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A Comprehensive Review of *Helicoverpa armigera*: Current status, Ecology and Management Approaches

Geeta Devi*[*], Lomash Kumar, Pooja Kumari, Pankaj Kumar and Kaushik Kumar Das
Department of Entomology, CCS Haryana Agricultural University, Hisar (Haryana), India.

(Corresponding author: Geeta Devi[*])
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ABSTRACT: *Helicoverpa armigera* is a major pest affecting both agricultural and horticultural crops across the globe. With a host range of over 100 cultivated and wild plants, its status as a significant pest is largely attributed to its polyphagous nature, high mobility, diapause capability and high fertility rate. The larvae can enter diapause to survive unfavourable climatic conditions, further complicating management efforts. *H. armigera* is widespread across majority of Asia, southern Europe, Oceania, Africa and South America. Management of *H. armigera* traditionally involves the use of synthetic insecticides, microbial insecticides, biocontrol agents (including both parasitoids and predators) and genetically modified crops like *Bt* cotton. However, the extensive use of chemical insecticides has led to the development of resistance in *H. armigera* populations, reducing the effectiveness of many conventional pesticides. Increasing resistance against existing pesticides directs the urgent need for utilizing integrated pest management (IPM) strategies, which are less dependent on traditional pesticides and manage the populations of pest below the economic threshold level (ETL). This review aims to highlight the significance of continued research and the adoption of modern approaches to effectively manage *H. armigera* populations and reduce crop losses.

Keywords: American bollworm, Polyphagous, Biology, IPM, Pesticides.

INTRODUCTION

In crop cultivation, yield can be significantly reduced by various factors, with arthropod pests being a major threat. Insects that damage ovary tend to be more destructive than those that target leaves, stems, or roots (Mapuranga *et al*., 2015). A range of plant families, including Asteraceae, Fabaceae, Malvaceae, Poaceae, and Solanaceae, suffer yield and quality losses due to various lepidopteran pests (Murúa *et al*., 2014). Among these pests, Helicoverpa armigera (Lepidoptera: Noctuidae) stands out as highly polyphagous, multivoltine, and cosmopolitan pest, widely regarded as one of the most damaging pests to field crops globally (Stark & Banks, 2003; Sharma *et al*., 2011; Saraf *et al*., 2015). This pest impacts approximately 300 plant species, affecting economically significant crops such as tobacco (*Nicotiana tabacum*), cotton (*Gossypium hirsutum* L.), maize (*Zea mays* L.), soybean (*Glycine max* L.), sorghum (*Sorghum bicolor* L.), pearl millet (*Pennisetum glaucum*), canola, tomato (*Solanum lycopersicum* L.), okra (*Abelmoschus esculentus*),sunflower (*Helianthus annuus* L.), pigeon pea (*Cajanus cajan*), chickpea (*Cicer arietinum* L.), and groundnut (*Arachis hypogaea*), and is anticipated to become a formidable pest in certain fruit crops (Sarate *et al*., 2012; Vinutha *et al*., 2013; Murúa *et al*., 2014; Safuraie-parizi *et al*., 2014; Saraf *et al*., 2015).

The life cycle of *Helicoverpa armigera* is influenced by various biotic and abiotic factors such as temperature, host availability, and environmental conditions etc. This resilience is due to its traits such as being polyphagous, highly adaptable nature, having a strong reproductive potential, and the ability to enter facultative diapause. (Yadav *et al*., 2022). The insect's capability to utilize a wide range of host plants is essential for its continued survival in ecosystems. Underoptimal conditions, it completes several generations within a single year. The larvae are voracious feeders and can cause significant damage to crops by consuming leaves, flowers, and fruit. *Helicoverpa* shows color variation in green to brown shades. Generally, the 3rd instar larvae show cannibalism. The insect has a unique feeding behaviour in which it inserts its head within the plant portion while keeping the remaining parts outside. This behaviour is mostly for respiratory requirements. Due to the extensive use of chemicals, *H. armigera* has developed resistance to many insecticides, including newer compounds such as fipronil, chlorfenapyr and indoxacarb (Ahmad *et al*., 2003; Wu 2007). Consequently, growers need to adopt new compounds with novel modes of action (MoA) (Ahmad *et al*., 2019) and implement rotational chemical use to effectively manage this pest (Razaq *et al*., 2007; Su *et al*., 2012). Integrated Pest Management (IPM) approaches, involving the use of biological controls, pheromone traps, and timely insecticide treatments, are widely implemented to regulate *H. armigera* populations and safeguard crops. However, it is old world bollworm but it is still continuing to damage different crops and difficult to manage in some cropping pattern. So, the current review is to unravelling the current status and management strategies of *H. armigera.*

