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Lepidopterous pests, biology and its effect on vegetable crops

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Abstract
Vegetable production is a preferred agricultural practice in India and many south east Asian countries. It is a highly profitable venture but comes with a major drawback of pest infestation. The Insect pests cause major damage to the crop production and are the major limiting factor. Even among the main insects pests, Lepidopteran cause significant damage to the crops. Lepidoptera order of insects includes butterfly and moths. Pests such as diamond-back moth (DBM) on cabbage (*Plutella xylostella*), fruit borer on tomato (*Helicoverpa armigera*), pod borer on chilli (*Spodoptera litura*), shoot and fruit borers on brinjal (*Leucinodes orbonalis*) and okra (*Earias fabia*) are among the major lepidopteran pests of vegetables. With the advent of intensive high yielding varities/hybrids, changing cropping patterns, and the shift in pest status along with drastic decline in the climate, habitat and ecosysytem; the vegetable cultivation is facing major challenges. There has been gradual expansion in the horizon of the pests. Chilli gall midge (*Asphondylia capparis*) in parts of Tamil Nadu and Andhra Pradesh, solenopsis mealy bug (*Phenacoccus solenopsis*) in brinjal, tomato, okra and cucurbits; Hadda beetle (*Henosepilachna vigitioctopunctata* and *Epilachna dodecastigma*) on cowpea and bitter gourd; plume moth (Sphenaeches *caffer*) in bottle gourd are some of the examples. As a result the end users have adopted indiscriminate use of synthetic insecticides leading to resistance against pesticides and secondary outbreaks. This paper depicts Lepidopterous pest, biology and its effects on vegetable crops.

Keywords: Lepidopterous pest, biocontrol agents, vegetables, natural enemies

Introduction
With about 4.5 million hectares involved in vegetable cultivation, India second ranks in vegetable production in the world next only to china, producing about 75 million tons each year. In India, there is a significant percentage of vegetarian population; hence vegetable crops hold an important position in the Indian agriculture. Unfortunately, the vegetable cultivation is fraught with challenges including mainly insect pests and several diseases. Therefore, a sizeable share of the produce is vulnerable to damages, due to attributes like tenderness and softness, as compared to other crops and low level of resistance after intensive hybridization. There are losses to the tune of 40 percent in vegetable production due to the insects pests. As a remedy, the Indian farmers largely rely upon chemical pesticides. The indiscriminate use of pesticides is the cause of the elimination of the natural biological enemies and ill effects on the non-target species. It further results in increased residue content in the consumables and increased pest resistance. Recent advances include, Bio-intensive pest management (BIPM) attracting the farmers for higher income in return to their production. In light of the deteriorating ecological balance and awareness of the end users, these concepts are gaining popularity in order to understand a weak link in their life cycle chain, there is requirement of a detailed study on these economically important pests aiding in their effective management. There is vast information available regarding 152 species of lepidopterous pests of vegetable crops of India. They are divided into the categories of defoliators, leaf feeders, pod borers, fruit borers, cut worms, leaf miners and stem borers.

Table 1: Vegetable crop losses due to insect pests in India

Crop/Pest	Yield Loss percentage
Tomato Fruit borer (*Helicoverpa armigera*)	24-73
Brinjal Fruit and shoot borer (*Leucinodes orbonalis*)	11-93
Chillie Thrips (*Scirtothrips dorsalis*) Mites (*Polyphagotarsonemus latus*)	12-90 34
Okra Fruit borer (*H. armigera*)	22
Leafhopper (*Amrasca biguttula biguttula*)	54-66
Whitefly (*Bemisia tabaci*)	54
Shoot and fruit borer (*Earias vittella*)	23-54
Cabbage	
Diamondback moth (*Plutella xylostella*)	17-99
Cabbage caterpillar (*Pieris brassicae*)	69
Cabbage leaf webber (*Crocidolomia binotalis*)	28-51
Cabbage borer (*Hellula undalis*)	30-58
Cucurbits	
Fruit fly (*Bactrocera cucurbitae*)	
Bitter gourd	60-80
Cucumber	20-39
Ivy gourd	63
Musk melon	76-100
Snake gourd	63
Sponge gourd	50

Source: Shivalingaswamy *et al*. (2002) [29]; Dhillon *et al*. (2005) [5]; Satpathy *et al*. (2005) [31]; Raju *et al.* (2007) [24]; Singh *et al*. (2007) [32]; Ghosal *et al*. (2012) [9].

Characteristics of Lepidopterans

Biology

There are four stages of development in lepidopteran insects: egg, larva, pupa and adult. These insects show complete metamorphosis. The larval stage is called as caterpillar which molts several times during its growth period. They have chewing mouthparts, three pairs of true legs on the front body segments and two to five pairs of false legs (prolegs) on the rear segments. At maturation, larvae change to an adult moth or butterfly at a protected site. The females produce sex pheromones for attracting the males for the purpose of mating. Soon after mating, the females produce eggs.

