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IPM practices for insect pests of major vegetable crops: An overview

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Abstract
Vegetable production is one of the more dynamic sectors of agriculture in view of the economic value of the production. Vegetables are very important in daily diet of human being and to improve our economic position by growing more vegetables. Brinjal, okra, cabbage, cauliflower, tomato, beans and cucurbits are important vegetables cultivated in India. Several biotic and abiotic factors limit the productivity of vegetables, mainly diseases and insect pests. Because of high susceptibility of vegetables to insects, farmers tend to apply chemicals for protective purposes. The indiscriminate use of insecticides has disrupted the delicate balance between the insect pests and their natural enemies. The development of insecticide resistance in diamond back moth (*Plutella xylostella*) in cabbage brinjal fruit borer (*Leucinodes orbonalis*), tomato fruit borer (*Helicoverpa armigera*) and serpentine leaf miner (*Liriomyza trifollii*) are a few examples. This has resulted in great hazards to the environment and ecological consequences like destruction of natural enemy fauna, effect on non-target organisms, residues in consumable product and the health of users and consumers, as well as serious resistance problems. IPM helps to reduce the dependence on chemical pesticides and ecological deteriorations. IPM includes bio-pesticides, botanicals, predators and parasitoids and all conventional chemical method of pest control.

Keywords: Integrated Pest Management Vegetables

Introduction

Throughout the world, vegetables are an important element of the human diet, providing a vital source of carbohydrates, vitamins, and minerals. Some vegetables remain unique to specific cultures, whereas others have gained wide acceptance and have been transported to several continents where they are grown extensively. Due to expanding urbanization and deforestation, most of the natural resources are depleting and shrinking with a rapid pace. With the limited land and depleting water resources, India has to feed the burgeoning population without destroying the ecological balances. Vegetable production is one of the more dynamic sectors of agriculture in view of the economic value of the production. Vegetables are rapidly becoming an important source of income for the rural population. India is fortunate enough to have a varied agro-climatic conditions found through out the length and breadth of the country which enable to produce both tropical and temperate vegetables. During the last 50 years, there is tremendous increase in vegetable production and therefore, India is the second largest vegetable producer only next to china with an estimated production of about 125.89 million tons from 7.80 million ha (Indian Horticulture Data Base, 2008), India contributing 13.38 per cent of total world production of vegetable. India occupies first position in cauliflower, second in onion and third in cabbage in world. The vegetable production scenario of the country, the state-wise distribution of area under different vegetable crops, the maximum area is in West Bengal followed by U.P., MP, Bihar & Gujrat (Table: 1, Indian Horticulture Data Base, 2020). There are variations among different states of the country with regards to productivity of vegetable crops. Potato, tomato, onion, cabbage and cauliflower account for around 60% of the total vegetable production in the country.

Table 1: Leading vegetable producing states of India

S. No.	State	Area (m ha)	Production (mt)	Productivity (t/ha)
1	West Bengal	1.49	29.55	19.82
2	Uttar Pradesh	1.25	27.7	22.05
3	Madhya Pradesh	0.897	17.77	19.79
4	Bihar	0.87	17	19.14
5	Gujrat	0.63	12.55	20.04

Source: Agri Business, 2020

Indian vegetable export is very low because of increased domestic requirement and other limitations in crop production. The major limiting factor, include the extensive crop devastation due to increased pest menace. In many cases there is 100 per cent yield loss due to viral diseases vectored by insects. The insect pests inflict crop losses to the tune of 40 per cent in vegetable production (Srinivasan, 1993) [30]. The extent of crop loses in vegetables varies with the plant type, location, damage potential of the pest involved and cropping season. Vegetables are more prone to insect pest and disease mainly due to their tenderness and softness. At the same time, vegetable cultivation is becoming more costly due to the increasing use of purchased inputs such as pesticides and fertilizers to sustain production levels.

Vegetable growers by and large depend on chemical pesticides to counter the problem of insect pests. It accounts for 13-14 per cent of total pesticides consumption as against 2.6 per cent of cropped area (Sardana, 2001) [21]. Because of high susceptibility of vegetables to insects, farmers tend to apply chemicals for protective purposes. Also, their high profitability combined with a lack of knowledge by the farmers has often led to improper use and handle of synthetic insecticides. These inputs are also a cause for concern due to their deleterious effect on human health and the environment like destruction of natural enemy fauna, effect on non-target organisms, residues in consumable product and the health of users and consumers, as well as serious resistance problems.