HOST RANGE AND DISTRIBUTION

Currently, *H. armigera* is widely distributed throughout the world, regarded as the primary agricultural pest in the Africa, Asia, Middle East, Southern Europe (Greece, Spain, Portugal, and Turkey), New Zealand, Australia and the Pacific Islands (Karim, 2000). According to Tay *et al*. (2017), *H. armigera* is native to the old-world including Africa, Asia, Europe and Australasia (Hardwick, 1965) identifying its original range between the latitudes of 40°N and 40°S (Fig. 1) (Yücel & Hanife 2018). The species is currently present in approximately 128 nations and other dependent territories. However, it is not yet well-established in some regions like Northern America (Gonçalves *et al.*, 2019) but, there is a strong likelihood of establishment of this pest (Kriticos *et al*., 2015).

One of the most polyphagous insect pest species, *H. armigera* infests over 200 host plant species across various families (Pratissoli *et al.*, 2015). It affects a broad range of economically important crops, including cotton, maize, sunflower, pigeonpea, chickpea, soybean, sorghum, as well as fruits and vegetables (Cunningham *et al.*, 1999; Khanam *et al.*, 2003; Rahman *et al.*, 2016). Since host plants differ in their nutritional content, *H. armigera* exhibits strong preference for certain host plants. The choice of the host species also affects the survival & growth of the larvae, which affects the population density of the species (Yongming & Kunjun 2001). Likewise, Sarate *et al*. (2012) observed that larvae reared on maize and pigeon pea experienced faster growth and bigger larval and pupal masses than those raised on vegetables and flowers. However, the leaves of tomato, okra, chickpea, and pigeonpea are considered to be favorable hosts for the oviposition of *H. armigera.*

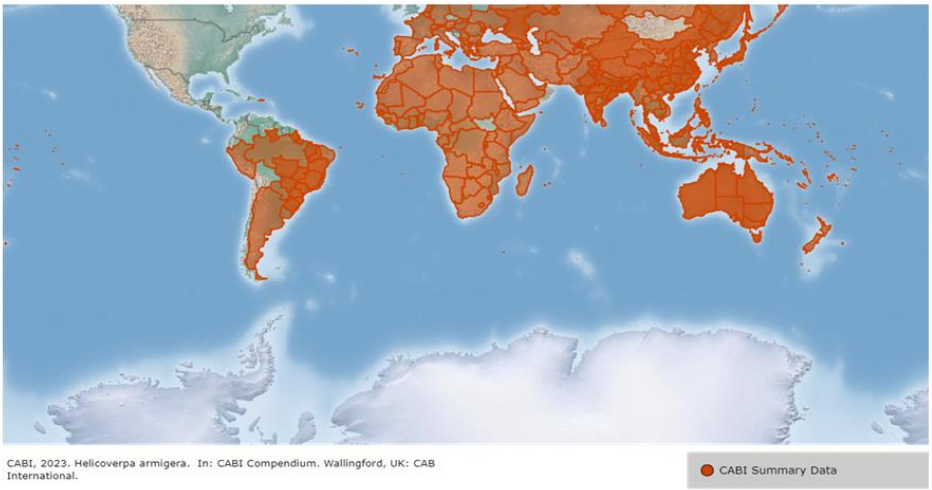

Fig. 1. Worldwide distribution of *Helicoverpa armigera*.

