Vegetable Science (2024) Vol 51 (Special Issue): 66-76

doi: 10.61180/vegsci.2024.v51.spl.07

ISSN- 0970-6585 (Print), ISSN- 2455-7552 (Online)

www.isvsvegsci.in

REVIEW ARTICLE

Emerging Insect Pests of Vegetable Crops under Changing Climate Scenario

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Abstract

Crop losses in vegetables vary greatly depending on plant variety, cropping season, geographical location, and pest damage potential. Vegetable crops are heavily impacted by insect pests and diseases due to their softness, fragility and short duration in comparison to other crops. An emerging insect pest is one that has been observed in a specific crop-infested area and has progressively increased in population over time. Emerging insect pests have the potential to cause economic harm. In other words, an emerging insect pest is a pest insect whose position has shifted from minor to major or secondary to primary pest. The number of existing minor pests is increasing, as is the arrival of new ones, such as mealybugs, fruit flies, stem borers, diamondback moths among phytophagous insects and red spider mites among acarine. Recent infestations, such as South American tomato pinworm and chili black flower thrips, have caused serious damage to tomato and chili harvests. This review envisages on the variables that contribute to the establishment of new invasive pests, the persistence of main pests, general pest management practices, and integrated pest management to achieve sustainable vegetable production.

Keywords: Vegetables, emerging insects, invasive pests, integrated management.

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Citation: Divekar, P.A., Halder, J., Srivastava, K. and Sridhar, V. (2024). Emerging Insect Pests of Vegetable Crops under Changing Climate Scenario. Vegetable Science 51(spl): 66-76.

Source of support: Nil

Conflict of interest: None.

Received: 03/09/2023 **Revised:** 14/12/2023 **Accepted:** 18/01/2024

Introduction

Indian vegetables are recognized for their broad range of colors, shapes, and sizes. Globally, around 1097 different vegetables are grown for human consumption. These veggies are low-cost sources of vitamins and nutrients that provide farmers with both on- and off-farm revenue. Vegetables high in fibre enhance digestion, lower cholesterol, and reduce the risk factors for heart disease, diabetes, and obesity. Although India was second in vegetable output after China, the yield of numerous vegetables is still considerably below the global average. One of the primary factors for reaching this goal is biotic stresses like insect and acarine pests, diseases, nematodes and weeds. Insect pests alone cause crop losses on an average 25 to 30% yield loss in vegetables (Rai *et al*. 2014(a)). Apart from direct losses many of them also serve as many plant diseases which aggravate the problem further (Kodandaram *et al*., 2017(b). The yield losses due to insect pest in different vegetables are listed as follows:

Sustainable vegetable production can be achieved through the management of insect pests in an eco-friendly way. The eco-friendly and sustainable pest management options like Cultural control (Halder *et al*., 2023), host plant resistance (HPR) (Divekar *et al*. 2019), plant secondary metabolites (Divekar *et al.* 2022), bio-control agents (Divekar P. 2023; Dukare *et al*. 2021), defense proteins (Divekar *et al.* 2022) and finally the chemical control (Kodandaram *et*

Table 1: Yield losses due to major, invasive and emerging insect pests in vegetable crops