Changing Pest Scenario and Yield Losses in Vegetable Ecosystem

With the introduction of high yielding varieties and hybrids vegetable seeds resulted in dramatic changes in insect pest scenario leading to minor pests assuming the status of major pests. The serpentine leaf miner (*Liriomyza trifolii*) attacks tomato, brinjal, melons, leafy vegetables and cucurbits while the spiraling white fly damage okra. The mealy bug, *Coccidohystrix insolita*, and leafhopper, *Empoasca motti*, attack brinjal and bitter gourd, respectively (Balasubramanian, 2004) cabbage leaf webber, *Hellula undalis* and red spider mites on okra, brinjal and cucurbits. Overall, the insect pests inflict crop losses to the tune of 30-40 per cent in vegetable production (Srinivasan, 1993) [30] and in many cases, there is 100 per cent yield loss due to viral diseases vectored by insects (Shivalingswami *et al.*, 2002) [24].

Major Vegetable Crops

Solanaceous vegetables

This is the major and economically important group of vegetables including Brinjal, tomato and chilli, extensively cultivated in India.

Brinjal: Shoot and fruit borer (*Leucinodes orbonalis*), hadda beetle or leaf feeding beetle (*Epilachna vigintioctopunctata*), leaf hopper (*Amrasca bigutula biguttula*), aphids (*Aphis gossypii*) and red spider mite (*Tetranychus cinnabarinus*) are some important pests of brinjal. Shoot and fruit borer has remained major pest since two decades due to poor natural enemy complex and extensive use of pesticides in brinjal. Crop losses in brinjal due to shoot and fruit borer ranges from 25.82-92.50 % and yield reduction of 20–60 %. Hadda beetles devastate the crop in some pockets, where adult beetles as well as grubs feed on the foliage and completely skeletonise the brinjal plant. Another key pest of brinjal is the stem borer, which tunnels in to stem and cause plant to wither and die.

Tomato: This plant is subject to infestation by the sucking insects, white fly (*B. tabaci*) and cotton aphid (*A. gossypii*), the cotton leaf worm (*S. littoralis*) primarily damages the summer crops. It causes defoliation, but also it can bore into and feed on interior of fruits. Leaf miner (*L. trifolii)* attacks also tomato leaves causing various losses. In tomato *H. armigera* is the key pest and it feeds on buds, flowers and fruits causing on an average 46% yield loss.

Table 2: Yield losses due to insect pests in vegetables

S.N.	Major crops and their relative insect pests		Yield losses (%)
	Crucifer crops		
1	Diamondback moth (*Plutella xylostella*)		16.87-98.83
2	Cabbage butterfly (*Pieris brassicae*)		68.5
3	Crucifer leaf webber (*Crocidolomia binotalis*)		28.09-50.88
4	Cabbage borer (*Hellula undalis*)		30-58
5	Crucifer aphid (*Lipaphis erysimi*)		36.5
6	Mustard saw fly (*Athalia lugens proxima*)		36.5
Chilli			
7	Chilli thrips (*Scirtothrips dorsalis*)		11.8-90
8	Chilli mites (*Polyphagotarsonemus latus*)		34.14
Brinjal (Egg plants)			
9	Fruit and shoot borer (*Leucinodes orbonalis*)		48-66
Tomato			
10	Fruit borer (*Helicoverpa armigera*)		22.39-37.79
Okra/ Lady's finger			
11	Shoot and fruit borer (*Earias vitella*)		22.79-54.04
12	Jassids/Leafhoppers (*Amrasca bigutulla bigutulla*)		54-66
13	White flies (*Bemesia tabaci*)		54.04
14	Fruit borer (*Helicoverpa armigera*)		22.1
Cucurbit crops/Summer vegetables			
15	Fruit flies (*Bactrocera cucurbitae*)	Bitter gourd	60-80
		Cucumber	20-39
		Muskmelon	76-100
		Snake gourd	63
		Sponge gourd	50

Chilli: Chilli is one of the most valuable spice crops and it is used in India as a principal ingredient of various curries and chutneys. The major pest of chilli includes thrips, *S. dorsalis*; mite, *P. latus*; fruit borer, *S. litura* and *H. armigera* (Dhandpani *et al*., 2003).

Malvaceous vegetable

Okra: Okra (*Abelmoschus esculantus* (L.) Moench) is major economically important vegetable falling under this category. Okra plants are subject to attack by White flies (*B. tabaci*), Jassids (*A. bigutalla bigutulla*) and Aphids (*Aphis gossypii*) are attack. Pods and flowers are primary targets of shoot and fruit borer (*Earias* sp.), while the caterpillar of the American bollworm (*H. armigera*) prefers the reproductive parts of the plant, including buds, flowers and fruits also.

Cruciferous vegetable

Cabbage and cauliflower: Cruciferous vegetable crop includes cabbage, cauliflower and knolkhol throughout the world. The poor productivity of cruciferous vegetables because of which suffers from a number of insect pests. The important ones are: DBM (*Plutella xylostella* Linn.), leaf webber (*Crocidolomia binotalis* Zeller), stem borer (*Hellula undalis* Zeller), aphids, *(Brevicoryne brassicae* Linn, *Hyadaphis erysimi* Kaltenbach), stink bug (*Bagrada cruciferarum* Kirkaldy), striped flea beetle (*Phyllotreta striolata* Fabr.), and mustard saw fly (*Athalia lugens proxima* Klug). Ash + soil mixture and cow urine dung are used to protect the cabbage plant from insect pests (Lal and Verma, 2006) [8].