BIOLOGY

Helicoverpa armigera is a holometabolous insect with a complete life cycle of egg, larval, pupal and adult stages (Fig. 2). The mature *H. armigera* moth has a dull black border on its hindwing and a "V"-shaped spot on its forewing. It is brown in colour. The insect lays one egg per host plant and it takes 4-7 days for the egg to hatch. When the larva reaches maturity, it is about 2 inches long, greenish with brown-gray lines and has dark and pale stripes on its dorsal side. The six larval instars occur throughout the 14-day larval stage. Then, pupates in the soil. The ideal temperature for growth and reproduction has been reported to be around 25°C (Mironidis & Savopoulou- Soultani 2014). In most cases, it complete its life cycle in 4–6 weeks during the summer and 8–12 weeks in autumn season (Ali *et al.*, 2009).

A. Eggs

Female moths of *H. armigera* lay their eggs singly or in small clusters on leaves, flowers or fruit. The eggs are spherical and initially pale white, but they gradually turn yellowish or reddish-brown just before hatching. The incubation period is about 3-7 days. At higher temperatures (on average 25ºC), fertile eggs will hatch in about 3 days. In cooler conditions, hatching typically takes between 6-10 days. As eggs develop, they undergo several stages, changing colour from white to brown and eventually to a stage with a black head before hatching. Not every egg is fertile. Physical factors have a significant impact on larval establishment and egg survival. Regarding the ovipositional preference of *H. armigera*, it has been reported that females lay significantly more number of eggs on pigeonpea in comparison to mungbean, cotton and common sow thistle (Rajapakse and Walter 2007). According to Jallow & Matsumura (2001), *H. armigera* preferentially oviposits on the leaves of okra, tomato and maize. Additionally, chickpea is also thought to be excellent host for oviposition (Razmjou *et al.*, 2014). In some regions, pigeonpea has been used as a trap crop since the 1990s because it serves as a well-known host for oviposition in *H. armigera* (Baker *et al.*, 2008; Baker & Tann 2014).

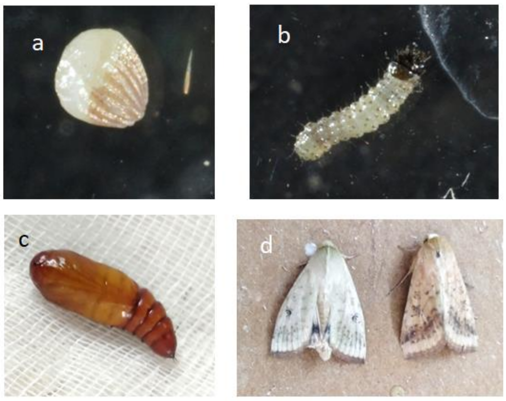

Fig. 2. Lifecycle of *Helicoverpa armigera* a. egg, b. larvae, c. pupae, d. adult male (left) and female (right).

B. Larvae (Caterpillars)

After hatching, the larvae emerge and start feeding on plant tissues. They undergo several instars (six stages) during their larval development and number of instars varies based on environmental conditions. This stage typically lasts for 14-30 days. The larvae have a cylindrical body with a brownish or greenish coloration, and they possess a characteristic pattern of stripes and spots. Neonate larvae chew through the eggshell to create an opening for their emergence. Newly hatched larvae have brown to black coloured head with white to yellowish-white body possess 1-1.5 mm long dark spots. Initially, the larvae feed on tender and immature leaves before moving to buds, flowers, young pods, bolls and fruits.

A larva is fully grown through six developmental stages (instars) in 2-3 weeks during summer and 4-6 weeks during spring or fall. When temperature go below 12ºC, larval activity and feeding cease. Third instar larvae, which are small to medium-sized (8–13 mm long) are responsible for 90% of the damage. The fifth and sixth instar are the most damaging stages, capable of consuming up to 80% of their total diet. Sixth instar larvae can grow up to 40 mm in length and exhibit a wide range of colors and patterns (Ali *et al.*, 2009; Queiroz- Santos *et al*., 2018; Herald & Tayde 2018).