Damage

Larval stage of the lepidoterans is most devastating to the crop. They cause the maximum damage by the chewing mandibles. Leaf damage substantially reduces the photosynthetic ability of the plant and thus the carbohydrate production.it severely affects the plant health and the fruit production. Further, defoliation causes the indirect damage from sunburn. Fruit feeding causes direct injury to the crop. Tolerance to the fruit feeding is much less compared to the foliar damage during vegetable cultivation.

Management

There is requirement of thorough knowledge of the biology of lepidopterans for their effective management. The best approach depends mainly on the understanding of the overwintering habit and the exact time of their infestation. There are few species which are vulnerable to winter sanitation. Based on this knowledge, their overwintering sites can be removed or destroyed. This practice leads to considerable reduction in the population emerging in the spring. Furthermore, the synthetic pheromones can also be used for manipulating the moths' mating communication signals in order to catch them during adult flight. This aids the growers in executing timely sprays for best results. Moreover, with the use of pheromones the male finding ability of the male moths can also be interfered with. Therefore, causing significant decline in their reproduction ability and population. The larval stages are susceptible to the stomach poisons such as cryolite and Bacillus thuringiensis Berliner (*B.t.*). These agents have the advantage of not being disruptive to the natural control organisms and do not cause secondary pest outbreaks. They should be used as the first choices when chemical control is required.

With the growing challenges of climate change, there is a greater need to work towards sustainable agricultural practices. The proponents of sustainable agriculture are creating awareness among the farmers, regulators and the general public. As a result, now there is greater demand for products grown in sustainable manner. But the growers are reluctant to adopt sustainable agriculture. But with the increasing pesticide resistance, we are bound to shift towards practices like biological control. The only limitation with biological control is the high cost and the doubtful efficacy. Biological control comprises three different strategies; importation, Augmentation and conservation. In importation an exotic biological control agent is introduced which will establish itself permanently in that region and control the pests. Augmentation involves the supplemental release of the natural enemy of the pest in the native population. Whereas in conservation the existing natural enemies are conserved through various means.

A brief overview of few lepidopteran pests

Spotted pod borer

Spotted pod borer (*Maruca vitrata*) Geyer (Pyralidae: Lepidoptera) was earlier considered as a minor pest of red gram but now it has become a serious problem in many vegetables like cow pea, field bean, cluster bean and pea. The damage due to this pest up to 42% in cow pea during rabi

season in Andhra Pradesh (Halder and Srinivasan, 2011) [12]. It causes considerable damage to the pods of the plant but also feeds flower, buds and sometime stem of the plants. These pests are highly active mainly in southern, northern and central part of the country during rabi and pre-kharif season. The reason for their widespread distribution is their over lapping generations, short life cycle, wide host range and protective web forming nature of this pest.

Management

Through proper removal of the web and clean cultivation the pest load can be considerably reduced. Conservation of bioagents like *Apanteles sp*. is effective. Need based spraying of azadirachtin @ 0.005% or NSKE 4% or Bacillus thuringiensis var Kurstaki @ 1 kg/ha is recommended (Rai *et al*. 2014) [25, 26]. For seed production, application of DDVP @ 0.75 ml/lit of water at flowering and early pod formation stage gives good control. Recently, Mittal and Ujagir, 2005 reported that Spinosad 90 g ai/ha was found to be effective against pod borer complex of pigeon pea including *M. vitrata*.

Serpentine leaf miner

The American serpentine leaf miner, *Liriomyza trifolii* Burgess (Agromyzidae: Lepidoptera) is a native of Southern United States of America and Central America but has spread to several countries in seventies along with Chrysanthemum flowers trade. It is doubted to have entered Karnataka along with plant materials during 1990-91 and after it spread in many other parts of the country like Andhra Pradesh, Maharastra, Gujarat, Tamil Nadu, Uttar Pradesh, West Bengal, Delhi, Haryana and Madhya Pradesh. It has a broad 78 host range of plants covering pulses, fibre, vegetables, ornamental and flowers, green manuring, fodder crops, narcotics and weeds belonging to 16 families. Amongst vegetables, they are found in tomato, French bean, summer squash, cucumber, cow pea, cluster bean, melons etc. The cause losses to the tune of 41% in cucumber, 15-70% in French bean, and 35% in tomato as reported by Krishna Kumar (1998) [15] from Karnataka.

