	Aphid (*Brevicoryne brassicae*)	All season, Red Drum Head, Sure Head, Express Mail
Cauliflower	Stem borer (*Hellula undalis*)	Early Patna, EMS-3, KW-5, KW-8, Kathmandu Local
Okra	Jassid (*Amrasca biguttula biguttula*)	IC-7194, IC-13999, New Selection, Punjab Padmini
	Shoot and fruit borer (*Earias vittella*)	AE 57, PMS 8, Parkins long green, PKX 9275, Karnual special
Onion	Thrips (*Thrips tabaci*)	PBR-2, PBR-6, Arka Niketan, Pusa Ratnar, PBR-4, PBR-5, PBR-6
Cucurbits	Fruit fly (*Bactrocera cucurbitae*)	Arka Tinda (Round gourd)
		Arka Suryamukhi (Pumpkin)
		Hissar-II (Bitter gourd)
		Punjab Hybrid-1 (Muskmelon)
	Pumpkin beetle	Punjab Chappan Kaddu- 1 (Squash)
	Leaf miner	Swarna Prabha (Sponge gourd)
French bean	Leaf miner	Swarna Priya, Swarna Lata

Table 3: Tolerant/resistantgenotypes of some vegetable crops against major diseases

Crop	Disease(s)	Genotype(s)
Tomato	Leaf curl and root knot nematode.	Kalianpur Angoorlata
	Root knot nematode	Hisar Lalit, Pusa Hybrid- 4, SEL-1-6-1-4, Arka Vardan, SL-120, PNR-7, NT-3, NT12,
	Bacterial wilt	Utkal Kumari, Mukthi, LE-415 (resistant to race 1), Swarna Baibhav, Swarna Naveen, Swarna Lalima, Swarna Sampada, Arka Alok
	Virus and blight	Vasundhara
	Fusarium wilt	Meenakshi
	Early blight	Swarna Sampada
	Bacterial wilt and early blight	Arka Rakshak, Utkal Urbasi

Table 3: Contd...

Crop	Disease(s)	Genotype(s)
Brinjal	Little leaf disease	Pusa Purple Round, Narendra Hybrid Brinjal-1, Junagadh Oblong
	Bacterial wilt	Pusa Purple Cluster, Utakal tarini, Pant Brinjal Hybrid- 1, Swarna Pratibha, Swarna Shyamali, Swarna Shree, Alka Keshav, Arka Nidhi, Utkal Tarini, Surya, BB-64, Swarna Abhilamb
	Phomopsis blight and bacterial Wilt	Pant Samrat, Swarna Ajay
	Root knot and *Reniform* nematode	Co-1
	Bacterial wilt and *Fusarium* wilt	Utkal Madhuri, Utkal Keshari
	Phomopsis blight, little leaf disease and wilt	JC-1
	Little leaf and *Phomopsis* blight	Azad B-1, Narendra Hybrid Brinjal-2
	Root knot nematode	Pusa Long Purple, Black beauty, Banaras Giant
Chilli	*Cucumber mosaic virus*, leaf curl viruses and dieback disease	Punjab Lal
	Viral disease	Punjab Surkh
	Fusarium wilt	Kashmiri Long-1
	Bacterial wilt	Utkal Ava, Anugraha
	Root knot nematode	NP-46A, Pusa Jwala, Mohini
Pea	Powdery mildew	Narendra Sabji Matar – 5, Kashi Mukti, Azad P-5, Arka Ajit, Jawahar Peas-4, Azad P- 2, JP-83, Priya, DPP- 9411
Cow pea	*Golden mosaic virus*	Kashi Gauri, SEL- 263
	Rust and *Cowpea golden mosaic virus*	Swarna Suphala
	Bacterial blight	Pusa Komal
	Golden mosaic virus and *Pseudocercospora* leaf spot	Kashi Kanchan
	Root knot nematode	GAU-1

Table 3: Contd...

Crop	Disease(s)	Genotype(s)
French Bean	Bean common mosaic and angular leaf spot	Pant Anupama
Indian Bean	*Yellow mosaic virus*	Wal Konkan-1
Cauliflower	Black rot	Pusa Shubra
	Downy mildew	Pusa Hybrid-2, Pusa Kartik Sankar
Cabbage	Black rot	Pusa Mukta
	Yellowing	Sri Ganesh Gol
Carrot	Powdery mildew and leaf spot	Ooty-1
Bottle Gourd	Powdery mildew and downy mildew	Narendra Rashmi
Muskmelon	Powdery mildew	Arka Rajhans, Punjab Hybrid-1
Cucumber	Downy mildew and powdery mildew	PCUCH-3
Squash	Downy mildew, Powdery mildew and *Cucumber mosaic virus*	Punjab Chappan Kaddu-1
Ridge Gourd	Downy mildew	Arka Sujat
Ridge Gourd	Mosaic and downy mildew	Deepthi
Watermelon	Powdery mildew, downy mildew and anthracnose	Arka Manik
	Blight and bud necrosis	Durgapura Lal
Sponge gourd	Wilt and *Bean mosaic virus*	Phule Prajakta

Table 3: Contd...

Crop	Disease(s)	Genotype(s)
Spinach beet	*Cercospora* leaf spot	Arka Anupma
Okra	*Yellow vein mosaic virus* (YVMV)	Punjab-7, Varsha Uphar, Hisar Unnat, HBH-142, Hisar Naveen, CO-3, Arka Anamika, Kashi Lila, Arka Abhaya, NDO-10
	YVMV and *Enation leaf curl virus* (ELCV)	Sheetla Upahar, Sheetla Jyoti, Kashi Pragati, Kashi Vibhuti, Kashi Bhairav, Kashi Mahima, Kashi Mohini
	Enation leaf curl virus (ELCV)	Kashi Mangal

6.2 PLANTING TIME

Careful consideration of sowing/planting date in vegetables reduces the attack of red pumpkin beetle, fruit fly and okra shoot and fruit borer. Early planting of cucurbits in November escapes from the attack of red pumpkin beetle, whereas flowering beyond October in bitter gourd suffers less from fruit fly damage. Sowing of okra during second week of June retains less population of borers thereby enhancing yield, whereas July planted brinjal faces the ravages of shoot and fruit borer. Thus, synchronization of most susceptible stage of the crop with the inactive period of insect pest reduces the infestation and chemical intervention.

6.3 TILLAGE

Summer ploughing is an effective practice to spoil the soil inhibiting stages of insect. Deep ploughing of the field after the harvest reduces the activity of fruit fly, red pumpkin beetle and cut worm as these insects remain in the soil in earthen cocoon to complete the dormant stage of their life cycle. Similarly, summer ploughing is effective to reduce the soil borne pathogens population because of solarization effect.

6.4 BARRIERS

At I.I.H.R., Bangalore and I.I.V.R., Varanasi use of nylon net as a barrier along with infested shoot clipping for control of brinjal shoot and fruit borer could reduce the borer incidence by 16 per cent. However, the cost of nylon net is high and studies are, therefore, being conducted on the use of live barriers like maize. Presently, this technology is being popular in many parts of the West Bengal to prevent fruit and shoot borer of brinjal. Similarly, for the management of *Yellow vein mosaic virus* (YVMV) disease in Bhendi, growing of maize as barrier is successful to reduce the disease incidence.

6.5 INTERCROPPING

Intercropping of crops with diverse plant geometry and insect pests breaks the standard mono-cropping and limits the infestation from the pest (Table 4). Diverse nature of plant not only obstructs the adults from egg laying but also the release of volatile allelo-chemicals from a particular crop deters the adult insect from damaging the crops. All such planting combination enhances the activity of predators and parasites, too.

Table 4: Combination of different intercrops effective in vegetable pest management

Crop combination	Target pest
Cabbage + Carrot	Diamond back moth
Broccoli + Faba bean	Flea beetle
Brinjal + Coriander /Fennel	Fruit and shoot borer
Cabbage + French bean	Root fly
Cabbage + Tomato	Diamond back moth
Cabbage + Chinese cabbage	Diamond back moth
Cabbage + Coriander	Aphids

6.6 TRAP CROPS

Mustard as trap crop along with cabbage has been successfully utilized for the management of diamond back moth, aphid and leaf webber on cabbage. This technology was developed in 1989 in which sowing of two rows of bold-seeded Indian mustard every 25 rows of cabbage has been found successful. Mustard attracts more than 80 per cent of the cabbage pests. Only mustard crop is sprayed with diclorovos 0.1 per cent. Recent studies indicated Chinese cabbage to be the potential trap crop for diamond back moth. African marigold from tight bud stage functions as good trap crop to attract the adults of *H. armigera* besides it also attracts the adults of leaf miner for egg laying on the leaves. Maize + bitter gourd and bait spray is effective to control fruit fly adults. Planting castor as a trap crop diverts the population of *Spodoptera litura* from cowpea.

6.7 BIOLOGICAL CONTROL

6.7.1 Predators and parasites

Vegetables ecosystem is endowed with a large complex of natural enemies attacking different stages of the insect pests to varying extent (Table 5). However, most of these natural enemies are under exploited for pest management in vegetables. Among the egg parasitoids, *Trichogramma* spp. has been utilized to some extent for control of tomato fruit borer. Inundative release of egg parasitoids *Trichogramma brasilensis* @ 2,50,000/ ha is recommended for control of fruit borers on okra and tomato. Five to six releases at weekly interval @ 50,000/ha with the first release coinciding with initiation of flowering in tomato is effective. *Chrysoperla zastrowi sillemi* is an effective predator for control of white fly, aphid, jassid and eggs of some lepidopterous borers, when the first instar larvae are released @ 50,000 /ha. The larval parasitoids of diamond back moth, *Cotesia plutellae* and *Diadegma semiclausum* can be incorporated into biological pest management because of their potential in suppressing the pest larvae. These will prove effective in areas where diamond back moth poses a serious problem because of insecticidal resistance.

Table 5: Natural enemies of insect pests of some important vegetable crops

Pest	Parasitoid /Predator
Crucifers	
Plutella xylostella	*Apanteles plutellae* *Diadegme semiclausum* *Brachymeria excarinata*
Crocidolomia binotalis	*Alanteles crocidolomea*
Hellula undalis	*Bracon* spp.
Tomato	
Helicoverpa armigera	*Trichogramma* spp.
Okra	
Earias spp.	*Trichogramma* spp.
Spodoptera litura	*Telenomus rowani* *Peribaea orbata*
Aphis spp.	*Coccinella septempuctata* *Chrysopela zastrowi sillemi*

6.7.2 Entomopathogens

Vegetable pest control through microbial intervention is so far limited to few pests only. *Bacillus thuringiensis* (*Bt*) @ 300-500 gm is the most extensively used biocontrol agent against *P. xylostella*, *E. vittella* and *H. armigera* in vegetables. Application of *Helicoverpa armigera* nuclear polyhedrosis virus (*Ha*NPV) and *Spodoptera litura* nuclear polyhedrosis virus (*Sl*NPV) @ 250 - 300 larval equivalents (LE) in the evening hour with some UV protectants like teepol (0.1%) and adjuvents like molasses (1%) reduces the population of the pests to a great extent. Use of entomopathogenic fungi has great potential and gaining importance against both chewing and sucking insect pests in vegetable crops. Among these, V*erticillium lecanii* at 2.8 x 10^9 spores/ml against diamond back moth in cole crops, *Nomuraea rileyi* @ 1.2 x 10^8 conidia/ml against *S. litura* in cabbage and *H. armigera* in tomato and *Beauveria bassiana* @ 1.6 x 10^4 conidia/ml against whitefly on cucubits and jassids on okra have been found highly effective. Some important parasitoids and microbial agents recommended against vegetable pests are given (Table 6).

Table 6: Biocontrol agents recommended in vegetable crops against some of the insect pests

Bioagent	Dose	Target pest
Trichogramma brassiliensis	2,50,000 parasitized eggs/ha (Inundative release)	Okra shoot and fruit borer
	50,000 parasitized eggs/ha (five releases at ten days intervals each, Inoculative release)	Tomato fruit borer
Chrysoperla zastrowi sillemi	50,000 first instar larvae/ha	Okra aphid Cabbage aphid
*Ha*NPV	250 LE/ha (10 days interval)	Tomato fruit borer
*Sl*NPV	250 LE/ha (10 days interval)	*Spodoptera litura*
Bacillus thuringiensis var *Kurstaki*	500 g ai/ha (10 days interval)	Diamond back moth, Shoot and fruit borer of brinjal and okra, and Tomato fruit borer

6.7.3. Biocontrol agents for management of diseases

Many biocontrol agents have been used to manage vegetable diseases and the technology is most successful against soil borne pathogens. Biocontrol agents of both in fungal and bacterial nature are being widely used. Among them, *Trichoderma harzianum*, *Pseudomonas fluorescens* and *Bacillus subtilis* are the most exploited species for the management of plant diseases. Success of biocontrol agents is also decided by formulations and delivery methods.