C. Pupae

In the pre-pupal stage, larvae stop feeding and grow lethargic, wrinkled with movement (Ali *et al.*, 2009). Individuals are typically between 22-29 mm long and 4-5 mm wide (Ali *et al.*, 2009). Usually, the shade ranges from slightly green to yellowish, eventually becoming dark brown. Typically, the pre-pupal period lasts 1-3 days. Once the larval stage is complete, the caterpillar pupates to become an adult moth. The pupal stage occurs either in the soil or within a cocoon spun by the larva. The pupa is typically brown with a hardened outer shell that safeguards the developing moth. This pupal period lasts approximately 10 to 14 days (Ali *et al.*, 2009; Nasreen and Mustafa 2000).

D. Adults (Moths)

After completing the pupal stage, an adult moth emerges. These medium-sized moths have a wingspan of approximately 3-4 cm and exhibit light brown or grayish-brown coloration with distinctive light and dark patches on their wings. Females have dull green to yellow or light brown forewings, while males display brownish or reddish-brown forewings. The hindwings are pale coloured with a broad black outer border and a prominent pale patch near the central black area of the border. Adult moths are primarily nocturnal and are attracted to lights. They have a lifespan of 1 to 2 weeks and feed on nectar. Females lay thousands of eggs singly on leaves, flower buds, developing fruits, and occasionally on stems and growing points throughout their lifecycle, often preferring the upper third of healthy plants and actively growing terminals (Zahid *et al.*, 2008; Ali *et al.*, 2009).

NATURE AND EXTENT OF DAMAGE

Starting from the second to third instar, larvae is the most destructive life stage, primarily feeding on the reproductive structures of plants. Although the first and second instars cause some damage by feeding on the leaf surface, the extent of this damage is generally minor. Polyphagy, facultative diapause, high fecundity and mobility are the four key characteristics of *H. armigera* (Fitt, 1989; Rahman *et al*., 2016). Its direct attack on plant reproductive organs, multivoltine nature, nocturnal habit and overlapping generations are further significant causes of their high infestations (Sarode, 1999). According to Sarode (1999), infestations of *H. armigera* in chickpea crops can lead to yield losses of up to 29% when no management practices are implemented. Similar losses have been documented in Pakistan for the tolerant and susceptible genotypes of chickpea (Sarwar *et al*., 2009, 2011). According to SreeLatha and Sharma (2018), the desi genotype of chickpea is observed to be more resistant to attack than the kabuli genotype. Different parameters like temperature and sowing time have a significant impact on the extent of larval damage by this pest (Akhtar *et al.*, 2014). Thakur *et al.* (2017) reported that in the absence of control strategies, infestation rates of the fruit ranged from 16% to 45% in tomatoes cultivated in Himachal Pradesh, India. Selvanarayanan (2000) observed similar yield losses of up to 55% in tomatoes, with infestations often rendering the fruit unfit for human consumption (Lal *et al*., 1999). According to Tripathy and Sharma (1985), the extent of plant damage varies depending on larval density and developmental stage. However, infestations commonly impact plant size, stem diameter, fruit morphology and overall fruit yield.

ETL AND EIL FOR *H. ARMIGERA* ON DIFFERENT HOST CROPS

The Economic Injury Level (EIL) and Economic Threshold Level (ETL) for *H. armigera* on various crops have been estimated by several researchers (Table 1). However, these thresholds, particularly the EIL, are dynamic and can vary from year to year or even from field to field within a single year. Factors influencing these variations include crop variety, market conditions, plant development stages, available management options, crop value, and management costs.

Table 1: EIL and ETL for *H. armigera* on various crops.