Cucurbitaceous crop

Cucurbits are an important group of vegetables, which includes bitter gourd, ash gourd, pumpkin, snake gourd, melons, cucumber etc. Many insect pests infest the crop and affect the appearance of marketable yield. These insect pests include red pumpkin beetle (*Aulacophora foveicollis*); fruit fly (*B. cucurbitae*), hadda beetle (*E. vigintioctopunctat*) and leaf minor**.**

Onion: Onion is one of the most important vegetable crops in this country. The major pest includes onion thrips, *T. tabaci* and onion fly, *Delia antique*.

Integrated Pest Management

Integrated pest management is a systems approach to pest control that combines biological, cultural, and other alternatives to chemical control with the judicious use of pesticides. The objective of IPM is to maintain pest levels below economically damaging levels while minimizing harmful effects of pest control on human health and environmental resources. IPM is a dynamic and constantly evolving system in which all the suitable control tactics and available surveillance and forecasting information are combined into a holistic management programme delivered to the farmer at requisite interval as part of the sustainable crop production technologies. In another words, IPM aims at combining all available methods or tools of insect pest control in a judicious manner that minimizes insecticide use and disturbance to the ecosystem but becomes a multidisciplinary one. A broader definition was adopted by the FAO Panel of Experts (Food and Agriculture Organization, 1975): "Integrated Pest Control is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury." This definition has been cited frequently and has served as a template for others.

Integrated Pest Management, or IPM, is a philosophy of pest control. It includes the use of several management techniques (e.g. bin cleanup, sanitation, facility repair, temperature manipulation, etc.) used together to reduce pest infestation levels below economic thresholds. An Economic Threshold is a given level of insect infestation which triggers a preventive treatment, such as an insecticide. The Economic Threshold is the level of insect infestation where treatment must occur to prevent the population from rising to the Economic Injury Level (or EIL). The EIL is that level of infestation where the cost of treatment equals the cost of control measures. Once the EIL is exceeded, the farmer loses money. In vegetables, insect pests cause great loss; this is well reflected by Table 3 given below:

Considering the above facts, it is must to control vegetable pests. Due to the easy accessibility and confirm action against pest, farmers prefer to use chemicals to control the pest population. We consume 13-14% of total pesticides to control pest in vegetables against 2.6% of cropped area of vegetables. This excessive and uncontrolled use of chemicals is not only leading to destruction of natural enemies but also risky, as vegetables are prone to retain pesticide residues. The indiscriminant use of chemicals is not desirable in vegetables as these are harvested in shorter interval and waiting period can not increased due to perishable nature of vegetables. All these complexities should be kept in the mind when we plan **"IPM strategy"** for vegetables.

Table 3: ETL for some vegetable crops for some pests are given below

Crop	Insect pest	Economic threshold level
Cabbage	DBM, *P. xylostella* Leaf webber, *C. binotalis*	0.5 larvae/plant 0.3 egg mass/plant
Okra	Jassid	4.46 nymph/plant
	Fruit borer	5.3% infestation of fruits
Okra	White flies (*B. tabaci*)	4 adults per leaf
Chilli/Capsicum	Fruit Borer	1 egg or 1 larva/plant or 1 damaged fruit per plant
Chilli/Capsicum	Leaf hopper	2 to 5 nymphs/leaf
Chilli/Capsicum	Thrips	2 thrips/leaf
	Mite	One mite/leaf
Potato	Cutworms	One larvae/10 plants
Pea	Aphid	3-4 aphid/stem tip
Tomato	Fruit borer, *H. armigera*	8 eggs/15 plants or 1 larvae/plant
Tomato	Leaf miner	2-5 miners pr plant
Tomato	Jassid	5-10 jassids per plant
Tomato	Leaf folder	One damaged leaf/hill
Tomato	Army worm	One larvae/hill
Brinjal	Shoot and fruit borer (*L. orbonalis*)	0.91% on shoots and 0.67% on fruits
Cucurbit	Leafhopper (*A. bigutulla)*	2.5 nymphs per leaf
Cucurbit	Spotted leaf beetle (*Epilachna* sp.)	1 insects per sq m
Onion	Thrips (*T. tabaci*)	13-15 thrips per plant 15 days after Transplanting
Potato	Cut worms (*Agrotis ipsilon*)	One larvae per ten plants

Source: DPPQS, 2003 Dhandapani *et al*, 2003 [6].