Fungal bio-formulation: Multiply fungal antagonist (*Trichoderma* spp.) in sterilized molasses-yeast broth (30 ml molasses; 5 g yeast; made up to 1000 ml) by inoculating with actively growing mycelial disc of nine mm diameter and incubate for 15 days. After that, incorporate the biomass (containing approx. 10^6 cfu/ml) along with the medium into the sterilized carrier (at 105°C for 12 h) talc/peat/lignite/kaolin etc. @ 500 ml suspension per 1 kg and thoroughly mix along with 5 g carboxy methyl cellulose (CMC as adhesive agent).

Bacterial bio-formulation: Inoculate *Pseudomonas* spp. and *Bacillus* spp. into the sterilized Kings B broth and Nutrient Agar broth respectively and incubate in a rotary shaker at 150 rpm for 48 h at room temperature (28 ± 2 °C). After this, mix 400 ml of broth suspension containing (approx. 10^8 cfu/ml), 1 kg of the sterilized carrier material (talc/peat/lignite/kaolin etc.) 15 g calcium carbonate (to bring the pH to neutral) and 5 g CMC.

A suitable bioformulation should be active and have long shelf life. Different successful bioformulations developed against many plant diseases and their shelf life have been well documented (Table 7).

6.7.3.1 Methods of application of bio-formulation

Seed treatment with fungal and bacterial bioformulations: In general the bio-formulations are applied @ 10 g/kg of seeds. This treatment was highly effective against soil borne fungal pathogens in wide range of crops like tomato, hot pepper, and cucumber etc.

Seedling dip: This method is mainly applicable to transplanting crops.Before transplanting the seedlings are dipped in antagonist suspension @1-2 per cent for 15 minute to 2 hours depending on the crop.

Table 7: Different carriers used to develop bio-formulations

Carrier(s)	Bio-control agent(s)	Shelf-life
Talc	*P. fluorescens* (P7NF, TL3)	12 months
	P. fluorescens (Pf1)	8 months
	B. subtilis	1.5 months
	P. putida	1.5 months
Lignite	*P. fluorescens* (Pf1)	4 months
Peat	*P. fluorescens* (Pf1)	8 months
Peat+chitin	*B. subtilis*	6 months
Peat	*P. chlororaphis* *B. subtilis*	6 months
Vermiculite	*P. fluorescens* (Pf1)	8 months
	B. subtilis	1.5 months
	P. putida	1.5 months
FYM	*P. fluorescens* (Pf1)	8 months
Kaolinite	*P. fluorescens* (Pf1)	4 months

Cutting dip: Mix 10 g of bacterial or fungal formulation in 1litre of water and dip the cuttings for 10 minutes before planting.

Nursery treatment: Raising healthy seedlings in nursery always gives good results in main field and the nursery is often affected by soil borne pathogens. Drenching of nursery beds with 5 g *Trichoderma* formulation/l of water before sowing is found highly effective.

Soil application of fungal bio-formulation: Mix 1 kg of *Trichoderma* formulation in 100 kg of farmyard manure and cover it with polythene for 7 days. Turn the mixture in every 3-4 days interval for a minimum period of 15 -20 days or until it is applied in the field.

Soil application of bacterial bio-formulation: Mix 2.5 kg of formulation with 50 kg of well decomposed farm yard manure and apply in one ha field.

Foliar spray: Application of bacterial formulation @ 1 kg/ha or 5 g/l found to be effective in both field and horticultural crops.

6.8 BOTANICALS

Botanicals, being non-persistent and safe to mammals, possess in depth promise in pest management. Neem products have shown efficacy against insects like jassids, aphids and leaf miners. Application of crude neem seed kernel extract (4%) controls diamond back moth very well. Sprays of neem and *Pongamia* soaps are found highly effective in controlling insecticide resistant DBM in cabbage and *H. armigera* in tomato. The list of some of the botanicals effective against vegetable pests is given (Table 8).

Table 8: Plant products used for management of insect pests of vegetables

Pest	Plant products	Mode of action
Leucinodes orbonalis	Oil (2%) of *Pongamia pinnata*, *Madhuca indica* and *A. indica*	Contact
	Neem Azal (0.03%), Neem oil (0.3%)	Antifeedant and contact
Epilachna vigintioctopunctata	Leaf extract (1%) of *Lantana camara*	Antifeedant
	Leaf extract (6%) of *Ageratum haustriarum* *Melia azedarach*	Contact
Bemisia tabaci	Neemal® (0.5%), Repelin® (Neem based formulation)	Mortality
Pieris brassicae	Achook, Neem oil and Nimbicidene	Insect growth regulator (IGR), Antifeedancy
Helicoverpa armigera	Methanolic extracts of *Vinca rosea* and *Callistemon lanceolatus*	IGR, Antifeedancy
Spodoptera litura	Leaf extract of *Persea americara*	Antifeedant and Contact
Earias vittella	NSKE (5%)	Contact and ovicidal
Pest complex of okra	NSKE (5%) Multineem (2.5 l/ha)	Contact
Pest complex of crucifers	Nimbecidine (7.5 ml/l)	Contact
Pest complex of tomato	NSKE/Melia seed extract (5%)	Contact
Pest complex of eggplant	Nimbecidine/ Neemgold/ Neem Azal (0.1%)	Contact

6.9 SAFER AND LABEL CLAIM PESTICIDES

Chemical insecticides cannot be out rightly rejected from vegetable pest control schedule. But selection of insecticides, which are comparatively safe to the insect natural enemies, should be taken into consideration (Table 9). Similarly, use of label claim pesticides in vegetables to ensure common name, registered formulations, target pests and crops (Table 10).

Table 9: Safer insecticides to natural enemies of vegetable pests

Insecticide(s)	Target insect pest	Safe for natural enemies
Sulphur	Mite	*Amblyseius tetranychivorus*
NSKE, Phosalone	Tobacco caterpillar	*Telenomus remus*
Phosalone, Permethrin, Deltamethrin, NSKE, Fenvalerate, Cypermethrin, Fluvalinate	Diamond back moth	*Cotesia plutellae*
Sulphur	Mites	*Amblyseius tetranychivorus*
Acephate, Phosalone	Fruit borer	*Campoletis chloridiae*
Fenvalerate		*Trichogramma brassiliensis*
Endosulfan, Phosalone, Rynaxpyre	*Epilachna* beetle	*Pediobius foveolatus*
Rynaxpyre, Flubendamide	Neonate larvae	*Coccinella septempunctata*

Table 10: Label claim pesticides for different vegetable crops

Tomato

	Common Name	Strength and formulation	Target Pests	Dose /ha			Waiting Period / PHI * (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
Insecticides							
1	Azadirachtin	1% (10000 ppm)	Fruit borer	-	1000-1500	500	3
2	Azadirachtin	5% (50000 ppm)	Aphids Whitefly Fruit borer	-	200	400	5
3	Carbofuran	3 % G	Whitefly	1200	40000	-	-
4	Chlorantranilprole	18.5% SC	Fruit borer	30	150	500	3
5	Dimethoate	30% EC	Whitefly	300	990	500-1000	

	Common Name	Strength and formulation	Target Pests	Dose /ha			Waiting Period / PHI * (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
6	Imidacloprid	17.8% SL	Whitefly	30-35	150-175	500	3
7	Indoxacarb	14.5% SC	Fruit borer	60-75	400-500	300-600	5
8	Lambda Cyhalothrin	5% EC	Fruit borer	15	300	400-600	4
9	Malathion	50% EC	Whitefly	750	1500	500-1000	
10	Methomyl	40% SP	Pod borer	300-450	750-1125	500-1000	5-6
11	Novaluron	10% EC	Fruit borer	75	750	500-100	1-3
12	NPV of *H. armigera*	0.43% AS	*Helicoverpa armigera*		1500	400-600	-
		2% AS	*H.armigera*		250-500	500	-
13	Oxydemeton methyl	25% EC	Whitefly	250	1000	500-1000	-
14	Phorate	10% G	Whitefly	1500	15000	-	-
15	Phosalone	35% EC	Fruit borer	450	1285	500-1000	-
16	Quinalphos	20% AF	Fruit borer	300-350	1500-1750	750-1000	7
		25% EC	Fruit borer	250	1000	500-1000	-
17	Thiamethoxam	25% WG	Whitefly	50	200	500	5
18	Trichloforon	5% G	Fruit borer	500-750	-	-	-
		5% Dust	Fruit borer	500-750	-	-	-
		50% EC	Fruit borer	500-750	-	-	-
Fungicides							
19.	Azoxystrobin	23% SC	Early/Late blight Powdery mildew	125 g	500 g	500	3
20.	Copper Sulphate	2.62% SC	Early/Late blight		1 ℓ	500	3 days
		75% WP	Damping off (Nursery)	0.25%	2500 g	1000 Soil drench in the nursery	NA
			Early & Late blight	1250 g	1667 g	1000	6
		75% WS	Damping off (soil drench)	15-25 g/kg seed	20-30 g per kg seed	1	-
		50% WP	Early & Late blight	1250 g	2.5 kg	750-1000	
21.	Iprodione	50% WP	Early blight	0.75 kg	1.5 kg	500	15
22.	Kresoxim-methyl	44.3% SC	Early blight	30- 37.5 ml 0.03-0.037%	1000-1250 g	500-600	03

	Common Name	Strength and formulation	Target Pests	Dose /ha			Waiting Period / PHI * (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
23.	Kitazin	48% EC	Early blight	0.1% or 100 g in 100 ℓ of water	0.2% or 200 ml in 200 ℓ of water	As required depending upon crop stage and plant protection equipment used	5
24.	Mancozeb	75% WG	Early blight	750 g	1000 g	500 ℓ	5-6
		35% SC	Early & Late blight	0.175% or 175 g / 100 ℓ water	0.5% or 500 g/100 ℓ water	500 ℓ water or as required depending upon crop stage	10
		75% WP	Late blight, Buck eye rot, Leaf spot	1.125-1.5 kg	1.5-2 kg	750	-
25.	Metarim	70% WG	Alternaria blight	1750 g	2500 g	500-750	6
26.	Propineb	70% WP	Buck eye rot	0.21% or 210 g/100 ℓ water	0.3% or 300 g/ 100 ℓ water	As required Depending upon crop stage and plant protection equipment used	10
27.	Pyraclostrobin	20% WG	Early blight	75-100 g	375-500 g	500	3
28.	Streptomycin Sulphate + Tetracylin Hydrocloride	9%+1% SP	Bacterial leaf spot	-	Spray seedlings with streptocycline 40 to 100 ppm solution in seed beds and fields after the appearance of first true leaves. Two sprays of streptocycline, one before transplanting and another after are effective for controlling the disease.		
29.	Thiophenate Methyl	70% WP	Ring rot	500 g	715 g	750-1000	7
30.	Ziram	80% WP	Early blight	1.2-1.6 kg	1.5-2 kg	750-1000	3
31.	Zineb	75% WP	Early & Late blight, Grey leaf mould	1.125- 1.5 kg	1.5-2 kg	750-1000	

	Common Name	Strength and formulation	Target Pests	Dose /ha			Waiting Period / PHI * (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
32.	Cymoxanil 8% + Mancozeb 64%	WP	Late blight	1080	1500 g	500-750	10 days
33.	Famoxadone 16.6% + Cymoxanil 22.1%	SC	Early and Late blight	210	500	500	3