Crop	ETL	EIL	References
Chickpea	0.81 larva/m row	1.1 larva/m row	Zahid *et al*. (2008)
Cotton	—	19.86 larvae/100 plants	Alavi and Gholizadeh (2010)
Tomato	1.0 larva/plant	—	Cameron *et al*. (2001)
Pigeon pea	—	0.78-0.80 larvae/plant	Reddy *et al*. (2001)
Mung bean	1-3 larvae/m^2	—	Brier *et al.* (2010)
Soybean	—	8 larvae/m^2	Rogers and Brier (2010)
Peanuts	4 larvae / m^2	—	Brier *et al.* (2010)

MANAGEMENT

A. Cultural Practices

• To keep *H. armigera* populations below the economic threshold level, certain cultural practices are implemented within the crop or cropping system. Fitt and Forrester (1987) highlighted the importance of ploughing cotton stubble to reduce populations of pyrethroid-resistant *H. armigera.*

• Clean cultivation in fields and removal of alternate weed host like *Legasca, Datura ferox, Lantana camera, Nicandra physaloides* grown on the bunds is beneficial in reducing pest populations (Mapuranga *et al*., 2015; Genç & Yücel 2017).

• Deep ploughing during the summer months is an effective method to kill immature stages of *H. armigera* by exposing the resting pupae to predatory birds and the intense heat of the sun (Mapuranga *et al*., 2015).

• It is important to follow the recommended fertilizer dosages and practice judicious water management to prevent excessive vegetative growth, which can create harbourage for larvae (Patil *et al*., 2017; Mahmood, 2021).

• Use of trap crops like Bhendi (cotton: bhendi, 25:1), Red gram and marigold are also used to trap & kill the eggs and young larvae of boll worms in early stage (Vinutha *et al*., 2013; Mapuranga *et al*., 2015; Genç & Yücel 2017).

• Crop should be sown at same time or in synchrony with short duration varieties in similar ecosystem. Avoid continuous cultivation of the same host crops during both rabi and kharif seasons in the same area, as well as ratooning, to reduce the risk of *H. armigera* infestations(Mapuranga *et al*., 2015; Patil *et al.*, 2017; Mahmood, 2021).

• Avoid mono-cropping and alternate host crops. Removal and destruction of old crop residues is also recommended to avoid carryover of the egg masses to the next season (Mapuranga *et al*., 2015).

B. Mechanical management

• Eggs and larvae can be handpicked and destroyed during early stage of infestation when they feed gregariously.

• Installation of bird perches @ 50/hectare & setting of light traps (1 light/5 acre) for reduction of adult moth population.

• Pheromone traps @ 5 traps/ ha can be installed for monitoring of adult moths and 15 traps/ ha for management of pest (Vinutha *et al*., 2013).

C. Biological control

Natural enemies rarely eliminate all eggs or larvae but can sometimes reduce infestations to below economic threshold levels. *H. armigera* is targeted by various parasitic and predatory insects, spiders, birds, bats, rodents, and diseases.

i) Predator: Many predators are opportunistic feeders, consuming *Helicoverpa armigera* when encountered, while some are regularly found in farms. Additionally, certain predators target specific life stages, such as eggs or larvae of particular sizes. The most common predators in field crops include predatory beetles (*Exochomus flavipes*, *Cheilomeneslinata*, *C. deisha*, *Hippodamia variegate*), bugs (*Phonoctonus* spp., *Aphidius* spp., *Encarsia sub lutea*, *Eretrocerus* spp), lacewings, spiders (*Cheirancanthium lawrencei*, *Prucetiakunensis*) and ants (Mapuranga *et al*., 2015).

ii) Parasitoids: Eggs, larvae, and pupae of *Helicoverpa armigera* are targeted by various wasps and flies. To complete their development, these parasitoids must kill their hosts. Notable parasitoids include wasp species like *Telenomus*, *Trichogramma* and *Microplitis*, as well as larger wasps such as *Netelia*, *Heteropelma*, and *Ichneumon*, along with flies like *Carcelia* and *Chaetopthalmus*. These parasitoids are particularly active in field crops against *Helicoverpa* (Pratissoli *et al.*, 2015; Saraf *et al.*, 2015).