Strategies for IPM in vegetables

Cultural practices: The activities under this method are:

(a) Tillage of soil: Summer ploughing is an effective practice to spoil the soil inhibiting inactive 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.

(b) Use of resistant/tolerant varieties: tolerant/less susceptible varieties are important component of IPM programme. They reduce the pest incidence by non-preference (antixenosis), antibiosis and tolerance.

Table 4: Some of less susceptible varieties of vegetables are:

Crop	Pest	Varieties
Brinjal	Shoot and fruit borer	SM 17-4, PBr 129-5, Punjab Barsati, ARV 2-C, Pusa Purple Round, Punjab Neelam
	Aphid, Jassid and white fly	Kalyanpur-2, Punjab Chamakila, Gote-2 GB-1 and GB-6.
Chillies	Whiteflies and aphids	HC 144
	Thrips	G5, K2 and X235
Tomato	Fruit borer	Roma AC and Punjab Kesari
	Sucking pest	Pusa Ruby, Pusa Sheetal and Pusa Gaurav
Cabbage	Aphid	All Season, Red Drum Head, Sure Head, and Express Mail.
Cauliflower	Stem borer	Early Patna, EMS-3, KW_5, KW-8 and Kathmandu Local.
Okra	Jassid	IC-7194, IC-13999, New Selection and Punjab Padmini
	Shoot and fruit borer	Punjab-7, Clemson Spineless, MP-7, AE-57
Onion	Thrips	PBR-2, PBR-5, PBR-6, Arka Niketan, and Pusa Ratnar
Round gourd	Fruit fly	Arka Tinda
Pumpkin	Fruit fly	Arka Suryamukhi
Bitter gourds	Fruit fly	HISSARII and Ghote
Muskmelon	Fruit fly	Lakhazda, Khara, IHR 40 & 47

Source: Dhandapani *et al*, 2003 [6].

(c) Manipulation in time of sowing: By manipulating the sowing and planting dates of the crop to keep it away from most damaging stager of pest, losses can be managed below economic threshold level.

- Plant the cucurbit crop in November to avoid the damage of Red Pumpkin Beetle.

(d) Inter cropping: As diverse nature of plant obstructs the life cycle of insect and obstructed conditions are unfavorable for further infestation. Some inter crop combination effective in vegetable pest management are:

- Two rows of maize and outer rows of maize and inner row of wheat effectively blocked the adult thrips movement in onion.
- Intercropping with tomato or carrot reduces the incidence of Diamond back moth in Cabbage
- Tomato intercropped with cabbage has been reported to inhibit or reduce egg laying by diamond back moth and leaf webber incidence.
- Single and double rows or border crop of coriander/fennel reduced the incidence (49.85-98.6%) of shoot and fruit borer of brinjal

(e) Trap Crop: The principle of trap cropping rests on the fact that virtually all pests show a distinct preference to certain crop stage. Some early crops are sown in narrow strips around a major crop to serve as a trap for the pest that might be common to both. Trap crop must be distinctly attractive to the pest than the main crop.

Table 5: Major trap crops of vegetables

S. No.	Trap Crop	Main Crop	Target Pest
1.	Mustard	Cabbage	Diamond Black Moth
2.	Maize	Bitter Gourd	Fruit Fly
3.	Marigold	Tomato	fruit borer, *H. armigera,*
4.	Hibiscus species	Okra	Shoot and fruit borer, *Earias* sp. and fruit borer, *H. armigera,*
5.	Buck wheat	Onion	Onion Thrips (*Thrips tabaci*)

Trap cropping has indicated a great benefit in terms of economic returns on an average of 10-30 per cent increase in net profits mainly resulting from reduced insecticide use and pest attack. The major benefit of trap cropping is that insecticides are seldom required to be used on the main crop and this enhances the natural control of pest. Moreover, trap crops may also attract natural enemies thus enhancing natural control. The attractiveness of trap crops may be enhanced by use of insect pheromones, plant kairomones or insect food supplements. Use of tall African marigold as trap crop for the management of tomato fruit borer, *H. armigera*, was demonstrated in 1992 (Srinivasan *et al.*, 1994) [31]. Planting Indian mustard as a trap crop for the management of insect pest of cruciferous vegetable (Moorthy and Kumar, 2004) [14]. It offers significant economic and environmental benefits and it can successfully integrated with cultural, biological and chemical control methods (Kambrekar, 2015).

Mechanical Control of Insect Pest

Reduction and suppression of pest population by means of manual devices is called as mechanical control. This includes: Hand picking of larvae (larvae of cutworm, leaf eating caterpillar etc), suction traps (aphids and white flies), light traps (moths, hairy caterpillars), pheromone trap (moths and fruit flies), Trenching the field (army worm, grasshoppers).