Management

The higher dose of nitrogen favours the population buildup of this pest. This requires the prudent use of nitrogenous fertilizer in order to reduce the pest build up in endemic areas. Leaves infested with the pests should be removed periodically and destroyed. The yellow sticky traps can also be used in the field for mass trapping of adults and exploiting the natural enemies. A new parasitoid *Neochrysocharis farmosa* (Eulophidae: Hymenoptera) has been recently reported from this pest. In Hawai, Gyaana and Senegal this pest was controlled by inundative release of parasitoids viz., *Hemiptarsenus*, *Chrysocaris* and *Chrysonomyia sp*. (Puri and Mote, 2004). Another study revealed that marigold (*Tagetes erecta*) plant serve as an attractant for this pest and also attracts large number of parasitoid *N. farmosa*. NSKE 4% can also be applied with a sticker found to deter the leaf miner. Spraying of Imidacloprid 17.8SL @ 0.3 ml/l of water during early stages of crop growth before flowering is effective to control severe infestation. Kumar *et al*. 2010 reported that soil application of phorate 10G @1 kg a.i./ha or seed treatment with Imidacloprid 70WS @ 3g/kg seeds or foliar applications of neem seed extract (NSKE) 5% on 10 days after germination gives better result in controlling the serpentine leaf miner. Rai *et al*. (2014) [25, 26] reported that spraying of imidacloprid 17.8 SL @ 0.35 ml/l of water during the early stage of the crops before flowering and application of dichlorovos 76EC @ 0.5 ml/l of water in severe infestation during reproductive phase crop is beneficial.

Plume moth White

Plume moth, *Sphenarches caffer* (Zeller) (Pterophoridae: Lepidoptera), majorly affects lablab, beans etc. It has been recently found to cause extensive damage to the foliage in bottle gourd. It causes damage to the leaves and buds of bottle gourd by scrapping the leaf portion thereby reducing its photosynthetic activity of the plants. They cause severe damage to the emerging buds resulting in stunted Growth. Its incidence was observed in Varanasi during the peak summer months of May June when temperature was around 45 ^{o}C.

Management

Conservation of solitary, larval, endoparasitoid *Apanteles paludicole* Cameron, 1909 (Braconidae: Hymenoptera) (maximum parasitization 40.91%) (Halder *et al*. 2014) [10] and chalcid pupal parasitoid, Tropimeris monodon are beneficial. Bacillus thuringiensis @ 1 kg/ha or malathion @ 2 ml/lit can be applied as per need to control the pest.

Tomato hornworm, *Manduca sexta* (L.), and *Manduca quinquemaculata* (haworth)

There are two large size lepidopterans; having similarity in appearance biology, ecology, and damage the tobacco hornworm (*M. sexta*) and tomato hornworm (*M. quinquemaculata*). Both these pests attack tomato and other plants. Five-spotted hawk moth and Carolina sphinx are the two common names for *M. quinquemaculata*. Goliath worm is the common name for *M. sexta*.

Description and Biology

Owing to its large size and ease of rearing *M. sexta* is often used as a teaching and research model for many aspects of biology. Female lays upto 1400 eggs on the foliage of host plants. Hatching occurs in 6-7 days/. The eggs hatch in 6–7 days and the larval stage lasts 20–30 days depending on temperature. The larval stage has eight "V-shaped" whitish patterns along their sides while larvae of *M. sexta* have seven whitish lines along their sides. The larvae of both these species have a horn like structure placed dorsally from the terminal abdominal segment.

Distribution, Host Range, and Seasonal Occurrence

The species *M. sexta* and *M. quinquemaculata* are distributed throughout Northern, Central and South America. These species feed only on the solanaceous species. Tobacco and tomato are their common hosts. Others hosts include eggplant and potato. These two species overwinter as pupae and undergo one–four generations per year depending on the temperature.

Damage

These last two larval instars of these two species cause extensive leaf damage in very short time. Most defoliation happens during feeding by the last two larval instars.

Management

The populations of *M. sexta* and *M. quinquemaculata* can be controlled by applying various strategies;-

Trapping
By using the mixture of various pheromones like hexadecanal, (E, Z)-10, 12-hexadecadienal, (E, E)-10,12-hexadecadienal, (E,E,Z)-10,12,14-hexadecatrienal the males can be trapped by attracting them.

Cultural Control
With the use of vermicomposts, the infestation of *M. quinquemaculata* gets reduced. This is caused due to increased level of phenolic compounds in the plants and balanced release of fertilizers.

Host-Plant Resistance
The tomato plants with genes for a protein from *Bacillus thuringiensis* var kurstaki (HD-1) suffer very little damages due to *M. sexta***.**

Biological Control
The larvae of various species such as *Jalysus spinosus*, s *Polistes fuscatus*, and a braconid *Apanteles congregates* can be used as parasitiods.

Chemical Control
Application of environmentally friendly insecticides such as spinosids and *B. thuringiensis* can help in controlling the pests.

Economics of pest control
There are approximately 35% losses accruing due to insect pests, weeds, and diseases. For preventing losses due to pests there is rampant application of insecticides. All this adds up to the cost of production. The costs are approximately 1–5% of the total cost of vegetable production. Therefore, we require to adopt a balanced integrated approach can be more sustainable and lead to higher revenues. It not only reduces costs and increase profits, but also slows the development of resistance.

Conclusion
The vegetable crops have suffered serious damages due to the lepidopteran pest complex worldwide. There is a need of an integrated approach in wake of the arising concern for the interest of human safety, environmental protection, and sustainability and incidence of increased resistance. Such approaches result into high yields and increase the profit. For sustainable vegetable cultivation, growers should include multiple strategies that work effectively together and can be applied over wide geographic areas. The new approach should address concerns of the resistance, biological controls and wise use of insecticides.

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