Crop	*Pest*	*Damage (%)*	*References*
Brinjal	Shoot and fruit borer *Leucinodes orbonalis*	70–75%	Dhandapani *et al*. 2003
Cabbage	Diamondback moth *Plutella xylostella*	52%	Krishnamoorthy 2004
	Cabbage butterfly *Pieris brassicae*	40%	Ali and Rizvi 2007
Cowpea	Spotted pod borer *Maruca vitrata*	36% flower and pod damage	Singh and Allen 1980; Phompanjai and Jamjanya 2000
	Hadda beetle *Epilachna vigintiopunctata*	13–88% leaf damage	Halder and Rai 2021
Okra	Shoot and fruit borer *Earias vitella*, *E. insulana*	35%	Krishnaiah 1980
	Red spider mite, *Tetranychus* spp.	7–48%	Kumaran *et al*. 2007
Tomato	Tomato fruit borer, *Helicoverpa armigera*	50–80%	Dhandapani *et al*. 2003
	South American Pin Worm, *Tuta absoluta*	50–100%	Maneno *et al.* 2016
Cucumber	Cucumber moth, *Diaphinia indica*	23%	Halder and Rai 2021
Pointed guard	Fruit fly, *Zeugodacus* (*Bactrocera*) *cucurbitae* (Coquillett)	30%	Nagaraju *et al.* 2018; Singh *et al.* 2000; Gupta and Verma 1992; Rabindranath and Pillai 1986; Halder *et al*., 2022
Watermelon		28.55%	
Bottle guard		30–100%	
Bitter gourd		41–89%	
Chili	Black thrips *Thrips parvispinus*	22.8	Sastrosiswojo 1991
	Chili thrips, *Scirtothrips dorsalis* Hood and yellow mite, *Polyphagotarsonemus latus*	50%	Kulkarni 1922; Desai *et al.* 2007

al., 2010) that are relatively safer should be preferred for crop protection to avoid any adverse effects on pollinator bees and natural enemies. Despite the availability of these safer options, farmers prefer chemical pesticides as their first choice in controlling the pest problems (Roy *et al*., 2017). This has aggravated problems like resurgence and resistance development in insects, pesticide residue hazards, destruction of non-target and beneficial insects etc. This review focuses on the new emerging insect pests, factors responsible for the emergence of new pests, the persistence of major pests, and the integrated management of these pests to achieve sustainable vegetable production.

Emerging Insect Pests of Vegetables and Factors Responsible for the Emergence of New Insects

With the changes in the cropping system, the introduction of input-intensive high-yielding varieties/hybrids, changing in the climatic conditions are the root cause for a shift in insect pest status in time and space, resulting in enhanced damage caused by them across the globe (Rai *et al*., 2014(a)). Many of them also act as vectors for several viral and mycoplasma diseases, aggravating the problem further. In addition to the regular pests, recently, many exotic and invasive insect pests have invaded in many parts of the country. South American pinworm (*Tuta absoluta* Meyrick), Solenopsis mealy bug, *Phenacoccus solenopsis* Tinsley) are few such insects. Similarly, mirid bugs (*Nesidiocoris cruentatus* (Ballard) and *Metacanthus pulchellus* Dallas), melon weevil [*Acythopius curvovistris citrulli* (Marshall)], white plume moth [*Sphenarches caffer* (Zeller)], cucumber moth (*Diaphania indica*) and moringa fruit and seed borer (*Noorda blitealis* Walker), tortoise beetle (*Cassida circumdata* Herbst) are the insects which have come up in bigger way in past few years either by expanding their host horizon or increase their severity (Halder and Rai 2021). The nature of damage and specific management practices for the emerging insect pests of vegetables are presented in Table 2.

Major Pests' Persistence in Vegetables

The persistence of several important pests on vegetables is one of the significant patterns that have been noticed. The diamondback moth (DBM), which is abundant in both hot and cool locations, is a classic example. The cabbage white butterfly, *Pieris rapae*, which is restricted to cooler and hilly areas, is another significant pest. Nonetheless, the webworm *Hellula undalis* has persisted as a significant problem in many locations in the hot tropical lowlands where cabbage are grown. Cutworms (*Agrotis ipsilon*), armyworms (*Spodoptera litura*), cabbage head worm (*Crocidolomia binotalis*), flea beetle (*Phyllotreta* spp.), and aphids (*Myzus persicae*, *Brevicoryne brassicae*) are a few other species that have also been reported to be significant (Venkateswarlu *et*

Table 2: Nature of crop damage and management of emerging insect pests in vegetables