- Regular pruning and prompt disposal of pest damaged eggplant shoots, especially up to the first harvest, is an important component in the BSFB IPM strategy (Satpathy *et al.*, 2005, Tiwari *et al.*, 2009) [22, 33].
- Affected twigs and fruits should be clipped off or removed from the field (Shankar *et al.*, 2010) [23].
- Installation of pheromone traps @ 5-7 per ha for early detection and 12-15 per ha for trapping and mass destruction for mating disruption
- Apply poison baits (40 ml malathion + 200g gur / molasses per 20L of water) in the form of spray or bait stations for management of fruit flies
- Mass trapping of fruit flies adults using cue lure
- Install yellow sticky traps coated with adhesive or sticky glue at crop canopy level for monitoring adult whiteflies.

Physical Control of Insect Pest

Reduction or suppression of pest populations by using the devices which affects them physically or alter their physical environment. Manipulation of temperature, humidity, light is used for the management of insect pest population.

- Soil solarization in nursery beds as well as in the main field.

Botanicals

- Soil application of neem cake reduced the incidence of fruit fly to 6 percent in cucurbits, whereas insecticide applied plots recorded its incidence at more than 15 percent. Many neem formulations have been found effective against serpentine leaf miner also. NSKE and karanj oil have found effective against cucurbit leaf miner (Rosaiah, 2001).
- In cabbage and cauliflower, Neem cake and NSKE sprays

application DBM significantly in cauliflower and cabbage (Srinivasan and Moorthy, 1992; Moorthy and Kumar, 2004) [13, 14]. Demonstration of NSKE sprays under mechanised cabbage farming was also done in a large area of Tamil Nadu by Moorthy *et al.* (1998) [12].

- The insecticide resistant brinjal shoot and fruit borer was effectively reduced to 6-10% by 2-3 soil applications of neem and pongamia cakes @ 250 kg/ha. Use of NSKE @ 5% and Neem gold @ 2 ml/l were found effective against *L. orbonalis* (Tiwari *et al*., 2009) [33] NSKE and nimbecidine was found effective against tomato fruit borer, *H. armigera* (Singh *et al*., 2009) [26].
- The soil application of neem cake @ 250 kg/ha at sowing and two repeated applications at 30-45 days interval was found to reduce the incidence of okra insects. Leaf extract of *Parthenium hysterophorus* 3% was found effective against leafhopper (Pawar *et al*., 2001) of okra. Leaf extract of *Lantana camara* was found effective against *Earias* sp. (Lok Nath, 2008) [9]. Pongamia extrct, Lantana leaf extract, Tobacco extract and Garlic extract were found effective against *L. orbonali* (Pandey & Thakur, 2017) [17].

Biological/ Microbial Control

Exploitation of natural enemies is very critical to IPM programme and it is being used very widely now-a-days by the farmers under IPM package. These includes

1. Predators: A predator is free living organisms which feed on its prey, is usually larger than its prey and requires more than one prey to complete its development is called predators. Examples: Ladybird beetle feeds on aphids.

- **Ladybird beetles**, *Rodolia cardinalis* and *Coccinella* sp: The ladybird beetles feeds mainly on aphids and other soft-bodied insects, such as mealy bugs and spider mites.
- **Syrphid fly larvae**- Larvae of this species feed on aphids and mealybugs.
- **Green lacewing larvae** - *Chrysoperla carnea* - Lacewing larvae, known as aphid lions, feed on insect eggs, aphids, spider mites, thrips, leafhopper nymphs, and small caterpillar larvae. Adult lacewings are not predacious.
- **Damsel bug**- The bug predate on aphids, leafhoppers, mites, and caterpillars.

2. Parasitoid: A parasitoid is a special kind of predator, which is often in same size its host, kills its host and requires only one host for development into a free living adult. *T. chilonis* parasitized the eggs of many lepidopterous insects i.e. *H. armigera*, *L. orbonalis*, *Earias* sp. etc.

- **Trichogramma wasp** - Trichogrammatidae - This tiny wasp attacks eggs of more than 200 pest species, including cutworms, corn borers, corn earworms, armyworms, codling moths, and cabbage moths. Release time is critical for their effectiveness since they only attack pest eggs.
- Inundative releases of the egg parasitoid, *T. brasilensis* @ 2,40,000/ha are also recommended for the control of fruit borer. Six releases at weekly intervals @ 40,000/ha with the first release coinciding with 50% flowering in tomato is recommended (Moorthy *et al.*, 1992) [13].
- *Cotesia plutellae* & *C. glomeratus* natural bio-agent of DBM larvae is effective to suppress its population in field condition (1000 adults per release every 2 week interval up to harvest).
- Release of *C. plutellae*, Conservation of *Campoletus chloridae*, a potential parasitoid of *H. armigera*.
- *Telenomus remus* parasitized the eggs of tobacco caterpillar *Spodoptera litura*.
- *Phryxe vulgaris* (dipteran fly) are also observed abundantly in cole crops fields to parasitize the caterpillars.