(Source: CIB& RC) * PHI: Pre-Harvest Interval

Brinjal

	Common name	Strength and formulation	Target Pests	Dose / ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
Insecticides							
1	Azadirachtin	1% (10000 ppm)	FSB**	-	1000-1500	500	3
2	Azadirachtin	0.03% (300 ppm)	FSB, Beetles	-	2500-5000	500	7
3	Carbofuran	3% G	Nematodes	2000	66600	-	-
4	Chlorantranilprole	18.5% SC	FSB	40	200	500-750	22
5	Chloropyrifos	20% EC	FSB	200	1000	500-1000	-
6	Cypermethrin	0.25% DP	FSB	50-60	2000-2400	500-750	3
		10% EC	FSB	50-70	550-760	150-400	3
		25% EC	FSB, Epilachna beetle	37-50	150-200	500	1
7	Dicofol	18.5% EC	Mite	250-500	1350-2700	500-1000	15-20
8	Difenthiuron	50% WP	Whitefly	300	600	500-750	3
9	Dimethoate	30% EC	Jassids FSB	600 200	1980 660	500-100	-
10	Emamectin benzoate	5% SG	FSB	10	200	500	3
11	Fenzaquin	10% EC	Mites	125	1250	500	7
12	Fenpropathrin	30% EC	Whitefly, FSB,Mites	75-100	250-340	750-1000	10
13	Fenvalerate	20% EC	FSB	75-100	375-500	500-750	5
14	Flumite/ Flufenzine	20% SC	Mites	80-100	400-500	500-1000	5
15	Lambda-Cyhalothrin	5% EC	FSB	15	300	500	4
		4.9% CS	FSB	15	300	500	5
16	Malathion	50% EC	Mites	750	1500	500-1000	-

	Common name	Strength and formulation	Target Pests	Dose / ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
17	Phorate	10% G	Jassids Aphids Mites Thrips	1500	15000	-	-
18	Phosalone	35% EC	FSB	500	1428	500-1000	-
19	Phosphomidon	40% SL	Jassids Aphid Whitefly	250-30	625-750	500	10
20	Quinalphos	20% AF	FSB, Jassids, Epilachnna beetle	300-350	1500-1750	750-100	7
		25% EC	FSB, Leaf hopper	250 375	1500 1000	500-1000	-
21	Spiromesifen	22.9% SC	Red spider mite	96	400	500	5
22	Thiodicarb	75% WP	FSB	470-750	625-1000	500	6
23	Thiamethoxam	25% WG	Whiteflies	50	200	500	3
24	Thiameton	25% EC	Aphids, Jassids, FSB	250	1000	750-1000	-
25	Trichloforon	5% G 5% Dust 50% EC	FSB	-	500-750 500 500	-	-
26	Triazophos	40% EC	FSB, Epilachna beetle	500	1250	500	5
27	Deltamethrin + Triazophos	1% + 35% EC	FSB, Epilachana beettle	-	1000-1250	-	21
Fungicides							
29.	Benomyl	50% WP	Powdery mildew	100 g	200 g	600	-
30.	Carbendazim	50% WP	Leaf spot, Fruit rot	150 g	300 g	600	-
31.	Captan	75% WP	Damping off in Nursery	0.25%	2500 g	1000 Soil drench in the nursery	-
32.	Zineb	75% WP	Blight	1.125-1.5 kg	1.5-2 kg	750-1000	-

(Source: CIB& RC) * PHI: Pre Harvest Interval;**FSB-Fruit & shoot borer

Chilli

	Common Name	Strength and formulation	Target Pests	Dose/ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
Insecticides							
1	Acetamiprid	20% SC	Thrips	10-20	50-100	500-600	3
2	Buprofezin	25% SC	Yellow mite	75-150	300-600	500-750	5
3	Carbofuran	3% G	Thrips	1000	33300	-	-
4	Carbosulfan	25% EC	Whitefly, aphids	200-250	800-1000	500-1000	8
5	Chlorfenpyre	10% SC	Yellow mite	75-100	750-1000	500	5
6	Deltamethrin	2.8% EC	Fruit borer	10-12.5	400-600	400-600	5
7	Difenthiuron	50% WP	Mites	300	600	500-750	3
8	Dimethoate	30% EC	Mites, thrips	300 200	990 660	500-1000	-
9	Emamectin benzoate	5% SG	Fruit borer, thrips, mite	10	200	500	3
10	Endosulfan	35% EC	Aphids	140	400	500-1000	21
11	Ethion	50% EC	Mite, Thrips	750-1000	1500-2000	500-1000	05
12	Fenazaquin	10% EC	Yellow mite	125	1250	400-600	10
13	Fenpropathrin	30% EC	Thrips, whitefly, mites	75-100	250-340	750-1000	7
14	Fenpyroximate	5% EC	Yellow mite	15-30	300-600	300-500	7
15	Fipronil	5% SC	Fruit borer, thrips, aphids	40-50	800-100	500	7
16	Flubendamide	39.35% SC	Fruit borer	48-60	100-125	500	7
17	Hexythiazox	5.45% EC	Yellow mite	15-25	300-500	625	3
18	Imidacloprid	70% WS	Jassids, aphids, thrips	700-1050 (per 100 kg seed)	500-1000	-	-
		17.8% SL	Jassid, aphid, thrips	25-20	125-250	500-700	40
19	Indoxacarb	14.5% SC	Fruit borer	50-60	333-400	300-600	5
20	Lambda Cyhalothrin	5% EC	Thrips, mite, pod borer	15	300	400-600	5
21	Methomyl	40% SP	Pod borer, Thrips	300-450	750-1125	500-1000	5-6
22	Milebemectin	1% EC	Mites	3.25	325	500	7
23	Novaluron	10% EC	Fruit borer, tobacco caterpillar	33.5	375	500	3
24	Oxydemeton methyl	25% EC	Aphids Mites Thrips	400 500 250	1600 2000 1000	500-1000	-

	Common Name	Strength and formulation	Target Pests	Dose/ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
25	Phorate	10% G	Aphids Mites Thrips	1000	10000	-	-
26	Phosalone	35% EC	Aphid Mite Thrips	700 450 700	2000 1285 2000	500-1000	-
27	Propargite	57% EC	Mite	850	1500	500-625	7
28	Quinalphos	25% Gel	Aphids	250	100	500-1000	-
29		25% EC	Aphid Mite	250 375	1000 1500	500-1000	-
	Spinosad	45% SC	Fruit borer	73	160	500	3
31	Spiromesifen	22.9% SC	Yellow mite	96	400	500-750	7
32	Thiacloprid	21.7% SC	Thrips	54-72	225-300	500	5
33	Thiodicarb	75% WP	Fruitbore	470-750	625-500	500	6
34	Indoxacarb + Acetamiprid	14.5% + 7.7% SC	Thrips, Fruit borer	88.8- 111	400-500	500	5
Fungicides							
35	Azoxystrobin	23% SC	Fruit rot, Powdery mildew	125 g	500 g	500 - 750	5
36	Benomyl	50% WP	Powdery mildew Fruit rot, Leaf spot	100 g	200 g	600	-
37	Copper Sulphate	2.62% SC	Fruit rot Anthracnose		1.0 l	500	3
38	Captan	50% WG	Fruit rot Anthracnose	750 g	1500 g	500	5
		75% WP	Damping off in nursery	0.25%	2500 g	1000 Soil drench	-
			Early blight	1250 g	1667 g	1000	8
		75% WS	Damping off (soil drench)	15-25 gmper kg seed	20-30 g per kg seed	1	
39	Copper Hydroxide	77% WP	Anthraconse,Cercospora leaf spot	625 g	1250 g	500	
40	Chlorothalonil	75% WP	Fruit rot	600 g	800 g	750	10
41	Difenocona-zole	25% EC	Die-back Fruit rot	0.0125 % Or 12.5g/ 100 l water	0.05% or 50 ml/100 l water	500	15
42	Dinocap	48% EC	Powdery mildew	108 g	225 g	750	--

	Common Name	Strength and formulation	Target Pests	Dose/ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
43	Fenarimol	12% EC	Powdery mildew	0.005% (5g/100 l of water)	0.04% (40 ml/100 l of water)	As required Depending on stage of crop	15
44	Flusilazole	40% EC	Powdery mildew	40-60g a.i/ ha	100-150 ml/ha	500	5
45	Hexaconazole	2% SC	Powdery mildew Fruit rot	60 g	3.0 l	500	7
46	Kitazin	48% EC	Fruit rot Die back	0.10% or 100 g in 100 l of water	0.20% or 200 ml in 200 l of water	As required depending upon crop stage	3
47	Mancozeb	75% WP	Damping off	2.25 g	3 g (soil drench)	1	-
			Fruit rot, Ripe rot Leaf spot	1.125 kg	1.5-2 kg	750	-
48	Myclobutanil	10% WP	Leaf spot Die back	0.004%	0.04%	500	03
49	Propineb	70% WP	Die back	0.35% or 350 g/100 litre of water	0.5% or 500 g/ 100 litre of water	As required depending upon crop stage	10
50	Sulphur	80% WP	Powdery mildew	2.5 kg	3.13 kg	750-1000	-
		52% SC	Powdery mildew	1.04 kg	2 litre	400.00	-
51	Streptomycin Sulphate + Tetracyline Hydrocloride	9%+1% SP	Bacterial leaf spot	-	Spray seedlings with streptocycline 40 to 100 ppm solution in seed beds and fields after the appearance of first true leaves two sprays of streptocycline, one before transplanting and another after are effective for controlling the disease.		
52	Triadimefon	25% WP	Powdery mildew	38 g	0.150 kg	750	15
53	Tebuconazole	25.9% m/m EC	Fruit rot, Powdery mildew	0.125-0.1875 kg	0.50-0.75 kg	500	5
54	Zineb	75% WP	Fruit rot Leaf spot	1.125-1.5 kg	1.5-2 kg	750-1000	-
55	Captan + Hexaconazole	70%+5% WP	Fruit rot Anthracnose	375-750 g	500-1000 g	500 .	5

(Source: CIB& RC) * PHI: Pre Harvest Interval

Okra

	Common name	Strength and formulation	Target Pests	Dose/ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
Insecticides							
1	Azadirachtin	0.03% (300 ppm)	FSB**, whiteflies, Jassids	-	2500-5000	500-1000	7
2	Azadirachtin	5% (50000 ppm)	FSB, whiteflies Jassids, aphids	-	200	400	5
3	Carbaryl	5% DP	Jassid	1000	20000	-	8
		10% DP	FSB, jassids	2500	25000	-	-
4	Carbofuran	3% G	Aphids	1000	33300	-	-
5	Chlorantranilprole	18.5% SC	FSB	25	125	500	5
6	Cypermethrin	10% EC	FSB	50-70	550-760	150-400	3
		25% EC	FSB, Jassids	37-50	150-200	500	3
7	Deltamethrin	2.8% EC	FSB, Jassids	10-15	400-600	400-600	1
8	Dicofol	18.5% EC	Red spider mite	250-500	1350-2700	500-100	15-20
9	Dimethoate	30% EC	Aphid, Jassids	700 600	2310 1980	500-1000	-
10	Emamectin benzoate	5% SG	FSB	6.75-8.5	135-170	500	5
11	Endosulfan	35% EC	Aphids	140	400	500-1000	21
12	Fenpropathrin	30% EC	Whitefly, FSB, Mites	75-100	250-340	750-1000	7
13	Fenvalerate	20% EC	FSB	60-75	300-375	600-750	7
14	Imidacloprid	70% WG	Jassids, aphids, Thrips	21-24.5	30-35	375-500	3
		48% FS	Jassids, aphids	300-540 (per 100 kg seed)	500-900	-	-
		70% WS	Jassids, aphids	350-700 (per 100 kg seed)	500-1000	-	-
		17.8 SL	Jassid, aphid, thrips	20	100	500	3
15	Lambda-Cyhalothrin	5% EC	Jassids, FSB	15	300	300-400	4
16	Malathion	50% EC	FSB, aphid, jassids	750 500 625	1500 1000 1250	500-1000	-

	Common name	Strength and formulation	Target Pests	Dose /ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
17	Oxydemeton-methyl	25% EC	Whitefly Jassids	250 400	1000 1600	500-1000	-
18	Permethrin	25% EC	FSB Aphids Jassids	100-125	400-500	750-1000	-
19	Phosalone	35% EC	FSB	525	1500	500-1000	-
20	Pyridalyl	10% EC	FSB	50-75	500-750	500-750	3
21	Quinalphos	20% AF	FSB	250-300	1250-1500	750-1000	7
		25% EC	FSB Jassids Mite	250	1000	500-1000	-
22	Spiromesifen	22.9% SC	Red spider mite	96-120	400-500	500	3
23	Thiamethoxam	25% WG	Jassid Aphid Whitefly	25	100	500-1000	5
		70% WDG	Aphids	200	286	-	-
Fungicides							
24	Dinocap	48% EC	Powdery mildew	108 g	225 g	750	-
25	Sulphur	80% WP	Powdery mildew	2.5 kg	3.13 kg	750-1000	-