S. No	*Insect*	*Host crop*	*Nature of damage*	*Specific management practices*	*Ref*
	Lepidopteran insects				
1	South American tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)	Tomato, potato, Chili, Eggplant and Black nightshade	Larvae feed on the mesophyll tissues of the leaves, leaving only the epidermis intact. They often cause conspicuous irregular leaf blotches which later turned to necrotic. Tomato plants, from seedlings to mature stage, attacked by this pest. On fruits, small minute pin sized hole is often visible. Damaged fruits with frassy galleries accompanied by an open areas acts as entry paths for invasion by secondary pathogens, leading to fruit rot is the common symptom of this pest.	• Removal of alternative host plants and associated weeds • Regular removal of infested leaves and plant parts to reduce the population eruption of *T. absoluta* during the season • Crop rotation with non-solanaceous crops could break the life cycle of *T. absoluta*. • Use of sex pheromone traps @ 1–4 traps/ha for early monitoring and use Delta or water traps @ 25–30 traps/ha for mass trapping. • Use of biopesticides, *Bacillus thuringiensis* var Kurstaki, *Bacillus subtilis*-2, Egg parasitoid, *Trichogramma achaeae* Nagaraja and Nagarkatti (Hymenoptera: Trichogrammatidae).	Mansour *et al.* 2019; Oliveira *et al.* 2017; Halder *et al.*, 2017
2	White plume moth, *Sphenarches caffer* (Zeller) (Lepidoptera: Pterophoridae),	Lablab, Beans, Bottle gourd	Larvae damages the leaves and buds of bottle gourd by scrapping the chlorophyll portion thereby reducing the photosynthetic activity of the plants. However, damage was more severe when they feed on the emerging buds resulting in restricted growth of the buds with characteristic black excreta inside it.	• Hand collection and destruction of the larvae is beneficial. • Conservation of solitary, larval, endoparasitoid *Apanteles paludicole* (Hymenoptera: Braconidae) and chalcid pupal parasitoid, *Tropimeris monodon*. • Need based application of *Bacillus thuringiensis* @ 1 kg/ha is able to control this pest.	Sujithra *et al.* 2010; Halder *et al*. 2014
3	*Diaphania indica* (Saunders) (Lepidoptera: Pyralidae)	Cucurbits like cucumber, bitter gourd, pointed gourd, snake gourd, gherkin and sponge gourd	Light green larvae, with two prominent longitudinal dorsal whitish lines, feed heavily on the chlorophyll portion of the leaves by webbing them together. The larvae make characteristic holes on the fruits and feed inside it. The bored fruits become unfit for human consumption.	• Collection and destruction of the larva from the plants followed by spraying of NSKE 4% or *Bacillus thuringiensis* var Kurstaki @ 2 g/lit during evening hour would be advantageous. • Use of natural enemies viz, *Trichogramma* chilonis, *Dolichogenidea stantoni*, larval pupal parasitoid *Xanthopimpla punctata* and the entomopathogen *Nomuraea rileyi*. • Need based application of Chlorantranilprole 18.5% SC @ 0.2 mL/lit of water in bitter gourd is recommended.	Jana 2014; Halder *et al.* 2017a; Visalakshy 2005
4	*Noorda blitealis* Walker (Lepidoptera: Pyralidae)	Moringa	The characteristic damage symptoms of this pest includes brown gummy secretions on freshly infested pendulous fruits and gradual drying of the fruits in the later stages. Small circular exit holes and a clear larval gallery filled up with frassy excreta on fully developed green pods. The brownish white larva also feeds on the cotyledon portion of the seeds. Damaged seeds showed direct feeding symptoms and are completely filled with frassy excreta.	• Collection and destruction of affected fruits are advisable to minimize the pest incidence. Similarly, installations of light trap @ 1/ acre are recommended. • Spraying of *Bacillus thuringiensis* var Kurstaki @ 2 g/lit during evening hour may be followed.	Halder and Rai 2014