3. Pathogen: Microorganisms like bacteria, viruses, fungi, protozoa and nematodes develop diseases to the pest and thus help in killing pest. This includes:

(i) Fungus: *Beauveria bassiana*, *Metarrhizium anisopliae*, *Nomuraea relyie* - Used for soft bodied insects, soil dwellers and lepidopterous larvae.

- Spraying of *B. bassiana* 1X10^4 cfu/g two times with a week interval satisfactorily managed whitefly nymphs and adults. Spraying of *B. bassiana* @ 2.5 kg/ha was found effective against shoot and fruit borer, *L. orbonalis* in brinjal (Tiwari *et al*., 2009) [33] and
- in okra also found effective against *Earias* sp. (Lok Nath, 2008) [9]

(ii) Bacteria: *B. thuringienesis* - Used against fruit and shoot borer of brinjal, Okra & tomato

- *Bt* @ 0.5 kg/ha + removal and destruction of infested twigs fruits and fallen leaves were found most effective against shoot and fruit borer, *L. orbonalis* in brinjal (Tiwari *et al*., 2009) [33] and
- Application of *Bt* in okra was found effective against *Earias* sp. (Lok Nath, 2008) [9].
- Spraying of bacterial formulation *Bt* @ 500 g/ha also may proved beneficial in regulating the *Helicoverpa* larvae in the field condition.

Table 6: Uses of different bio control agents for insect pest of vegetables

Bioagent	Dose	Target pest
T. brassiliensis	2,50,000 parasitized eggs/ha (Inundative release)	Okra shoot and fruit borer
	50,000 parasitized eggs/ha (Weekly inoculative release)	Tomato fruit borer
C. zastrowi arabica	50,000 first instar larvae/ha (weekly release)	Okra aphid
		Cabbage aphid
HNPV	250 LE/ha (10 days interval)	Tomato fruit borer
SNPV	250 LE/ha (10 days interval)	Tobacco caterpillar
B. thuringiensis	500 g ai/ha (10 days interval)	Diamondback moth
		Shoot and fruit borer of brinjal and okra, Tomato fruit borer

Source: Satpathy *et al*., 2005 [22]

(iii) Virus: Ha-NPV - Used against tomato fruit borer: S-NPV- Used against tobacco caterpillar. Ha NPV @ 300 LE was found effective against tomato fruit borer, *H. armigera* (Singh *et al*., 2009) [26]. The sprays of Ha NPV at 250 larval equivalents/ha has been found to be effective in controlling fruit borer. Studies at IIHR have indicated that 3-4 applications at weekly intervals, the first spray coinciding with flowering, reduced pest incidence to minimum (> 5%) (Mohan *et al.*, 1996) [15].

- Sprays of *Ha* NPV @ 250 LE /ha at 28,35 and 42 days after transplanting found effective against tomato fruit borer, *H. armigera*

- Spray *Spodoptera* NPV 250 LE/ha + 1% jiggery along with sticker (0.5 ml/litre) during evenings (Monobrullah and Shankar, 2008) [23].

Judicious selection of chemicals may sustain the IPM system

These insecticides should be judiciously used considering certain aspect like waiting period of chemical, economic threshold level and initiation of control measures through pheromone /light trap catches.

Safe Use of Chemical

Safe use of chemicals can be adopted in IPM. For this Regular monitoring of crop for occurrence of pest, Economic Threshold Level and Judicious selection and use of chemicals is important.

Following points should be given emphasis at the time of selection of chemicals to be used:

- Vegetable with less picking interval should be sprayed with insecticide having less waiting period.
- Chemicals like plant-origin insecticides and growth regulators can also be a part of IPM. For eg. Neem products have shown efficacy against insects like jassids & borers of okra.
- ETL based application schedule helps in maintaining minimum pest population & use of pesticides in such a manner that it does not affect survival of natural enemies.

Last, but not the least, comparatively safe chemicals, should be taken into consideration for use if required after all practices are adopted.

Though IPM is quite popular and well-known term today but still we need to speed up the movement to save the earth and environment through this concept and this is possible by a thorough and well planned IPM strategy development and implementation of this at grass root level. The IPM is yet to make a large scale impact in farmers' fields. Therefore, there is an urgent need to popularize the new technologies after taking stock of the existing techniques and if necessary, modify them to suit different ecological needs. This paper presents a status report of the available IPM technologies for vegetable crops including their limitations and economic aspects.