(Source: CIB & RC) * PHI: Pre Harvest Interval, **FSB- Fruit and shoot borer

Cucurbits

	Common Name	Strength and formulation	Target Pests	Dose /ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
Insecticides							
1	Chlorantranilprole	18.5% SC	Fruit borers Caterpillars	20-25	100-125	500	7
2	Dichlorvos	76% EC	Red pumpkin beetle	500	627	500-100	-
3	Dicofol	18.5% EC	Red spider mite	250-500	1350-2700	500-100	15-20
4	Imidacloprid	70% WG	Jassids Aphids	24.5	35	500	5
5	Trichloforon	5% G	Red pumpkin beetle	500-750	-	-	-
		5% Dust	Red pumpkin beetle	500-750	-	-	-
		50% EC	Red pumpkin beetle	500-750	-	-	

	Common Name	Strength and formulation	Target Pests	Dose /ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
Fungicides							
6	Benomyl	50% WP	Powdery Mildew, Anthracnose	100 g	200 g	600	-
7	Carbendazim	50% WP	Powdery mildew	150 g	300 g	600	
8	Thiophanate Methyl	70% WP	Powdery mildew, Anthracnose	1000 g	1430 g	750-1000	1
9	Zineb	75% WP	Downy mildew, Anthracnose Leaf spot	1.125-1.5 kg	1.5-2 kg	750-1000	
10	Cymoxanil 8% + Mancozeb 64%	WP	Downy mildew	1080 g	1500 g	500-600	10

(Source: CIB & RC) * PHI: Pre Harvest Interval

Cruciferous vegetables (Cabbage and Cauliflower)

	Common name	Strength and formulation	Target Pests	Dosage /ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
Insecticides							
1.	Acetamiprid	20% SC	Aphids	15	75	500-600	7
2.	Azadirachtin	0.03% (300 pm)	Aphids, DBM**	-	2500-5000	500-100	7
3.	Azadirachtin	5%	DBM, *Spodoptera*, Aphids	-	200	400	5
4.	*Bacillus thuringiensis* var. *kurstaki*	5% WP	DBM	25-50	500-1000	500-1000	-
5.	Carbaryl	5% DP	Borers	600	12000	-	8
		10% DP	DBM, Armyworm	2500	25000	-	-
6.	Carbofuran	3% G	Nematodes	1000	50000	-	-
7.	Chlorantranilprole	18.5% SC	DBM	10	50	500	3
8.	Chlorfenpyre	10% SC	DBM	75-100	750-1000	500	7
9.	Chlorpyrifos	20% EC	DBM	400	2000	500-1000	
10.	Cypermethrin	10% EC	DBM	60-70	650-760	100-400	7
11.	Difenthiuron	50% WP	DBM	300	600	500-750	7

	Common name	Strength and formulation	Target Pests	Dosage /ha			Waiting Period / PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
12.	Dimethoate	30% EC	Aphids, Bugs	200	660	500-1000	
13.	Emamectin benzoate	5% SG	DBM	7.5-10.0	150-200	500	3
14.	Fenvalerate	20% EC	DBM, borer	60-75	300-375	600-750	7
15.	Fipronil	5% SC	DBM	40-50	800-100	500	7
16.	Flufenoxuron	10% DC	DBM	40	400	500-1000	7
17.	Indoxacarb	14.5% SC	DBM	30-40	200-266	400-750	7
		15.8% SC	DBM	40	266	500-1000	5
18.	Lufenuron	5.4% EC	DBM	30	600	500	14
			DBM	30	600	500	5
19.	Malathion	50% EC	Aphids	750	1500	500-1000	
			Head borer	750	1500	500-1000	
20.	Metaflumizone	22% SC	DBM	165-220	150-1000	500	3
21.	Novaluron	10% EC	DBM	75	750	500-1000	5
22.	Permethrin	25% EC	DBM	50-125	200-500	750-1000	
23.	Phorate	10% G	Aphids	2000	20000		
24.	Phosalone	35% EC	Aphids	500	1428	500-1000	
25.	Pyridalyl	10% EC	DBM	50-75	500-750	500-750	3
26.	Quinalphos	25% EC	Aphid Head borer	250 500	1000 2000	500-1000	
27.	Spinosad	2.5% SC	DBM	15-17.5	600-700	500	3
28.	Trichloforon	5% G	DBM	500-750	-	-	-
		5% Dust	DBM	500-750	-	-	-
		50% EC	DBM	500-750	-	-	-
Fungicides							
29.	Captan	75% WP	Damping off (Nursery)	0.25%	2500 g	1000 Soil drench in nursery	-
		75% WS	Damping off (soil drench)	15-25 g/ kg seed	20-30 g per kg seed	-	-
30.	Mancozeb	75% WP	Collar rot	2.25 g	3 g	-	-
			Leaf spot	1.125 kg	1.5-2 kg	750	-
31.	Zineb	75% WP	Leaf spot	1.125-1.5 kg	1.5-2 kg	750-1000	-

(Source: CIB & RC) * PHI: Pre Harvest Interval, **DBM: Diamond back moth

Pea

	Common name	Strength and formulation	Target Disease	Dose /ha			Waiting Period (days)/ PHI*
				a.i. (g)	Formulation (g/ml)	Dilution in water (Litre)	
1.	Benomyl	50% WP	Powdery mildew	100 g	200 g	600	2
2.	Carbendazim	50% WP	Powdery mildew	125 g	250 g	600	-
3.	Fenarimol	12% EC	Powdery Mildew	0.005% (5g/100 l of water)	0.04% (40 ml/100 l of water)	As required depending on stage of the crop	15
4.	Sulphur	80% WP	Rust	2.5 kg	3.13 kg	750-1000	-
		80% WG	Powdery mildew	1.50-2 kg	1.875-250 kg	750-1000	-
		40% WP	Powdery mildew	2.25-3 kg	5.65 kg	750-1000	-
		52% SC	Powdery mildew	1.04 kg	2 litre	400	-
		85% DP	Rust Powdery mildew	12.75-17 kg	15-20 kg	-	-
5.	Triadimefon	25% WP	Rust, Powdery mildew	0.025%	0.1%	750	25

(Source: CIB& RC) * PHI: Pre Harvest Interval

Legume vegetables

	Common name	Strength and formulation	Target Disease	Dose /ha			Waiting Period /PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
1.	Benomyl	50% WP	Powdery mildew	100 g	200 g	600	-
2.	Carbendazim	50% WP	Powdery mildew	175 g	350 g	750	-
3.	Captan	75% WP	Damping off in nursery	0.25%	2500 g	1000 for Soil drench	NA
4.	Dinocap	48% EC	Powdery mildew	108 g	225 g	750	-
5.	Lime Sulphur	22% SC	Rust	The liquid is used at one per cent in conventional sprayers. Doses: 2-5 l/ha			-

	Common name	Strength and formulation	Target Disease	Dose /ha			Waiting Period /PHI* (days)
				a.i (g)	Formulation (g/ml)	Dilution in water (Litre)	
6.	Sulphur	80% WP	Powdery mildew	2.5 kg	3.13 kg	750-1000	-
		80% WG	Powdery mildew	1.50-2 kg	1.875-250 kg	750-1000	-
		40% WP	Powdery mildew	2.25-3 kg	5.65 kg	750-1000	-
		85% DP	Powdery mildew	12.75-17 kg	15-20 kg	-	-
			Rust	12.75-17 kg	15-20 kg	-	-
7.	Streptomycin Sulphate + Tetracylin Hydrocloride	9%+1% SP	Halo blight	-	Spray Streptocycline 100 to 150 ppm solution thrice at interval of 7 days. For prevention, apply first spray at 10 days after emergence of leaf.		-

(Source: CIB& RC), * PHI- Pre Harvest Interval

6.10 IPM FOR MANAGING MAJOR PESTS OF VEGETABLES

Prevention is always better than cure. There are several ways and means to prevent incidence of pests. In the event their incidence, it is also necessary to protect the crop to avoid yield loss. Many of the farmers while protecting their crop do not know what to do, how to do, why to do, what not to do and why not to do. An attempt has been made to compile pest-wise information on these aspects in Table 11a; Table 11b; Table 11c and Table 11d.

Table 11a: IPM Packages for managing major insect pests of vegetables

Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
BRINJAL						
Brinjal shoot and fruit borer (*Leucinodes orbonalis*)	Seedling root dip treatment	Before transplanting	By dipping the seedling root in solution of Rynaxypyr 18.5 SC @ 0.5 ml/l for 3 hours.	To prevent the plants from initial infestation of shoot borer	Higher or lower doses of insecticides should be avoided	Higher doses may be toxic and the lower doses may be ineffective.
	Intercropping	At the time of transplanting of brinjal in the main field	Intercropping brinjal with coriander/ fennel (2:1) or as border crop	Due to repellent effect, it reduces the incidence of *Leucinodes* in main crop as well as it also attracts the natural enemies especially *Trichogramma* and *Trathala flavoorbitalis*	--	--
	Weekly clipping and destruction of infested shoots and fruits	Throughout the crop period	With a sharp knife the damage shoots and fruits should be removed and destroyed by burning or burying deep in to the soil.	Damage shoots and fruits harbour the larvae.	Clipped shoots and fruits should not be kept in the field.	Larvae inside the bored shoot and fruits complete their life cycle and re-infest the crop.
	Installation of sex pheromone trap.	25-30 days after transplanting and to be continued through the crop period.	Sex pheromones funnel traps @ 100/ha (at 10 m x 10 m distance) should be installed just above the crop canopy with the help of bamboo stick or iron rod.	For mass trapping of the adults and subsequent reduction of further generations.	The lure should not be left for long time and should be replaced after 25-30 days.	Because, lure effect for efficient trapping of adult persists for 25-30 days.

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Release of *Trichogramma chilonis* and application of biopesticides	Coinciding with initiation of flowering, thereafter at 10 days interval in case of innoculative release or once, in case of inundative release	Five innoculative releases, first release (@ 50,000 parasitized eggs/ha) or once (@ 2,50,000 parasitized eggs/ha) along with weekly 2-3 application of NSKE 4% or *Bt* formulation @ 500 g/ha should be made. "Trichocards" with parasitoid eggs should be stapled on underside of the foliage of randomly selected plants covering whole plot or they can also be installed with the help of a rope passing through an inverted plastic or paper made cup.	Being an egg parasitoid, *T. chilonis* parasitizes the eggs of *L. orbonalis* and is self-perpetuating. Spray of NSKE and *Bt* are safer to the parasitoid.	Immediate spraying of synthetic chemical insecticides should be avoided.	Broad spectrum chemical insecticides will kill the egg parasitoid also.
	Chemical control	Need based application of synthetic chemical insecticides when the shoot/fruit damage reaches 5% (ETL)	Spraying of Chlorantranilprole 18.5 SC @ 0.3-0.4 ml/l or Emamectin benzoate 5 SG @ 0.4 g/l or Lamda-Cyhalothrin 5 EC @ 0.6 ml/l or Quinalphos 25 EC @ 2 ml/l or Thiodicarb 75 WP @ 1.5-2 g/l or Triazophos 40 EC @ 2-2.5 ml/l of water Spraying should be done during the early morning or evening hours. Mix sticker [Triton AE (@ 0.1%)] in the spray solution, if rains are expected.	To reduce the incidence of shoot and fruit borer.	Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose is ineffective.
					Wear mask and hand gloves while spraying and do not spray in opposite wind direction. Do not spray when crop is at maturity/ harvesting stage. Avoid using same insecticides. Rotation of chemicals of different groups is advisable.	To protect the spray person from the toxic effects of the insecticides. Increase in cost of cultivation and pesticide residues in the produce. To avoid the chances of development of resistance, resurgence and pest outbreak.

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Brinjal stem borer (*Euzophera perticella*)	Destruction of the infested plants	When the symptom of wilting appears in the field	Uprooting and burning of the infested plants	Infested plants harbour the larvae and/or pupae in main stem.	After uprooting, the damaged plants should not be left in the field.	Larvae and/or pupae inside the damaged plants complete their life cycle and re-infest the crop.
	Botanical/Chemical control	At the time of transplanting of the plant in the main plot.	Application of neem cake @ 500 kg/ha or Carbofuran 3G @ 1 kg a.i./ha at the time of transplanting around the base of the plant	To control stem borer infestation	Carbofuran should properly be mixed with soil. Grazing of cattle should not be allowed in the field.	Carbofuran 3G is highly toxic, so utmost care should be taken during and after its application.
Hadda beetle (*Henosepilachna vigintioctopunctata*)	Mechanical control	With appearance of any stages of the beetle in the field	Hand picking and destruction of the different stages *viz*., eggs, grubs, pupae and adults of the pest	To reduce the pest population in the field.	After collection they should not be left in the field	Insect will complete its life cycle and re-infest the crop.
	Biological control	With appearance of the beetle in the field	Spraying of mixture of Neem oil @ 5% + *M. anisopliae* @ 5 g/l (1:1 ratio)	To minimize the pest population and to avoid the toxic hazards.	--	
	Chemical control	With appearance of the beetle in the field	Need based application of Malathion or Carbaryl @ 1 kg a.i/ha or Cypermethrin 25 EC @ 0.4 ml/l or Triazophos 40 EC @ 2-2.5 ml/l of water. Spraying to be done preferably with power sprayer during the early morning or evening hours.	To reduce the infestation of the hadda beetle	As mentioned in brinjal shoot and fruit borer.	