	Coleopteran insects				
1	Melon weevil [*Acythopeus curvirostris citrulli* (Marshall) (Coleoptera: Curculionidae)]	Sponge and Ridge gourd	Gravid females lay eggs in small batches on tender fruits just beneath the rind and on hatching, grubs start feeding on soft, tender fruit pulp and continue till pupation. Due to its feeding, affected fruits rot and there was no seed formation. Pupation occurs inside the fruits. Cocoons are hard blackish in color made up of fibrous materials of the fruits and larval excreta. Adults emerge from the dry fruits by making small emerging holes. Affected fruits exhibited characteristic brown gummy encrustations on the fruits which significantly reduce its market value	• Early sowing crops escapes the severe than the late sown. • Raised bed planting should be preferred than the trailing system. • Biopesticides like *Lecanicillium lecanii* and *Metarhizium anisopliae* are effective, compatible and synergistic in nature with neem oil (1%). • Amongst insecticides tested, Quinalphos, Deltamethrin and Thiodicarb were found promising and caused 100% mortality within 24 hours under laboratory conditions.	Halder *et al*. 2016
2	Tortoise beetle [*Cassida circumdata* Herbst (Coleoptera: Chrysomelidae: Cassidinae)]	Water spinach	Early instar grubs scrap the chlorophyll part of the leaves resulting skeletalization of the leaves of water spinach. Later instars make small irregular shot holes and notches on the leaves. Numerous such small holes occurred on a single leaf. Black excreta were often visible on the upper surface of the leaves. Affected leaves had lower photosynthetic activity and also fetch lower market values.	• Collection and destruction of the grubs, adults and severely infested plant parts is advisable.	Halder and Rai 2020
	Sucking insects				
1	Solenopsis mealy bug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae),	Malvaceous (ladies finger), Solanaceous (tomato, brinjal, potato, chili, Capsicum), Leguminous (cow pea, field bean), Cucurbitaceous (pointed gourd, cucumber, pumpkins and gourds)	Both nymphs and adults suck the sap, they also secret the copious amounts of honey dew which deposited on the plants and create black sooty mould and thereby reducing the photosynthetic activity of the plants. Problems are more severe in poly and net-house conditions.	• Removal of alternate hosts and weeds like *Parthenium hysterophorus* from and around the field will help to reduce the pest incidence. • Ants help in transmitting the mealybug beside they give protection to mealybugs against its natural enemies So, selective destruction of the ants' colonies during land preparation is advisable. • Uprooting and burning the affected plants reduce the pests load from the field. • Spraying of fish oil resin soap (FORS) @ 20 g/lit of water or entomopathogenic fungi Lecanicillium lecanii (2 × 108 cfu/mL) @ 5 g/lit of water give better control. • Combination of Lecanicillium lecanii (2 × 108 cfu/mL) @ 2.5 g/lit of water and Neem oil (0.5%) at 1:1 ratio was found compatible and synergistic activity against many vegetable sucking pests including mealybugs • Buprofezin @ 625 g ai/ha is effective in controlling this pest.	Saini *et al*. 2009; Sankar *et al*. 2011; Kumar *et al*. 2008; Kumar *et al*. 2012; Halder *et al*. 2018; Patel *et al*. 2010