IPM interventions

- Seed treatment with systemic chemical pesticides to avoid attack of sucking insect pests.
- Inter cropping with legumes to augment natural enemy population and trap cropping to reduce damage caused by important insect pests to main crop.
- Plant 45-day old marigold seedlings and 25-day old tomato seedlings simultaneously in a pattern of one row of marigold for every 16 rows of tomato (optional for tomato fruit borer management)
- Sow one row of mustard for every 25 rows of cabbage (optional).
- Bird perches for alighting insectivorous birds to predate on harmful insects.
- Pheromone traps for monitoring or mass trapping of moths.
- Yellow sticky traps and light traps to control sucking pests like white flies, jassids and aphids
- Scouting to monitor status of pests and beneficial insects at regular intervals.
- Periodical removal and destruction of dropped squares, dried flowers, infested shoots and fruits of brinjal, tomato and okra.
- Biological control is self propagating and self perpetuating. Augmenting bio-control agents like *Trichogramma, Chrysoperla, Syrphid, Ichnumonid, Coccinellids* and *Braconids.*
- Spraying of bio-pesticides like *B. bassiana, B. thuringiensis, Metarhizium anisopliae, Verticillium lecanii,* Ha NPV, Sl NPV, botanicals, neem seed kernel extract (NSKE).

Conclusions

Despite use of pesticides, insect pests and diseases cause considerable losses in vegetables. Moreover, many insect pests have developed resistance to insecticides used to control them, implying repeated applications of insecticides and increase in the cost of protection, secondary out break and pest resurgence. There is an urgent need to popularize the new technologies after taking stock of the existing techniques and if necessary, modify them to suit different ecological needs. The perusal of literature shows that there are several eco-friendly ways available to reduce the pesticide uses in vegetable cultivation and produce optimization. As most of the vegetables are being eaten row, so, proper care and precautions are to be taken care of while recommending the use of pesticide. Sole reliance on chemical control should be avoided. The preference should be given to the other effective methods of control like cultural practices, host plant resistance, biocontrol, use of biopathogen/botanicals to minimize the use of pesticides. The newer technologies and practices provide better protection against insect pests by adoption of integrated pest management towards food quality and high yield production for domestic and export market of vegetable crops.

References

1. Anonymous. Indian Horticulture Database, 2020.
2. Balasubramanian P. The Vegetable Industry in India: Critical IPM Needs. TheAsian Regional IPM CRSP Workshop- Impact and lessons learned. June 29-30, 2004, Philippines. 2004.
3. Chellaiah S, Srinivasan K. Bio ecology and Management of diamond back moth in India. In:" Diamond back moth Management Proceedings of International workshop, Thainan, 11 -15, March, 1985. AVRDC, Taiwan, 1986, pp 63–76.
4. David Abilash, RB. Studies on development of IPM techniques for brinjal shoot and fruit borer, Leucinodes orbonalis. M.Sc. Thesis, TNAU, Coimbatore, India, 2000, 1-67 p.
5. Dhamo K Butani, MG Jotwani. Insects in Vegetables. Periodical Expert Book Agency, Delhi, 1984, pp. 356.
6. Dhandapani N, Umeshchandra RS, Murugan M. Bio-intensive pest management (BIPM) in major vegetable crops: an Indian perspective. Food, Agriculture and Environment. 2003;1(2):333-339.
7. Mambrekar DN. Trap crops in insect pest management. The Hindu, July, 2015, 1.
8. Lal C, Verma LR. Use of certain bio-products for insect-pest control. Indian Journal of Traditional Knowledge. 2006;5(1):79-82.
9. Lok Nath. Bio-intensive management of shoot and fruit borer, Earias sp. on okra. Ph.D thesis submitted to S.V.P.University of Agriculture & Technology, Meerut, India, 2008.
10. Mall NP, Pande RS, Singh SV, Singh SK. Seasonal incidence of insect pests and estimation of losses caused