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Red spider mite (*Tetranychus cinnabarinus, T. urticae*)	Adoption of clean cultivation and sanitation	Before transplanting	Removal and destruction of ratoon crops, weeds (*Parthenium* etc.) from the main field	To minimize the mite population in the main crop	After uprooting, the ratoon crops and weeds should not be left in the field.	To avoid re-infestation in the main crop.
		After transplanting in the main crop	Removal and destruction of infested leaves during dry period	To reduce the mite population in the main crop	After removal, the infested leaves should not be left in the field.	To avoid re-infestation in the main crop.
	Frequent irrigations	At regular interval during dry period coinciding with infestation of red mite	By surface and/or sprinkler irrigation, water spraying	Prolonged dry spells favors the rapid multiplication of spider mite and frequent irrigations helps to minimize population. Forced water spray destroys the webs with inhabitant mites.	Irrigation water should be given judiciously.	Excess irrigation will increase the cost of production and deplete the ground water level.
	Chemical control	When infestation is noticed in the field	Need based application of Fenazaquin 10 EC @ 2.5 ml/lit or Spiromesifen 22.9 SC @ 0.8 ml/l or Wettbale Sulphur 80 WP @ 0.3% or Flumite/ Flufenzine 20 SC @ 0.6-0.8 ml/l of water with appearance and repeated after 10-15 days when infestation is high.	To reduce the infestation of red spider mite.	Immediate harvesting of the fruits should be avoided.	A waiting period of 7 days should be followed before harvesting the fruits.

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
TOMATO						
Fruit borer (*Helicoverpa armigera*)	Cultural control	Before planting	Deep summer ploughing by mould board plough or other means so that deep layer of the soil will be exposed.	To expose the larvae and pupae of the fruit borer to sunlight and predatory birds	--	--
		During planting	Planting of one row of 40 days old seedlings of marigold every after 16 rows of 25 days old seedlings of tomato.	Marigold will serve as trap crop for attraction of adults for egg laying and colonization. Besides, it also attracts another pest *i.e.*, tomato leaf miner as well as natural enemies of both the pests.	--	--
	Mechanical control	On colonization of pest population on trap crop	Hand picking and destruction of larvae from the marigold flowers OR Spray of Dichlorovos 76 EC @ 1 ml/l of water only on merry gold	This will reduce the pest population in the field. Sixteen times pesticide load can be reduced from main crop	After collection they should not be left in the field	Insect will complete its life cycle.
	Installation of pheromone tarps (@ 5/ha)	One month after transplanting of the crop for early detection.	Sex pheromone traps (funnel tarp) should be installed just above the crop canopy.	For early monitoring of the pest.	The same lure should not be used for long time.	Lure activity lost in 25-30 days hence it should be replaced with fresh lure at every 25-30 days.

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Biological control	During flowering stage	Two release of egg parasitoid *T. brasiliense* @ 250000 parasitized eggs/ha during peak flowering stage at 10 days interval. "Trichocards" with parasitoid eggs have should be stapled on underside of the foliage of randomly selected plants covering whole plot OR they can also be installed with the help of a rope passing through an inverted plastic or paper made cup.	Being an egg parasitoid, they will parasitize the eggs of fruit borers there by reducing the successive population	Immediate spraying of insecticides should be avoided.	Broad spectrum chemical insecticides will kill the egg parasitoid also.
		Coinciding with the appearance of infestation (early stage of the larva) during reproductive stage of the crop.	Application of HaNPV @ 250 LE with jaggery (10 g/1), soap powder (5 g/l) and Tinopal (1 ml/l) during evening hours.	HaNPV is specific to *H. armigera* and they will kill the pest and will perpetuate naturally, infecting succeeding population in the field	Avoid spraying during hot day.	Activities of HaNPV will decrease during bright sunlight and high temperature.
	Chemical control	Need based application when pest population reaches ETL or 1 larva/plant or 2% fruit damage.	Spraying of Chlorantranilprole 18.5 SC @ 0.35 ml/l or Flubendiamide 20 WG @ 0.2 - 0.25 g/l or Indoxacarb 14.5 SC @ 0.75 ml/l or Novaluron 10 EC @ 1 ml/l or Quinalphos 25 EC @ 2 ml/l of water etc.	To reduce the incidence of *H. armigera* there by increase the marketable yields.	As mentioned in brinjal shoot and fruit borer.	

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Leaf miner (*Liriomyza trifolii*)	Cultural control	During basal application	Judicious use of nitrogenous application at recommended dose in pest endemic areas	Excess application of nitrogenous fertilizer favours incidence of leaf miner and other sucking pests.	Nitrogenous fertilizer should be applied in split doses.	Single dose application will increase the pest population Reduce the loss of nitrogenous fertilizer from the soil.
	Mechanical control	With the infestation of pest	Removal and destruction of heavily infested old/lower leaves followed by application of NSKE 4% with sticker (0.5 ml/lit of water) whenever the incidence is noticed	Help reduce the pest population in the field. Neem product acts as repellent apart from having killing effect	After collection infested leaves should not be left in the field	Insect will complete its life cycle.
	Chemical control	Before flowering and during severe infestation	Spraying of Imidacloprid 17.8 SL @ 0.35 ml/l of water during the early stage of the crops before flowering. OR Application of Dichlorovos 76 EC @ 0.5 ml/l of water in severe infestation during reproductive phase crop.	To check the leaf miner incidence. Dichlorvos because of its fumigant action kills the pest irrespective of mode of feeding.	As mentioned in brinjal shoot and fruit borer.	
Whitefly (*Bemisia tabaci*)	Seed treatment	Before sowing the seeds	Imidacloprid 70 WS or Thiamethoxam 70 WS @ 3 g/kg of seeds	To prevent the plants from infestation of whiteflies up to 25-30 days	Higher or lower doses of insecticides should be avoided	Higher doses may be toxic and the lower doses may be ineffective.
	Cultural control	Periodical removal of weed hosts	By manual or mechanical weeding	Many of them serve as alternate host as well as to reduce the incidence of whiteflies and associated viral diseases.	--	--

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Mechanical control	During nursery raising	Protection of the seedlings in the nursery with nylon net (200 mesh) for 25-30 days	For mechanical exclusion of the pests including whitefly	The cage should be tightly fitted without any open space to avoid ingress of pest.	Through open areas insects will get its entry
	Botanical control	Prophylactic spray	Spraying of neem oil (2-3 ml/l) with a sticker (0.5 ml/l of water)	Neem oil will repel the pests. Beside these, neem also has antifeedancy, IGR and lethal effects.	Spraying should be done at the evening hours.	To prevent the photodegradation of the Neem products. Populations of pollinators are also lowered during this period.
	Chemical control	Need based application	Spraying of Imidacloprid 17.8 SL @ 1 ml/3 1 or Thiamethoxam 25 WG @ 0.4 g/l or Dimethoate 30 EC @ 1.5-2 ml/l of water	To check the infestation of whitefly and other sucking pests.	As mentioned in brinjal shoot and fruit borer.	
CHILLI						
Braod mite or yellow mite (*Polyphagotarsonemus latus*)	Chemical control	Immediately after infestation is noticed	Spraying of Propergite 57 EC @ 3 ml/lit or Spiromesifen 22.9 SC @ 1.5 ml/l or Chlorfenapyr 10 SC @ 1.5-2 ml/l of water.	To reduce the yellow mite infestation in the field.	As mentioned in brinjal shoot and fruit borer.	

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Implementation of BIPM module	From transplanting onwards	Seedling dip with Imidacloprid 1 ml/l and subsequent sprays of Buprofezin @ 1 ml/l, Fipronil @ 0.2 g/l, *Verticillium lecanii* @ 5g/l, Chlorfenapyr @ 1 ml/l and neem oil 1% from 25 DAT onwards at 10 days intervals each.	To reduce the yellow mite infestation in the field.	--	--
Chilli thrips (*Scirtothrips dorsalis*)	Mechanical control	During nursery	Protection of the seedlings in the nursery with nylon net (200 mesh) for 25-30 days	For mechanical exclusion of the pests including whitefly	The cage should be free from holes and should not be opened.	Through the hole or through open areas insects will get its entry
	Chemical control	Before sowing	Seed treatment with Imidacloprid 70 WS@ 2.5 g/kg of seed.	This will protect the crops up to 25-30 days from the sucking pest infestation	--	--
		Need based application	Spraying of Dimethoate 30 EC @ 1.5-2 ml/l or Emamectin Benzoate 5 SG @ 0.4 g/l or Fipronil 5 SC @ 1.5-2 ml/l or Actamiprid 20 SC @ 0.1-0.2 ml /l of water	To check the infestation of whitefly and other sucking pests.	As mentioned in brinjal shoot and fruit borer.	

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
OKRA						
Bhendi shoot and fruit borer (*Earias insulana, E. vittella*)	Periodical clipping and destruction of the early infested shoots	At the early stage of the infestation when symptoms first observed.	With a sharp knife the damage shoot has to remove. After removal, they should be destroyed by burning or buried in to the deep layer of the soil or crushing the larvae.	Damage shoots harbour the early instars larvae.	Clipped shoots should not be kept in the field after they removed from the plants.	Larvae inside the bore shoot complete their life cycle.
	Cultural control	Deep summer	Deep ploughed using bullock drawn or tractor mounted plough. So that deep layer of the soil will be exposed.	To expose the larvae and pupae of the fruit borer to sunlight and predatory birds	--	--
	Installation of sex pheromone trap @ 100/ha (10 m x 10 m).	15 days after transplanting.	Sex pheromone traps (funnel tarp / sticky trap / water pan trap etc) to be installed just above the crop canopy.	For monitoring and mass trapping of the pest.	The lure should not be left for long time.	Lure lost its activity after 25-30 days.
	Chemical control	Starting from 40 days after sowing, There after 10 days interval depending up on the severity of the pest damage.	Spraying of Cypermethrin 25 EC @ 0.5-0.75 ml/l or Emamectin Benzoate 5 SG @ 0.35-0.5 g/l or Lambda-Cyhalothrin 5 EC @ 1ml/l of water	To control the borers infestation.	As mentioned in brinjal shoot and fruit borer.	

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Implementation of BIPM module	From seed treatments onwards	Seed treatment with Imidacloprid @ 3 g/kg of seed, sprays of Rynaxpyr @ 0.15 ml/l at 25 DAS, NSKE 4% at 35 DAS, Emamectin benzoate @ 0.5 g/l at 45 DAS, *Bt* @ 1 ml/l at 55 DAS and NSKE 4% @ 5 ml/l at 65 DAS	To minimize the borer incidence	--	--
Solenopsis mealy bug (*Phenacoccus solenopsis*)	Mechanical control	Destruction of okra stalks after the last harvesting	Destruction of the okra stalks after harvesting reduces the food supply and shelter to mealy bug and their carry over to the next season.	The dry okra stalks should be uprooted from the fields and must be burnt off *in situ*.	Stacking of dry okra stalks in or nearby areas of the fields	This favours survival and migration to the of the mealy bug populations to the next season.
	Clean cultivation: Destruction of alternate hosts and associated weeds	During the crop season and off-season	Mechanical- Hand weeding and destructions. Spray weedicide + insecticides on bunds. Biological- Inoculative release of *Zygogramma bicolorata* @ 500-1000 beetles /ha on *Parthenium* grass	Weeds especially *Parthenium* and *Xanthium* are the most suitable hosts for mealy bug.	Infested plants should not be let off in to the irrigation channel.	Mealy bug spreads through water.