2	*Nesidiocoris cruentatus* (Ballard) and *Metacanthus pulchellus* Dallas (Hemiptera: Miridae)	Bottle gourd	Damage was more prominent on young fruits with typical brown puncture spots often in the form of irregular lines on the rind with sap oozing out from the tender fruits formed the characteristic symptoms of these sucking pests. Affected fruits therefore had significantly reduced market value.	• Preferable use raised bed system than the trailing (i.e., bower) system for crop cultivation. • Biopesticides like, neem oil (1%) entomopathogenic fungi, *Beauveria bassiana* and *Leucanicilium lecanii*. • Flonicamid 50% WG and Spiromesifen 22.9% SC are promising chemicals under field and laboratory conditions.	Halder *et al*. 2017b
3	Black thrips *Thrips parvispinus* (Karny) (Thysanoptera: Thripidae)	Papaya, Gardenia sp. vegetables like Capsicum, green beans, potato, and brinjal.	The symptoms due to thrips damage include deep punctures and scratches on underside of the leaves. Infested undersurface of the leaf turns reddish brown, whereas upper side of such leaf looks yellowish. Distorted leaf lamina with necrotic areas and yellow streaking are quite common symptoms. On floral parts, brownish streaks appear on petals due to scraping by thrips. The damage results in drying and withering of flowers leading to reduced fruit set. Severe infestation affects the growth of the plant as thrips feed on growing portions of the plant and flower drop is also observed in the severely infested fields. Several adults, both males and females were observed feeding and hiding in the nectariferous area of chili flowers.	• Collect and destroy infested crop debris. Uproot infected Chili plants & weeds (*Parthenium* spp, *Abutilon* spp, *Cleome viscosa*, *Prosopis* sp., *Lantana camara*, *Calotropis* sp., *Tecoma* sp) present in the vicinity of field bunds which are acting as off season host to prevent further spread in field. • Seed treatment with Imidaclorpid 70WS @10 g per kg seed; Seedling root dip for 30 minutes with Imidachlorpid 17.8% SL @ 0.5 ml/ L' • Border cropping with 2-3 rows of tall growing crops like sorghum/maize/ bajta/ fodder grasses etc. sown thickly as a barrier for thrips movement • Erection of blue or yellow/white sticky traps @ 50-70 traps/ha at crop canopy height for mass trapping purpose and 20-25 traps/ ha for monitoring purpose' • Spraying of microbial based insecticides like *Beauveria bassiana* or *Lecanicilium lecanii* 5 g or m1/L (spore load - $lx10^8$ cfu/g or m1), or Bacillus a/bas - NBAIR-BATP @ 20 g/L uniformly covering whole plant. • Spraying of Neem Seed Kernel Extract (NSKE) or 0.5% Pongamia oil (5 ml/L), and • Spray application of insecticides like • Fipronil 05% SC @ 800-1000 gm in 500 litre, Emamectin benzoate 05% SG @200 gm in 500 litre, Spinosad 45% SC @160 gm in 500 litre Tolfenpyrad 15 % EC @1 litre in 500 litre Cyantraniliprole 10.26% OD @600 gm in 500 litre	Murai 2002; Sridhar *et al*. 2021; DPPQS advisory 2021

al. 2011). Nonetheless, despite their frequent awareness, these often consistently cause significant harm. The importance of certain of these pests may vary depending on the species. DBM and the cabbage white butterfly are specific illustrations. There are many instances where natural enemies are unable to exhibit their full effects because of excessive usage of hazardous pesticides, even in situations where the natural enemies have been properly introduced. In general, the majority of pests have persisted due to a lack of ecological engineering management strategies and a poor understanding of pest bio-ecology in the tropics. All along, management attempts have concentrated on employing and discovering chemical pesticides that are increasingly effective.

The most significant pest of cruciferous crops is the diamondback moth, which can reduce marketable yield by up to 52%. Because of a weakened natural enemy complex and heavy pesticide use, the shoot and fruit borer of brinjal and cowpea pod borer, *Maruca vitrata* in cowpea, shoot and fruit, *Earias vitellia* in okra, cucurbit fruit fly, *Zeugodacus* (*Bactrocera*) *cucurbitae* on cucurbits has continued to be a major pest for the past 20 years (Kodandaram *et al.* 2017(a); Ba *et al.* 2019; Halder *et al.*, 2022). The gram pod borer, *Helicoverpa armigera* (Hubner), is a severe pest that infects tomatoes, peas, Indian beans, chilies, and okra etc. inflicting damage to both the vegetative and reproductive phases of the host plant (Wang and Li 1984). Similarly, the tobacco caterpillar, *Spodoptera litura* Fab., is a polyphagous pest that feeds on foods such as tomato, chili and Indian bean etc., inflicting considerable damage at times.