iii) Pathogen: Insect-infecting pathogens include bacteria, fungi, and viruses, which can naturally infect and kill *Helicoverpa armigera*. The most common pathogens affecting larvae are fungi such as *Metarhizium*, *Nomurea*, and *Beauvaria*, as well as nucleopolyhedrovirus (NPV) (Haile *et al.*, 2021; Toffa *et al.*, 2021; Souza *et al.*, 2020). Additionally, ascovirus, spread by wasp parasitoids, inhibits larval growth. Two commercially available pathogens for controlling *Helicoverpa* larvae are NPV and bacterium *Bacillus thuringiensis* (Bt). NPV is safe for use around people, animals, and beneficial insects, while Bt, which exclusively targets moth larvae, is widely available. Moreover, cotton plants have been genetically modified to produce the Bt toxin in their tissues (Patil *et al.*, 2017; Mantzoukas, 2019).

D. Host Plant Resistance

Using resistant crop cultivars is one of the most effective and reliable methods for managing *H. armigera*. These cultivars are often a key component of integrated pest management (IPM) strategies, significantly reducing crop losses (Rahoo *et al.*, 2017; Shahzaman *et al.*, 2015; Thia *et al.*, 2021). The primary aim of this approach is to minimize the use of broad-spectrum synthetic pesticides, which helps mitigate the negative environmental impacts of pesticide use, lowers production costs, and protects natural enemies of *H. armigera*, such as ichneumonid and braconid wasps (Kambrekar, 2016; Kassi *et al*., 2018).

E. Biotechnological control

(i) RNA interference (RNAi) technology: The *H. armigera*, is well known for its resistance to various common insect poisons. Thus, a biotechnological approach, such as RNA interference (RNAi) mediated by dsRNA is started. It involves the silencing of specific deadly genes. The dsRNA is delivered either by ingestion, infusion or by ingesting specially engineered microbial forms expressing dsRNA (Jing & Zhao-jun 2014).

Another biotechnological strategy for pest control is nanotechnology. This involves pest management using formulations of pesticides, insecticides, bio-forms, anti-agents and pheromone based on nanoparticles. This improves the survivability and efficacy of these substances. In order to protect host plants from lepidopteran pests, it is also utilized to deliver DNA and other desirable synthetic materials into plant tissues (Vinutha *et al*., 2013).

(ii) Sterile insect technology: This technique is crucial for reducing pest populations in the field. It involves releasing radiation-sterilized male insects to limit population growth. Mating with these sterile males produces abnormal progeny, effectively controlling the pest population. This sterility method is advantageous as it does not interfere with other pest control strategies (Yadav *et al.,* 2022; Yadav *et al.,* 2022).

F. Botanicals

Azadirachtin: Applied at a concentration of 0.03% or in quantities ranging from 2.50 to 5 kg, azadirachtin functions both as an antifeedant, which reduces feeding activity and as a growth regulator, which impedes the development of *H. armigera* larvae (Mehta *et al.,* 2010; Vinutha *et al.,* 2013; Salman Ahmad *et al*., 2015).

Neem and Garlic Extracts: These botanicals exhibit multiple effects against *H. armigera*. Neem extracts can be utilized for their larvicidal and ovicidal properties for effective killing of larvae and eggs. They also act as toxic repellents, deterring the pests from feeding and have anti-ovipositional effects, reducing the likelihood of egg laying. Garlic extracts similarly contribute to pest management through their repellent and toxic properties, impacting both feeding behaviour and reproduction (Prakash & Srivastava 2008; Mehta *et al.,* 2010; Vinutha *et al.,* 2013).