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Spray foliar botanicals and biocontrol agents	Initial stage of infestation.	Neem Seed Kernel Extract (NSKE 5%) 50 ml/1 + Neem oil 5 ml/l + detergent powder 1 g/l can be sprayed as spot application on infested stalks. *Verticillium lecanii* (potency $2x10^8$ CFU/ml) @ 5 g/lit + Neem oil (5%) (1:1 ratio) is also effective.	Spray on the crop adjacent to the infested plants as well as at the base of the infested plants without disturbing the mealy bug colonies.	Do not use the synthetic chemical insecticides at early stage of crop.	Broad spectrum chemical insecticides will kill the natural enemies (parasites, predators) and pollinators.
	Chemical control	Need based application	Spraying of Buprofezin 25 SC @ 1 ml/l or Acephate 75 SP @ 1 g/l or Malathion 50 EC @ 2 ml/l or Chlorpyriphos 20 EC @ 2 ml/l or Imidacloprid 17.8 SL @ 0.3 ml/l of water. Spray the chemicals first on plants around infested plants and then as spot application on the infested plants.	WHO Class II (moderately hazardous) Chlorpyriphos, Imidacloprid, WHO class III (Slightly hazardous) Acephate, Malathion and WHO Class IV (Unlikely hazardous) Buprofezin cause less harm to the environment.	As mentioned in brinjal shoot and fruit borer.	
Jassid (*Amrasca biguttula biguttula*)	Chemical control	Before sowing	Seed treatment with Imidacloprid 70 WS or Thiamethoxam 25 WG @ 3 g/kg of seed.	This will protect the crops up to 25-30 days from the sucking pest infestation	--	--
		At 25 days interval with the appearance of the pest.	Foliar spray of Thiamethoxam 25 WG @ 0.3 ml/l or Imidacloprid 17.8 SL @ 0.3 ml/l	To check the infestation of jassids and other sucking pests.	As mentioned in brinjal shoot and fruit borer.	

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Implementation of BIPM module	From seed treatments onwards	Seed treatment with Imidacloprid @ 3gm/kg of seed, sprays of Thiamethoxam at 25 DAS, Indoxacarb at 35 DAS, Dimethoate at 45 DAS, Emamectin benzoate at 55 DAS and Cypermethrin at 65 DAS	To minimize the jassids incidence in okra	--	--
COLE CROPS						
Diamond back moth (*Plutella xylostella*)	Cultural control	Appropriate time of planting	Avoidance of early and late planting of the crops in endemic areas	Early and late seasons planting suffer from more infestation	--	--
		During planting	Intercropping with tomato or carrot	This will reduce the DBM infestation as well as favour its natural enemies.	--	--
			Trap crop with Chinese cabbage	Chinese cabbage will attract the DBM which can be collected mechanically or can be killed by spraying insecticides.	--	--
	Biological control	Conservation of the parasitoids of *Cotesia plutellae*, *Diadegma semioclausum*	By conservation and habitat management	Being an larval parasitoid, they will parasitize the larvae of DBM	Avoid use of broad spectrum pesticide during the peak activity of the parasitoids	Broad spectrum insecticide will kill the natural enemies.
		Spraying of *Bacillus thuringiensis* var *Kurstaki* @ 1 kg/ha	By spraying	At least twice during primordial stage at 10 days interval.	Spraying should be done at the evening hours.	To prevent the photodegradation of *Bt* products

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control	Need based application	Spraying of Chlorantraniliprole 18.5 SC @ 0.1 ml/l or Chlorfenapyr 10 SC @ 1.5-2 ml/l or Fipronil 5 SC @ 1.6-2 ml/l or Flubendiamide 20 WG @ 0.1 ml/l or Indoxacarb 14.5 SC @ 0.5 ml/l of water.	To reduce the incidence of DBM.	As mentioned in brinjal shoot and fruit borer.	
Cabbage aphid (*Myzus persicae*)	Cultural control	Immediately after the appearance of the pest	Aphid infested plant parts have to be removed from the plants and their subsequent destruction.	Being viviparous they can also multiply parthenogenitically. So, destruction of infested shoots will reduce their population from the field.	After clipping the infested plant parts should not be left in the field.	They will migrate to other plants.
	Chemical control	Need based application	Foliar spray of Acetamiprid 20 SP @ 0.15 g/l or Dimethoate 30 EC @ 1.5 ml/l or Quinalphos 25 EC @ 2 ml/l of water is recommended. Second spray may be done at 15 days interval, if necessary.	To check the infestation of the aphids.	As mentioned in brinjal shoot and fruit borer.	
Cabbage butterfly (*Pieris brassicae*)	Mechanical control	During the early stage of the pest attack	Hand picking and destruction of the caterpillars	This will reduce the pest population in the field.	After collection they should not be left in the field	Insect will complete its life cycle.
	Biological control	Before the pest attack the crop	Foliar spray of *Bacillus thuringiensis* var *Kurstaki* @ 1 kg/ha	To reduce the pest population from the field.	Spraying should be done at the evening hours.	To prevent the photodegradation of *Bt* products

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control	Need based application	Foliar spray of Malathion 50 EC @ 2 ml/l or Cypermethrin 10 EC @ 1.5-2 ml/l of water is beneficial	To check the infestation of the cabbage butterfly.	As mentioned in brinjal shoot and fruit borer.	
CUCURBITS						
Fruit fly (*Bactrocera cucurbitae*)	Cultural control	During summer and after the harvest of the crops	Deep ploughing using bullock drawn or tractor mounted plough.	To expose the pupae for desiccation and predation by birds	--	--
		Raking the soil around the vines	By spade or any other implements		--	--
	Mechanical control	At regular interval	The infested fruits to be collected and destroyed.	To kill the maggots inside the damaged fruits	After collection the damaged fruits it should not be left in the field	Insect will complete its life cycle.
	Poison bait	Spray at 4-5 days interval during reproductive stage	Application of bait containing 10% molasses or jaggary along with Carbaryl 50 WP @ 2 g/l or Malathion 50 EC @ 2 ml/l of water. Such bait has to be installed 250 spots/ha	To check population build up.	--	--
	Male annihilation technique (MAT)	During reproductive stage	MAT of adult flies through plastic bottle trap with ethanol, any insecticide (Carbaryl / Malathion), cuelure (6:1:2) coated in wooden block. Installation of such trap @ 25-30 traps / ha		--	--

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Name of the Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Red pumpkin beetle (*Aulocophora foveicollis*)	Cultural control	Deep ploughing during summer months after the harvest of the crops	Deep ploughing using bullock drawn or tractor mounted plough.	To expose the eggs, grubs or pupae for desiccation and predation by birds	--	--
	Chemical control	During the pest infestation	Dusting of Carbaryl 80 WP @ 1 kg ai/ha (during cotyledonous stage) or spraying of Dichlorvos 76 EC @ 1-1.5 ml/l of water.	To control the red pumpkin beetle population in the field	As mentioned in brinjal shoot and fruit borer.	
Cucumber moth (*Diaphania indica*)	Mechanical control	Regular interval	Collection and destruction of the larvae	This will reduce the pest population in the field.	After collection they should not be left in the field	Insect will complete its life cycle.
	Biological control	Before the pest infestation	Spraying of *Bt var Kurstaki* @ 1 kg/ha	To reduce the pest incidence from the field.	Spraying should be done at the evening hours.	To prevent the photodegradation of *Bt* products
COWPEA						
Spotted pod borer (*Maruca vitrata*)	Biological control	Before the pest infestation	Spraying of *Bacillus thuringiensis* var *Kurstaki* @ 1 kg/ha	To check the pod borer infestation.	Spraying should be done at the evening hours.	To prevent the photodegradation of *Bt*/neem products
	Botanical control	At flowering initiation	Spraying of NSKE 4%			
	Chemical control	Need based application	Spraying of Malathion 50 EC @ 2-2.5 ml/1		As mentioned in brinjal shoot and fruit borer.	
Black bean aphid (*Aphis craccivora*)	Mechanical control	At regular interval	Collection and destruction of the infested shoots, buds, pods etc.	This will reduce the pest population in the field.	After collection they should not be left in the field	Insect will complete its life cycle.
	Chemical control	Need based application	Foliar spray of Oxydemeton – methyl 25 EC @ 2 ml/l of water or Imidacloprid 17.8 SL @ 0.35 ml/l of water. If required second spray may be done after 15 days.	To reduce the incidence of *A. craccivora*	As mentioned in brinjal shoot and fruit borer.	

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Table 11b: IDM packages for the management of major fungal diseases of vegetables

Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
TOMATO						
Early blight (*Alternaria solani*)	Use healthy seeds	Procure healthy seeds before sowing	Purchase only certified seeds from reliable source	Pathogen is seed borne nature hence there is chance of carrying inoculum on the seeds	Do not purchase seeds from unauthenticated source or without certification tag	Seeds may be spurious
	Crop rotation with non solanaceous plants	After harvest	Prepare a crop calendar for one to two years	To avoid presence of inoculums continuously	Do not sow same crop continuously for two consecutive seasons/years	To prevent carrying the inoculum to next crop
	Chemical seed treatment	Seed treatment on one day before sowing	Treat the seeds with Captan 75 WP @ 2 g/kg of seeds	As pathogen is seed borne the seed treatment will be effective to control seedling infection	Do not treat the seeds with untested fungicides	Untested fungicide may affect the germination and harmful to crop
	Foliar spray	Immediately after notice of the symptom	Mix 2 g of Mancozeb 75 WP or Iprovalicarb 5.5% + Propineb 61.25% WP @ 2.5 kg/ha and spray at 10 days interval	To check the disease	Do not mix two fungicides together	May be toxic or some time chemicals will not mix properly
Late blight (*Phytophthora infestans*)	Use disease free tomato seedling	Observations on seedlings before transplanting	Examine the seedlings for blight infection and discord the infected ones	To avoid spread of infection from nursery to main field	Do not plant seedling without examination	Chance of carrying inoculum from nursery to main field
	Destroy volunteer tomato	Immediately after crop is over	Collect the volunteer plants and burn outside the field	Volunteer plants may carry inoculum to next season crop	Do not plough the volunteer plants in the same field	If the volunteer plants are ploughed in same field there is a chance to continuous survival of the pathogen in soil

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Avoid moving in field when foliage is wet	In the morning hours	If late blight incidence is noticed avoid movement inside the field during morning hours Do the cultural operations after sun rise	To avoid the spread of disease	Avoid movement in the morning hours	Sporangia production is more in the morning especially the foliage is wetted. Movement inside the field will spread the sporangia from one plant to another
	Cop rotation	After harvest	Follow crop rotation with non-solanaceous vegetables like cucurbits or okra or cruciferous vegetables	Late blight pathogen only infect tomato and other solanaceous vegetable especially potato	Do not grow tomato or potato in two consecutive seasons	Since, the pathogen infecting tomato and potato is same there is chance of cross infection
	Other cultivation practices	During Planting and irrigation	Irrigate the field early in the morning and late in the evening.	To lower the leave wetness and RH which may favour sporangia to spread	Avoid overhead irrigation	Water splashing in overhead irrigation will spread the disease through fast movement of sporangia from one place to another
			Follow planting of tomato in wider spacing	To allow enough ventilation so as to avoid leaves wetness	Avoid closer planting	Closer planting will reduce the ventilation which in turn existence of long wetness which is more suitable for aggressiveness of the disease

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical spray	Before and immediately after the disease is noticed	Mancozeb 75 WP @ 2 g/l of water and spray before the disease is noticed	To check late blight disease some extend	Do not spray opposite to wind direction.	To avoid drift effect, spraying should be done onward direction to wind.
			Mix 2.5 g of Metalaxyl 4% + Mancozeb 64% WP in one litre of water or Iprovalicarb 5.5% + Propineb 61.25% WP @ 2.5 kg/ha or Fenemidine 10% + Mancozeb 50% WG @ 1.5 kg/ha	To control the late blight disease	Use optimum dosage.	Over dosage is toxic and under dosage is not effective
Fusarial wilt (*Fusarium oxysporium* f.sp. *lycopersci*)	Soil solarization	During summer months (April to June)	Covering the soil by clear polythene sheeting of 400 gauge (94 g m^2 and 100 µm thick) for 4-6 weeks	Temperature inside the polythene will raise thereby soil borne pathogens will be killed	Do not cover the soil with black colour polythene sheet	Black polythene will absorb heat by itself there by soil will not get solarized
	Application of bioagents	Seed treatment one day before sowing and soil application during planting	Treat the seeds with bioagents (*Bacillus subtilis* or *Trichoderma harzianum*) @ 10 g/kg Soil application-mix bioagent 2.5 kg with well decomposed FYM 50 kg and apply in one ha land	Biocontrol agents have several mechanism to control the pathogen growth	Do not mix bioagents and chemicals	Mixing chemicals with bioagents can be lethal to biocontrol agents