Effect of Climate Change on the Emergence of New Insect Pests

The increasing population and the resulting requirement for higher crop production represent a significant challenge to food security. Storms, droughts, floods, precipitation, increased CO_2 levels, and higher temperatures all have a considerable impact on food supply (IWGCC 2007; Tripathi *et al.*, 2016). According to research, anthropogenic activities increase greenhouse gas concentrations, primarily carbon dioxide, resulting in climate change. Air and soil temperature, solar radiation, precipitation, relative humidity, and wind speed are all climatic variables that have a direct impact on plant physiological activities (Tripathi *et al.*, 2016). Climate change has the greatest impact on pests, diseases, and weeds (Sharma 2014). Insects are poikilothermic, have variable population sizes, have short life cycles, are highly sensitive to climatic change, and are strongly affected by temperature (Tripathi *et al.* 2016). The importance of climate change's effects on insect pests is increased by the fact that insects participate in numerous biotic interactions with plants, natural enemies, pollinators, and other organisms that are essential to ecological functioning (Boullis *et al.* 2015). The effectiveness of synthetic chemicals, host-plant resistance, natural plant products, bio-pesticides, natural enemies, and other insect pest management strategies are all expected to be significantly impacted by climate change. The increased global mean precipitation would significantly affect crop production as well as the diversity and quantity of biota, and cropping systems (Sutherst 1991; Porter *et al.* 1991; Lobell and Gourdji 2012).

Moreover, the spread of insect pests' geographic boundaries will have a significant impact on crop productivity (Sharma (2014). According to the most recent Intergovernmental Panel on Climate Change assessment (IPCC (2014), temperatures rose by 0.85°C [0.65–1.06°C] between 1880 and 2012. In addition, the CO_2 concentration has increased from 280 (pre-industrial value) to 401 ppm in 2015 (Mauna Loa Observatory: Hawaii). Phenomenon like geographical ranges, seasonal activities, migration patterns and abundances, as well as intra- and inter-specific relationships among insects, have all changed (War *et al.* 2016**)**.

Integrated Pest Management (IPM) and Recent Tools for Pest Management in Vegetables

IPM, by definition, refers to diseases, weeds and destructive species of phytophagous organisms (mostly insects and mites). The focus of plant protection in the context of sustainable agriculture is on precautionary or indirect methods, which must be completely utilized before control or direct measures are being used. The use of forecasting tools and criteria that have undergone scientific validation must be considered when determining the necessity of control measures. If economically unbearable losses cannot be avoided by indirect means, direct pest control tools are the last option (Boller *et al.* 2004).

IPM strategies are primarily created by growers and researchers to maximize crop yields and financial returns while minimizing adverse environmental effects (FAO 2021). In order to improve heterogeneous agroecosystems that are resilient enough to tolerate weather variability, it is necessary to re-evaluate current preventive agricultural practices and IPM strategies. However, in recent years, it has been projected that to address the significant implications of climate change, researchers and producers will need to modify many of these carefully designed IPM strategies (Barzman *et al.* 2015).

Several IPM systems have concentrated on making choices based on an in-depth understanding of the number of insect pests that can be tolerated before the economic yield losses occur, commonly known as economic or intervention thresholds. IPM has traditionally developed in the realm of pest management, where the application of established thresholds has produced positive outcomes. Although they are crucial to IPM, intervention thresholds are not always applicable, sufficient, or even feasible. Thresholds are not used when decision assistance systems are unavailable or not suitable (Barzman *et al*. 2015). It is crucial to comprehend how the environment influences the growth of plants and pests since this knowledge enables agricultural advisors to adapt to climate change. Recommendations for crop protection are affected by environmental factors including drought stress. The economic threshold can readily be lowered when a crop is under drought stress because it is less able to handle the additional stress brought by herbivorous insects (Lamichhane *et al.,* 2015). Insect populations grow more quickly and agricultural damage happens earlier than currently anticipated as a result of the faster insect development at higher temperatures. In order to avoid yield losses, treatment thresholds based on the quantity of insects per plant must be lowered (Trumble and Butler 2009**)**.