G. Chemical control

Insecticides are continuing to be a crucial aspect of pest management, especially in short- and medium-term scenarios, allowing farmers to cultivate crops of sufficient quality at affordable prices (Bueno *et al.,* 2017). In comparison to biopesticides, synthetic pesticides are often more effective at controlling *H. armigera* (Rizvi & Jaffar 2015). Ambule *et al*. (2015) reported successful control of *H. armigera* on tomato crop in India after the introduction of novel insecticides like flubendiamide and chlorantraniliprole. Spinosad, a mixture of various substances derived from the bacteria *Saccharopolyspora spinosa* (Mertz & Yao), is also very efficient in controlling this pest (Ambule *et al.,* 2015; Hakeem *et al.,* 2017). High pesticide doses can completely eradicate the target pest, although sublethal effects can also reduce the pest species' fitness and reproductive rates without actually killing them. According to Carneiro *et al.* (2016), sublethal pesticide doses in *H. armigera* produce physiological abnormalities and have a negative impact on the fertility, development and longevity of the pupal stage, pupal weight and the oviposition phase. Novaluron, indoxacarb, chlorantraniliprole, cyantraniliprole, imidacloprid, diazinon and flubendiamide, as well as the bacterium-derived substances spinosad and emamectin, are a few examples of synthetic chemical insecticides that have been successfully utilised against *H. armigera* in different crops (Table 2).

Table 2: List of Insecticides and Biopesticides approved by CIB & RC against *Helicoverpa armigera* in different crops.

Insecticides	Dosage per ha in required water	Waiting period (in days)	Crop
Acephate 95 % SG	790 g in 500 L	07	Chilli
Broflanilide 300 g/l SC	42-62 g in 500 L	1	Chilli, Soyabean, Redgram
Broflanilide 300 g/l SC	62-84g in 500L	1	Tomato
Broflanilide 20% SC	125 g in 500L	1	Chilli, Okra
Chlorantraniliprole 18.50 % SC	150g in 500 L	9, 3,3,5	Cotton, Tomato, Chilli, Okra
Chlorantraniliprole 35 % WG	71 g in 500 L	5	Okra
Chlorantraniliprole 35 % WG	86 g in 500 L	3	Tomato
Cyantraniliprole 10.26 % OD	600 g in 500 L	3	Chilli
Cyantraniliprole 10.26 % OD	900 g in 500 L	3	Tomato
Cypermethrin 10 % EC	550-760 g in 1000 L	7	Cotton
Emamectin benzoate 05 % SG	220 g in 500 L	14	Red gram/ Chick pea
Fenpropathrin 10 % EC	750g in 1000 L	14	Cotton
Fenvalerate 20 % EC	300-375 g in 750 L	7	Cauliflower
Fipronil 18.87 % w/w SC	250 g in 500 L	5	Chilli
Flubendiamide 20 % WG	250 g in 500 L	30,5,5,15	Cotton, Tomato, Chilli, Bengal gram
Indoxacarb 14.50 % SC	400-500 g in 600L	5	Chilli, Tomato

Lambda-cyhalothrin 05 % EC	300 g in 600 L	4-6	Tomato, Chilli, Chickpea
Novaluron 10 % EC	1kg in 1000 L	40	Cotton
Novaluron 10 % EC	750g in 1000L	3	Tomato, Chilli
Spinosad 45 % SC	150-200g in 500L	10,3	Cotton, Chilli
Cypermethrin 3 % + Quinalphos 20 % EC	1kg in 600 L	15	Cotton
Emamectin Benzoate 01.50 % + Fipronil 03.50 % SC	500 g in 500L	3	Chilli
Novaluron 05.25 % + Indoxacarb 04.50 % SC	825-875 g in 500 L	5-14	Tomato, Chick pea, Soyabean, Chilli
Pyriproxyfen 05 % + Fenpropathrin 15 % EC	500 g in 750 L	7-14	Cotton, Okra, Chilli
Chlorantraniliprole 09.30 % + Lambda-cyhalothrin 04.60 % ZC	200-250 g in 500 L	18-20	Cotton, Pigeon pea
Azadirachtin 00.30% EC	4000 g in 1000 L	5	Cotton
Azadirachtin 01.00% EC	1000 g in 500 L	3	Tomato
Beauveria bassiana 1.0% WP	3.0 kg in 500 L	-	Chick pea
Nuclear Polyhedrosis Virus of *Helicoverpa armigera*	1500-3000 LE in 600 L	-	Cotton, Tomato