by shoot and fruit borer on brinjal. Ind. J. Ent. 1992;l54(3):241–247.
11. Monobrullah Md, Shankar U. Sub-lethal effects of SpltMNPV infection on developmental stages of Spodoptera litura (Lepidoptera: Noctuidae). Biocontrol Science and Technology. 2008;18(4):431-437.
12. Moorthy PN Krishna, NK Krishna Kumar, C Selvaraj, John Satiasheelan Daniel. Neem seed kernel extract applications for diamond back moth management: Transfer of technology for mechanised farming. Pest Management in Horticultural Ecosystems. 1998;4:128-130.
13. Moorthy PN Krishna, K Srinivasan, KS Mohan, M Mani, C. Gopala krishnan. Integrated management of Heliothis armigera in tomato. Paper presented at the Golden Jubilee Symposium on Horticulture Research: Changing Scenario, held at Bangalore. 1992;24-28:258.
14. Moorthy PNK, Kumar NK. Integrated Pest Management in Vegetable Crops. Proceedings 11. Integrated Pest Management in Indian Agriculture. National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi, And National Centre For Integrated Pest Management (NCIPM) New Delhi, India, 2004, pp. 95-108.
15. Mohan KS, Asokan R, Gopalakrishnan C. Isolation and filed application of a nuclear polyhedrosis virus for the control of fruit borer: Helicoverpa armigera (Hubner) on tomato. Pest Management in Horticultural Ecosystems. 1996;2:1-8.
16. Paroda RS. For a food secure future. The Hindu Survey of Indian Agriculture. 1999.
17. Pandey NS, Thakur S. Bioefficacy of some plant products against Brinjal (Solanum melongena L.) Shoot and Fruit borer, Leucinodes orbonalis (Guenee), Journal of Pharmacognosy and Phytochemistry. 2017;6(4):876-878
18. Panwar VPS. Pests of fiber crops. In "Agricultural insect pests of crops and their control", 1995, pp. 87-104.
19. Panwar DB, Warade SD, More TA. Efficacy of different plant extracts against leaf hopper (Amrasca devastans Dist.) and fruit borer (E. vitella) of okra. In: Procengs of the second National Symposium on Integrated Pest Management (IPM) in Horticultural Crops: New Molecules, Biopesticides and Environment. October 17-19. Bangalore, India. 2001, 66 p.
20. Rosaih B. Effect of different plant product against serpentine leaf miner, Liriomyza trifolli on ridge gourd Luffa accutangula. Pestology. 2001;25(4):7-9.
21. Sardana HR. Integrated pest management in vegetables. In: training manual-2, Training on IPM for zonal Agriculture Research Stations. 2001;21-26:105-118.
22. Satpathy S, Shivalingaswamy TM, Akhilesh Kumar, Rai AB, Mathura Rai. Biointensive management of eggplant shoot and fruit borer (Leucinodes orbonalis Guen.). Vegetable Science. 2005;32(1):103-104.
23. Shankar U, Kumar D, Gupta S. Integrated pest management in brinjal. Technical Bulletin No. 4, SKUAST-J, Jammu. 2010.
24. Shivalingswami TM, Satpathy S, Banergee MK. Estimation of crops lossesdue to Insect pests in vegetables Ed. by Sarath Babu, B.,Varaprasad, K.S. Anitha, K., Prasada Rao, D.V.J., Chakrabarthy S.K. and Chandurkar, P.S. Resource management in plant protection. 2002:1:24-31.
25. Singh D. Pests of solanaceous vegetables in "A decade of research on pests of horticultural crops, 1980–1990", Group discussion of entomologists working on coordinated prioject of horticultural crops held at CIHNP, Luknow. 1991.
26. Singh R, Prasad CS, Tiwari G.. Eco-friendly management of tomato fruit borer, Helicovrpa armigera (Hub.). International Conference on Current trends in Bio-technology, 19-21 Feb. 2009. S.V.P.U.A. & T., Meerut, India, 2009, pp: 160-161.
27. Singh R, Dhaka SS, Kumar A, Ali N, Tiwari G. Bio-efficacy of some neem formulations against Helicovrpa armigera (Hub.) in tomato. Ist Indian Agricultural Scientist and farmers Congress, 03-04 Oct. 2009. C.C.S. Uni. Meerut, India, 2009, pp: 276.
28. Srinivasan K, Veeresh K. The development and comparison of visual damage threshold for chemical control of Plutella xylostella and Crocidolomia binotalis on cabbage in India. Insect Sci. Appli. 1986;7:547-557.
29. Srinvasan K, Krishnamoorthy PN. Development and adoption of integrated pest management for major pests of cabbage using Indian mustard as trap crop: diamond back moth and other crucifer pests. Proceedings of the Second International Workshop, Tainan, Taiwan, 10-14 December 1990. Asian Vegetable Research and Development Centre, AVRDC Publication Centre, AVRDC Publication No. 1992;92-368:511-521.
30. Srinivasan K. Pests of vegetable crops and their control. In: Advances in Horticulture, 6: Vegetable crops Eds. K.L. Chaddha and G. Kallu. Malhotra Pub. House, New Delhi, 1993, pp: 859-886.
31. Srinivasan K, Krishnamoorthy PN, Raviprasad TN. African marigold as a trap crop for the management of the fruit borer; Helicoverpa armigera on tomato. International Journal of Pest Management. 1994;40(1): 56-63.
32. Srivastava KP. Pests of vegetables. A Textbook of Applied Entomology. Kalyani Publishers, New Delhi, 2000, 116-132 pp.
33. Tiwari GN, Prasad CS, Lok Nath. Integrated management of brinjal shoot and fruit borer, Leucinodes orbonalis Guen. in western Uttar Pradesh. Annals of Horticulture. 2009;2(1):54-61.
34. Tiwari GN, Prasad CS, Singh R, Lok Nath. Bio-intensive management of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. (Pyralidae: Lepidoptera). Ist Indian Agricultural Scientist and farmers Congress, 03-04 Oct. 2009. C.C.S. Uni. Meerut, India, 2009, pp: 328.Ṁ