To lessen the effects of agricultural pests on crops in a changing environment, modified cropping techniques and adaptive management measures are required. To reduce exposure to pest outbreaks, these measures may include (I) planting diverse crop varieties; (II) planting at varying times of the year; and (III) enhancing biodiversity at field boundaries to increase the number of natural enemies (Thomson *et al*. 2010; Andrew *et al*. 2017). The interaction of planting dates and *Piper* emulsion or intercropping treatments can be effectively used to control cabbage pests (diamondback moth, *Plutella xylostella* and cabbage webworm, *Hellula undalis* and cabbage Looper, *Trichoplusini*) to improve yields, with the late planting date as viable alternative farm-level adaptation to climate variability. These represent cost-effective and environmentally friendly pest management strategies that can be adopted by farmers to control cabbage pests below the economic injury threshold and improve yield (Tanyi *et al.* 2018). Similarly, insects employ pheromones and allelochemicals to perceive their surroundings, which is a crucial process. They have a significant impact on a number of IPM strategies, including monitoring, trapping, push-pull tactics, biological control, and mating disruption (Heuskin *et al.* 2011) The usage of pheromones and allelochemicals in their current form is anticipated to become less successful as the climate heats and microclimates become more changeable, and may require a synergist or other adjuvant to lessen their volatility under high-temperature circumstances (Andrew *et al.,* 2017). Moreover, a few biopesticides based on entomopathogenic bacteria, nematodes, fungi, viruses, and bacterial strains are quite vulnerable to environmental changes. Some of these control strategies may become less effective with a rise in temperature and a fall in relative humidity, and synthetic pesticides are predicted to have a similar impact (Nihal 2020). In this situation, novel pest control techniques and potential insecticide formulations, as well as attractants and repellents, should be the main focus. Under field conditions, entomopathogenic fungi such as *Metarhizium anisopliae*, *Lecanicillium* (=*Verticillium*) *lecanii*, and *Beauveria bassiana* at 1 L/ha (1.6x10^4 conidia/mL) are efficient in controlling sucking insects such thrips, whiteflies, hoppers, etc. Botanicals have a significant role in the treatment of vegetable pests because they are non-persistent and safe for mammals. Neem products, among other botanicals, have demonstrated effectiveness against sucking insects like jassids, aphids, thrips, whiteflies, and mealybugs. For the management of sucking insects and mites, two to three weekly applications of 5% neem seed kernel extract (NSKE) are also helpful.

The aromatic plants such as dill and coriander can be used as inter-crop components in tomatoes to control *Bemisia tabaci*. Further, field studies also revealed that when coriander and dill crops were raised as intercrop components with tomato, whitefly incidence was significantly reduced over tomato when raised as a sole crop. This study emphasizes the potential use of dill as well as coriander as intercrop components with tomato to reduce whitefly incidence. Further, whitefly being a potential vector for a wide array of plant viruses (persistent/semi-persistent/circulative/non-circulative), the repellency of dill as well as coriander plants observed in the present study can be exploited as a potential 'push stimuli' to formulate push–pull strategies. The synthetic version of GC-EAD-active VOCs identified in dill and coriander will be helpful as push stimuli while devising semiochemical-based pest management strategies against *B. tabaci* (Padala *et al*. 2023).

Vegetable crop-integrated pest management programs must include chemical control of sucking pests as a crucial component. Chemical pesticides are a quick and effective way to control insects in the crop canopy. Nonetheless, choosing selective insecticides that are safe for insect natural enemies and those are under label claim by Central Insecticide Board and Registration Committee (CIBRC) should be considered. Several systemic insecticides, such as dimethoate (2 mL/L), imidacloprid (0.5–0.75 mL/L), thiamethoxam (500 g/ha), acetamiprid (100 g/ha), fipronil (1.5 mL/L), azadirachtin (3 L/ha), and neem oil (3 mL/L) from crop emergence to fruit formation stage will effectively reduce insect population and minimize losses caused by sucking pests. The effectiveness of newer synthetic chemicals viz., chlorantraniliprole and spinetoram in the control of vegetable insect pests of okra and cabbage has been reported by many researchers (Divekar *et al*. 2022; Majumder *et al*. 2023).