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical treatment	Seed treatment one day before sowing and soil drenching 30 days after planting	Seed treatment with Carbendazim 50 WP (2g/kg of seeds) followed by soil drenching with 0.1% of Carbendazim 25% + Mancozeb 50% WS at 30 days after transplanting.	To control the *Fusarium* infection	Over and under dose should not be used	Over dose leads to wastage of chemical and under dose will not control the disease
Damping off disease (*Pythium aphanidermatum* and *Rhizoctonia solani*)	Soil solarization	As stated in Fusarial wilt management				
	Nursery soil preparation	Before sowing seeds on nursery beds	Use neutral pH soil for raising nursery or add lime to bring soil pH up to 7.0	Because, acidic pH favours fungal growth	Do not sow the seeds without knowing the soil pH	Acidic or alkali pH of soil is favours different kinds of pathogens and harmful to seedlings
	Other nursery practices	Before and after sowing seeds	Prepare raised beds (about 15-20 cm height)	To provide enough drainage	Avoid flat bed for nursery	In flat bed system, the drainage will be poor thereby chance of stagnation of water which leads to development of damping off

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
			Follow line sowing: Sow the seeds in line by keeping 4-5 cm gap between the rows.	In order to provide enough aeration	Avoid broad cast or conventional sowing	Because of overcrowded seedlings, the sun light will not pass to bottom hence the soil will not dry quickly after watering results in development more humid and moist conditions which in turn favours fungal spores to germinate
			Apply recommended dose of nitrogenous fertilizer to soil	To maintain optimum crop growth	Avoid excess use of nitrogenous fertilizer to soil	Application of excess fertilizer especially ammonium form creates acidic pH which in turn favours fungus spores to germinate
			Apply a thin layer of sand on the surface of the soil	To create more aeration at stem region which will keep the stems to dry at the soil surface otherwise the pathogens easily attack the stem when it is moisten		
	Biocontrol agents	Before sowing	Apply *Trichoderma harzianum* as seed treatment @ 10 g/kg of seeds and soil application @ 10 g mixed in 1 kg well decomposed farm yard manure/m^2 nursery area	Biocontrol agents may attack the pathogens or their propagules by producing certain chemicals or enzymes	Do not wait for disease development and to apply biocontrol agents	Prophylactic application of bioagents will help to establish their own niche so as to attack when the pathogen starts to geminate

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical treatment	Seed treatment and soil application	Seed treatment with Carbendazim 50 WP @ 2g/kg of seeds	To control damping off caused by *Rhizoctonia* pathogen	Avoid indiscriminate use of fungicides	Indiscriminate or in appropriate application of fungicides will not be effective for target pathogen
			Soil drenching with Fosetyl Al 80 WP @ 0.1%.	It is effective to control damping off caused by *Pythium* spp		
BRINJAL						
Wilt or collar rot (*Sclerotium rolfsii*)	Crop rotation	Crop rotation for minimum of four years	Crop rotation with cereals especially paddy	Paddy is normally grown in flooded conditions. High moisture or water logging conditions will suppress the pathogen survival	Avoid mono cultivation of solanaceous vegetables	In case of mono cultivation, development of pathogen inoculum will be very high
	Summer ploughing	During summer months April to June	Deep ploughing	The practice will expose the pathogens to high temperature and kill the pathogen	Avoid shallow ploughing	Shallow plough may not expose the pathogen completely
	Application of organic amendments	Before sowing	Apply well decomposed FYM (10 t/ha) and neem cake (100 kg/ha)	The practice will encourage activity of biocontrol agents like *Tichoderma* spp which in turn attack the pathogen	--	--
	Chemical treatment	Immediately after collar rot incidence is noticed	Drenching and spray of Carbendazim 50 WP (0.1%)	To control the pathogen	Do not apply repeatedly same fungicide	Chance of development of resistance in pathogen system against particular chemical

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Phomopsis rot (*Phomopsis vexans*)	Cultural practices	During transplanting	Carefully examine the seedlings during transplanting and remove the infected seedlings	To avoid transmission of disease from nursery to main field.	--	--
		During harvest	Seeds should be collected from healthy and disease free fruits.	To avoid seed born inoculum	Avoid bulk harvest	There is chance of admixing healthy ones with infected ones
		After harvest	Sanitation of field immediately the crop is over.	As the remnant plants and infected plant debris may carry the pathogen to next season	--	--
	Chemical treatment	Before sowing	Seed treatment with Captan 75 WP @ 2g/kg and field spray of Carbendazim 50 WP (0.1%)	To control the pathogen infection and spread	--	--
CHILLI						
Anthracnose or die back disease (*Colletotrichum gloeosporioides* and *C. capsici*)	Cultural practices	During harvest	Collect seeds from disease free fruits/plants	To avoid seed borne infection	Avoid bulk harvest of fruits especially for seed purpose	Chance of contamination of infection from infected seeds to healthy seeds
		During intercultural operation	Careful movement of implements like spade, hand hoes etc. in the seed production plot	To avoid injuries to crop/fruits	Injuries on crops or fruits may pave the way to entry of pathogen into plant system or fruits	
	Crop rotation	After chilli crop	Crop ration for 2~3 years with non- host crops like cruciferous and malvaceous vegetables	To avoid continuous presence of inoculum	--	--

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical treatment	Before sowing and immediately after disease symptom appears	Seed treatment with Captan 75 WP @ 4g/kg of seeds and foliar spray of Mancozeb 75 WP (0.2%) or Chlorothalonil 75 WP (0.1%) or Flusilazole 40 EC (0.02%)	To control seed borne infection and spread in the main field	Use only recommended fungicides	Non-recommended fungicides may be injurious to crop
CABBAGE AND CAULIFLOWER						
Club root disease (*Plasmodiophora brassicae*)	Cultural practice	Before transplanting	Examine the nursery seedling root for the presence of club root symptoms and discord the infected ones	To prevent the spread of disease from nursery to main field	Do not ignore club root infection	Plasmodium will spread fast in field under favourable conditions and cause huge yield loss
	Crop rotation	After harvest of present crop	Avoid growing cabbage and cauliflower or other cruciferous vegetables continuously and rotate with cucurbits, bhendi, carrot, tomato etc.	Club root disease is specific to cruciferous vegetables hence crop rotation restrict further infection	Mono cropping should be avoided	Pathogen produces resting spores in the soil and plant debris and if cruciferous crop is grown continuously, there is chance of more infection by readily available pathogen inoculum.
	Soil reclamation	Before transplanting	Apply lime to bring the soil pH to 7.3 is important step to manage club root disease	Acidic pH favours the disease development	Do not grow cruciferous vegetables without testing the soil pH especially in hill region	Under hill regions leaching of salts in the soil is the common phenomena especially during rainy season and hence the soil become acidic

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control	Before sowing and after transplanting	Seed treatment with Captan 75 WP @ 2g/kg. Soil drenching with Copper oxychloride 50 WP @ 2g/l of water.	Effective to control the infection during germination and later too	-	-
Head rot (*Sclerotinia sclerotiorum*)	Zero tillage	During cultivation	Do not plough the land	In general sclerotia are found in the soil top 3-4 cm depth and if zero tillage is followed the beneficial microbes present in the top 5 cm layer will attack the pathogen (or its resting structure *i.e.,* sclerotia) and reduce the infection. If it is ploughed there is a chance of burial of sclerotia to deeper layer where the beneficial microbe activity is very less or zero.		
	Crop rotation	After cabbage is harvested	Following crop rotation with cereal crops	To avoid infection	Crop rotation should be followed for at least five years	Sclerotia will survive in soil for four years
	Application of biocontrol agents	Before planting	Application of biocontrol agents like *Trichoderma harzianum, Pseudomonas fluorescens* and *Coniothyrium minitans* @ 10^6-10^8CFU/ml in any of the formulation	To control the disease	--	--
	Chemical treatment	Before sowing and immediately after start of disease symptom	Seed treatment with Captan 75 WP @ 2 g/kg as prophylactic method and spray Carbendazim 25% + Mancozeb 50% WS (0.2 %) for three times at 10 days interval	To control the disease	--	--

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Alternaria leaf spot (*Alternaria brassicae* and *A. brassicicola*)	Use healthy seeds	Before sowing	Collect the seeds from healthy plants	Because the pathogen is seed borne nature	Do not use unauthorized seeds	Seeds may be spurious
	Use healthy transplant	During planting	Examine the seedlings and discard infected ones	To avoid spread to main field	--	--
	Chemical treatment	Immediately after symptom appears	Spray of Cholorothalonil 75 WP (0.1%) or Mancozeb 75 WP (0.2%) three to four sprays at 10 days interval	To control the disease	Do not spray same chemical repeatedly	Chance of development of resistant in the pathogen
CUCURBITS						
Downy mildew (*Pseudoperanospora cubensis*)	Produce disease free seedlings	Sowing	Grow nursery in greenhouse and transplant disease free seedlings	To control disease spreads to main field	Do not raise nursery on nursery beds.	If nursery is raised on nursery beds there is chance of spread of inoculum to all the seedlings. Hence, need to follow tray system to avoid the spread of infection from one seedling to another

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Follow bower system	During planting in main field	Grow cucurbits in bower system *i.e.,* train the seedlings on iron wires	To keep enough space between the row so as to provide enough aeration in order to avoid developing humidity on canopy which actually favors the disease	Avoid conventional way of growing cucurbits	In conventional system, the crop is grown on ground. Hence after certain period the ground is covered entirely by plant canopy. Because of the coverage, the soil will not dry quickly after the irrigation rather it creates high humidity which favours more disease
	Irrigation practice	Late in the morning	Irrigate the field after sun rise *i.e.,* around 9-10 am	Leaf wetness allows the sporangia to germinate fast. If irrigation done in late morning, the bright sunlight will facilitate rapid drying of leaf wetness	Avoid overhead irrigation	Chance of spread of sporangia in water splash is more
	Field sanitation	Before and after the crop	Eradicate volunteer cucumber and wild cucumber	These act as alternate host	--	--

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control	Prophylatic spray immediately after the incidence	Spray Mancozeb 75 WP (0.2%) as preventive spray and once incidence is noticed immediately spray fungicides like Fosetyl Al 80 WP (0.1%) or Metalaxyl 8% + Mancozeb 64% WP (0.25%) at 7 days interval 3-4 sprays and to the maximum of 7 sprays	To control the disease	Do not apply same fungicides repeatedly	To avoid fungicide resistance apply systemic and contact fungicides alternatively
Powdery mildew (*Erysiphe cichoracearum*)	Chemical control	When symptom is initiated	Spray Dinocap 48 EC (0.03%) or Flusilazole 40 EC (0.02%) three times at 10 days interval	To control the disease	Do not stop with single spray and continue up to 3 time or until complete control of disease	Single spray may not be sufficient to control the disease
					Do not spray Sulphur fungicides	Sulphur fungicides are toxic to cucurbits
PEA						
Powdery mildew (*Erysiphe pisi*)	Chemical control	Immediately after symptom initiated	Three foliar of sprays of Flusilazole 40 EC (0.02%) or Dinocap 48 EC (0.03%) at 10 days interval	To control the disease	--	--

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Name of the disease	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Rust (*Uromyces fabae* and *U. pisi*)	Chemical control	Immediately after symptom initiated	Field spray of Wettable Sulphur 80 WP (0.3%) for three times at 10 days interval from initiation of disease	To control the disease	--	--
OKRA						
Cercospora leaf spot (*Cercospora abelmoschi*)	Sanitation	After harvest	Remove left out okra plants and infected debris	Left out plants and infected debris serves as inoculum for next season crop	Do not plough the debris in the same field	Infected debris present in the soil serves as primary inoculum
	Crop rotation	After harvest	Follow non malvaceous vegetables like cucurbits, legumes or cruciferous family	To avoid occurrence of disease	--	--
	Chemical control	Immediately after initiation of symptom	Application of Mancozeb 75 WP (0.2%) or Zineb 75 WP (0.2%) or Chlorothalonil 75 WP (0.1%) or Thiophanate methyl 70 WP (0.15%) at 15 days interval from the initiation of disease	To control the disease	--	--
Wet rot (*Choanephora cucurbitarium*)	Chemical control	Immediately after initiation of disease	Spray Mancozeb 75 WP (0.2%) or Chlorothalanil 75 WP (0.1%) at 10 days interval 3-4 times	To control the disease	--	--
Powdery mildew (*Erysiphe cichoracearum*)	Chemical control	Immediately after initiation of disease	Spray Wettable Sulphur 80 WP (0.3%) or Dinocap 48 EC (0.03%) for three times at 15 days interval	To control the disease	--	--

Table 11c: IDM packages for the management of major viral diseases of vegetables

Name of the disease /Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Viral diseases and Sucking insect pests	Use healthy seeds	Healthy seed is to be procured before planting.	Procure healthy seeds from a reliable source and obtain receipt	Some the viruses are seed borne in nature hence to avoid infection from seeds	Do not purchase seeds without seed class tag and receipt.	Seeds are likely to be unreliable.
Cucumoviruses (*Cucumber mosaic virus*) Spread by several Aphids and some crops CMV is a seed borne in both solanaceous and cucurbitaceous vegetables	Use tall barrier crops and bare land to reduce the numbers of aphids entering the crop.	Before planting	Growing tall barrier crops (maize, sorghum, bajra) around the main crop and maintaining bare land about 2.5 meter between main crop and barrier crops	Aphids landing on barrier crops can lose the virus from their mouthparts before they move on to main crop or they may remain trapped in the barrier plants	Bare lands should not be with weeds and volunteer crops	Aphids may spread virus on weeds and volunteer plants which in turn pass the virus to main crops
	Chemical control	At the time of sowing	Seed treatment with Imidacloprid @ 3 g/kg of seeds	Systemic insecticides help in protecting the crop from sucking insects and in turn prevent virus transmission.	Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose in ineffective.
		At the time of planting.	Apply Phorate 10 G @ (15 kg/ha) in furrows	--	Wear mask and hand gloves while applying pesticide.	To protect the worker from hazardous compounds of the pesticide.