Understanding the impacts of global warming on the effectiveness of various synthetic insecticides, their longevity in nature and the emergence of pesticide resistance in pest populations is urgently needed (Vadez *et al.* 2012**)**. As a result, it would be required to take into account the use of effective biological control agents or the introduction of crop types that are resistant to insect pests that were developed through conventional genetic breeding or genetic engineering (Gomez *et al*. 2020). Many functional genomics investigations could make use of more precise genome editing methods, such as base editors and prime editors, to elucidate novel molecular players in the plant-insect battle (Divekar *et al.* 2022). With the use of CRISPR/Cas9, it is possible to precisely knock in an enhancer or activator or a constitutive/strong promoter upstream of the gene to increase the expression of the plant defense proteins that confer insect resistance to crops (Molla *et al.* 2021).

Conclusion

Sucking insect pests such as mealybugs, whiteflies, and black thrips, as well as defoliators/foliage feeders like leaf miners, hadda beetle, tortoise beetle, white plume moth and fruit borer like melon weevil, are now serious pests in vegetable crops. Vegetable pest problems have altered over time and space, and this is mostly due to changes in cropping patterns, ecosystems, and habitat, as well as changes in climate and the inappropriate use of agrochemicals. There are currently a number of approaches that can be used in IPM programs in instead of conventional synthetic pesticides. The key challenge faced by applied entomologists is to create, validate, and make available to the area-specific biointensive IPM module. Also, there is a need to intensify research in key areas including pest-resistant transgenic crops and genetically enhanced bioagents/biopesticides. In order to get beyond the fundamental drawbacks of biological pest control, it is necessary to use molecular techniques. By avoiding repeated application of the same insecticide and/or from the same group, this can be stopped or postponed. Research is required to create pest management technology in protected environments since these emerging pest problems are more prevalent there. Further investigations and understanding of molecular, biochemical, and physiological mechanisms of insect growth and development will help to identify the essential target genes for pest management with the help of recent molecular tools like RNAi-based pest control methods, CRISPR/Cas9 tools.

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सारांश

सब्जियों की फसल का नुकसान पौधों की विविधता, फसल के मौसम, भौगोलिक स्थिति और कीट क्षति की क्षमता के आधार पर काफी भिन्न होता है। अन्य फसलों की तुलना में सब्जियों की फसलें अपनी कोमलता, नाजुकता और कम अवधि के कारण कीड़ों और बीमारियों से बहुत अधिक प्रभावित होती हैं। एक उभरता हुआ कीट वह कीट है जो एक विशिष्ट फसल-संक्रमित क्षेत्र में देखा गया है और समय के साथ इसकी आबादी में उत्तरोत्तर वृद्धि हुई है। उभरते कीट-पतंगों में आर्थिक नुकसान पहुंचाने की क्षमता होती है। दूसरे शब्दों में, एक उभरता हुआ कीट एक कीट है जिसकी स्थिति छोटे से बड़े या माध्यमिक से प्राथमिक कीट में स्थानांतरित हो गई है। मौजूदा छोटे कीटों की संख्या बढ़ रही है, साथ ही नए कीटों का आगमन भी हो रहा है, जैसे कि मिलीबग, फल मक्खियाँ, तना छेदक, फाइटोफैगस कीटों में डायमंडबैक पतंगे और एकारिन में लाल मकड़ी के कण। हाल ही में हुए संक्रमण, जैसे कि दक्षिण अमेरिकी टमाटर पिनवॉर्म और चिली ब्लैक फ्लावर थ्रिप्स, ने टमाटर और मिर्च की फसल को गंभीर नुकसान पहुंचाया है। यह समीक्षा उन चरों पर परिकल्पना करती है जो नए आक्रामक कीटों की स्थापना में योगदान करते हैं, मुख्य कीटों की दृढ़ता, सामान्य कीट प्रबंधन प्रथाओं और टिकाऊ सब्जी उत्पादन प्राप्त करने के लिए एकीकृत कीट प्रबंधन में योगदान करते हैं।