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Name of the disease /Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Potyviruses: {(*Papaya ring spot virus* (PRSV-W), *Zucchini yellow Mosaic virus* (ZYMV), *Chilli vein mottle virus* (ChiVMV), *Bean common mosaic virus* (BCMV), *Pepper Mottle virus* (PepMV), *Water melon mosaic virus* (WMV2)} in solanaceous, leguminaceous and cucurbitaceous vegetables and spread by several Aphids and seed borne in nature		Need based application	Spray foliage with Imidacloprid 17.8 SL @ 0.3 ml/l at an interval of 15 days if needed after 40 days of planting.	--	Do not spray when crop is at maturity.	Increase in cost of cultivation and pesticide residues in the produce.
					Do not use same pesticide in repeated sprays.	This may result in resistance development in aphids.
	Follow best cultural practices.	Adjust vegetable crops sowing during relatively aphid-free period.	Plant vegetable crops during less aphid population period.	To escape severe infestation of aphids	--	--
	Control weeds and other hosts of viruses	Before and during the cropping period	Keep the field weed-free and volunteer plants before aphid population reaches critical level (20 aphids/100 compound leaves). Remove weeds manually or apply weedicide (Paraquat dichloride 24 SL @ 2.5 l/ha) on sunny days.	Many weeds are hosts for aphids.	Do not use non-specific herbicides	Non-specific herbicides may toxic to vegetables.
	Avoid overlapping crops of same kind	Plant before sowing or planting	Crop plan or calendar should be prepared where it should not overlap one another crop of same kind	To prevent the virus inoculum	--	--

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Name of the disease /Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Use highly reflective mulches	During planting	Spread white reflective mulches and sow/plant the crop by making holes at specified distance	To deter aphids landing and feeding and interfere with probing/feeding patterns.	Should not use non-reflective mulches	Other than white mulches will not reflect
	Oil spray	After 2 months of sowing/planting at 15 days intervals	Spray oil (e.g. Neem or Pungamia oil) @ up to 3% at 15 days intervals on crop including young and recently unfolded leaves.	To deter aphids landing, feeding and oviposition which in turn interfere with probing/feeding of the insects.	Use only recommended and quality oils	Higher dose and inferior quality oil will affect the transpiration
Tobamoviruses (*Tobacco mosaic virus* *Tomato mosaic virus* *pepper mild mottle virus*) These viruses are seed borne in nature	Seed treatment	Before sowing	Treat the seeds in 15% Trisodium Phosphate (TSP) for 20 minutes or for 2.5 hours in 10% TSP and change the solution after 30 minutes if 10% TSP is used. Stir seeds during treatment and rinse seeds thoroughly in water after treatment to remove residues of TSP and then spread seeds under shade to dry.	To eliminate the externally seed borne viruses	Store seeds in a clean container not previously used for seed storage. Do not reuse the TSP solutions	Old used containers may have contaminated with virus Reuse of TSP solution may not be that much effective as fresh one
	Hand and cloth washing	Before handling the seeds or planting material	Using hot water and strong detergent to wash the hands and cloths	To remove from TMV from hand and cloths because TMV is highly contagious nature	--	--

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Name of the disease /Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Tospoviruses: {(*Peanut bud necrosis virus* (PBNV), *Watermelon bud necrosis virus* (WBNV) *Capsicum chlorosis virus* (CaCV) *Melon chlorotic spot virus*)} the viruses are spread by Thrips (*Frankliniella occidentalis, F. schultzei, F. Intonosa, F. bispiosa, F. fusca, Thrips setosus* and *T. tabaci*)	Use tolerant varieties.	Before planting	Check the label mentioned on the seed bags for tolerance to Tospovirus disease	To minimize the virus infection.	--	--
	Early or late planting	At the time of planting	Based on previous record on population dynamics of thrips, the planting date should be adjusted	To escape topsoviruses spread by thrips and their population is more in early part of dry season.	--	--
	Use highly reflective mulches	During planting seed/seedling	Spread preferably black mulches and sowing/planting the crop by making holes at specified distance	To deter thrips landing and feeding and interfere with probing/feeding patterns.	Other mulches are not much effective	Black mulches are effective against thrips
	Oil spray	After 2 months of sowing/planting at 15 days intervals	Spray oil (*e.g.,* Neem or Pungamia oil) @ up to 3% at 15 days intervals on crop including young and recently unfolded leaves.	Same as in Poty viruses		
	Chemical control	Before planting	Dip seedling in Imidacloprid 17.8 SL (0.3 ml/l) for 10 minutes and transplant immediately.	Imidacloprid is systemic insecticide and it will protect the crop from thrips for few days after emergence.	Do not use the same solution for more than three times to dip the seedlings	Effectiveness of the solution decreases with repeated use.

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Name of the disease /Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
		At about 80% emergence.	Spray the crop with Imidacloprid 17.8 SL (@ 0.2 ml/l) or Fipronil 5 SC @ 1.5 g/l of water	To protect the crop from thrips and in turn from stem necrosis.	Do not spray with sprinkler irrigation.	Sprinkler may deliver more amount of pesticide which is toxic to the crop.
Begomoviruses and Whiteflies (Solanaceous, legumes, cucurbits leafy vegetables and okra)	Use healthy seeds	Before sowing or planting.	Procure healthy seeds from reliable source and get receipt.	Viral diseases spread from infected seeds originated plants to healthy plants.	Do not purchase seeds without seed class tag and receipt.	Seeds are likely to be unreliable.
					Check suitability of the variety in your region.	Unsuitable variety yields less.
	Seed treatment	Before seeds were sowing into the nursery/main field	Dry coating or wet coating of seed with Imidacloprid 17.8 SL @ 3 g/kg using a seed dressing machine or by manually and dry the seed under shade condition before planting into the nursery	To prevent transmission of viruses	Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose in ineffective.
	Cultural practice	During nursery raising	Raising seedlings in nursery under nylon net of 40 mesh size for 24-25 days	To prevent transmission of Begomoviruses from whiteflies (vector of the disease)	Do not purchase nylon net of less than 40 mesh size.	Otherwise the whitefly will enter inside the net and transmit the viruses

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Name of the disease /Insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control	Before transplanting	Mix 0.3 ml of Imidacloprid 17.8 SL in one litter of water and spray on seedling before transplanting into the main field	To prevent virus transmission through its vector	Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose in ineffective.
	Seedling root dip	Before transplanting	Mix 1 ml of Imidacloprid 17.8 SL in one litter of clean water and dip seedling for 5 min before transplanting into the main field	To prevent virus transmission through its vector		
	Delay or early planting	At the time of planting	Plant vegetable crops 10-15 days later or early than the optimum planting time.	Whiteflies are vectors of Begomoviruses. The population is more in high temperatures in early part of the crop season and goes on reducing at low temperatures of later part.	--	--
	Chemical control	After transplanting planting	Spray foliage with Imidacloprid 17.8 SL @ 0.3 ml/l at an interval of 15 days if needed after 40 days of planting.	Imidacloprid is systemic insecticide. It will protect the crops from whiteflies	--	--

Table.11d: INM Packages for the management of major plant parasitic nematodes of vegetables

Name of the Nematode pests	What to do	When to do	How to do	Why to do	What not to do	Why not to do
Plant parasitic nematodes (Root knot Nematodes- *Meloidogyne* sppand Reniform Nematodes- *Rotylenchulus reniformis*)	Fallowing	Summer season	Land is left without ploughing and do not allow any living plants in field	Nematode gets starved and killed due to unavailability of food material	Do not allow even grasses	Nematode life cycle would continue which maintain nematode inoculum carry over to next crop
	Soil solarization	Hot summer period (May-June)	Deep ploughing (15-30 cm depth) with little moisture and cover the soil with transparent polythene sheet in air tight condition	Increases the soil temperature which will kill the nematodes	Do not use colour polythene sheet and do not practice in dry field condition	Do not use colour polythene sheet because which will not allow to penetrate more heat into the soil and do not practice in dry field condition. Hence it is not effective
	Summer ploughing	During hot summer months	Infected fields should plough deep using bullock drawn or tractor mounted plough (up to 15-30 cm depth)	During deep plough nematode eggs and juveniles exposed to surface where hot sunlight to kill them	Do not follow in heavy rainfall area	Vulnerable to soil erosion
	Crop rotation	Before planting or at time of sowing	Rotate vegetables with non- host crops (Mustard or Onion or Garlic or Wheat) for 2 years	To break life cycle to reduce populations build up due to non-availability of food	Do not grow mono cultivation	More population build up
	Selection of nursery site	Before sowing	Diagnose the soil nematode through soil sampling the area	To prevent nematode infestation at early stage and spread to main field	Do not use unhealthy seedlings	Do not raise nursery in infested field
	Trap crop	Before sowing	To grow Sunnhemp all over the field to allow nematode to infects up to one month	Nematodes penetration takes place but growth and developments will not occur	Do not grow longer period and destroy after one month from sowing	Loss of time to grow next crop

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Name of the Nematode pests	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Antagonistic crop	At the time of planting	Grow marigold (*Tagetus erecta* and *T. patula*) between two row (2:1) of susceptible crops	Nematode population build up will be reduced due to production alpha-terthinyl from root	--	--
	Organic amendments	During nursery preparation and main field	Application of Neem cake @500 kg/ha	It kill the nematode in field and encourage natural enemies	--	--
	Bio-control agent	Procure good biocontrol agents before sowing the crop	As described in disease management			
	Resistant varieties	Selection of varieties before sowing	Grow resistance varieties (Tomato: SL-120, PNR-7 and Hissar Lalith, Brinjal: Pusa Long Purple, Black beauty, Chillies: Pusa Jwala) for two seasons and one season with susceptible cultivar.	Prevent the development of new strain of nematodes or break down of resistance	Do not grow resistance varieties continuously more than 2 years	Development of new strain
	Fumigation	Before planting	Drench the soil with Metam sodium @ 300-500 l/ha	Nematodes get killed	After application do not allow to entry of workers inside fumigated area for one month	Very poisonous and get suffocation

Contd......

Name of the Nematode pests	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control	Nursery seedling treatment, basal application and middle of the crop period.	Dip seedlings in Carbosulfan 25 EC @ 500 ppm for 1 hour and seed dressing with Carbosulfan 25 DS @ 3% w/w. Apply Carbofuran 3 G and Phorate 10 G @ 1.5 kg a.i/ha in field at transplanting and 30-40 days after planting.	To kill different stages of root knot nematodes in soil and plant.	Do not use over-/under-dose of pesticide. Wear mask and hand gloves while applying nematicides.	Over-dose is toxic while under-dose in ineffective. To protect the workers from hazardous effects of the nematicides.

NOTE

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