CONCLUSION AND FUTURE SCOPE

Helicoverpa armigera, a globally significant insect pest, is currently responsible for agricultural crop losses amounting to billions of dollars annually. Despite past successes with synthetic pesticides and genetically modified crops, such as *Bt* cotton, the development of resistance to these control measures has reintroduced significant challenges to the agricultural sector worldwide. To manage *H. armigera* effectively in the future, a comprehensive Integrated Pest Management (IPM) strategy is essential. This approach should integrate biological, chemical, and physical control techniques to address the pest's complex behavior and resistance issues. In developing countries, such as India, where *H. armigera* poses a severe threat to agriculture, there is a critical need for further research. This research should focus on developing and optimizing IPM strategies tailored to local conditions, improving pest monitoring and forecasting and exploring alternative control methods. By advancing these areas, we can enhance the efficacy of pest management efforts and reduce the economic impact of *H. armigera* on global agriculture.

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Conflict of Interest. None.

REFERENCES

Ahmad, M., Arif, M. I. and Ahmad, Z. (2003). Susceptibility of *Helicoverpa armigera* (Lepidoptera, Noctuidae) to new chemistries in Pakistan. *Crop Protection*, *22*(3), 539-544.

Ahmad, M., Rasool, B., Ahmad, M. and Russell, D. A. (2019). Resistance and synergism of novel insecticides in field populations of cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Pakistan. *Journal of Economic Entomology*, *112*(2), 859-871.

Ahmad, S., Ansari, M. S. and Muslim, M. (2015). Toxic effects of neem-based insecticides on the fitness of *Helicoverpa armigera* (Hübner). *Crop Protection*, *68*, 72-78.

Akhtar, M. F., Ijaz, A., Imran, N., Qaisar, A., Ali, R., Yousaf, M. J., Riaz, A. and Tariq, N. (2014). Impact of different dates of sowing on gram pod borer (*Helicoverpa armigera*) infestation in chickpea crop. *World Journal of Zoology*, *9*, 270–275.

Alavi, J. and Gholizadeh, M. (2010). Estimation of economic injury level (EIL) of cotton bollworm *Helicoverpa armigera* Hb.(Lep., Noctuidae) on cotton. *IAU Entomological Research Journal*, *2*(3), 203-212.

Ali, A., Choudhury, R. A., Ahmad, Z., Rahman, F., Khan, F. and Ahmad, S. (2009). Some biological characteristics of *Helicoverpa armigera* on chickpea. *Tunisian Journal of Plant Protection*, *4*, 99–106.

Ambule, A. T., Radadia, G. G., Patil, D. L. and Toke, N. R. (2015). Morphological characters of tomato in relation to resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner). *International Journal of Plant Protection*, *8*, 152–156.

Ambule, A. T., Radadia, G. G., Shinde, C. U. and Patil, D. L. (2015). Relative efficacy of newer insecticides against *Helicoverpa armigera* (Hubner) in tomato under South Gujarat condition. *International Journal of Plant Protection*, *8*, 250–255.

Baker, G. H. and Tann, C. R. (2014). Refuge crop performance as part of the Bt resistance management strategy for *Helicoverpa* spp. (Lepidoptera: Noctuidae) in Australian cotton production systems. *Austral Entomology*, *53*(2), 240-247.

Baker, G. H., Tann, C. R. and Fitt, G. P. (2008). Production of *Helicoverpa* spp. (Lepidoptera, Noctuidae) from different refuge crops to accompany transgenic cotton plantings in eastern Australia. *Australian Journal of Agricultural Research*, *59*(8), 723-732.

Brier, H., Quade, A. and Wessels, J. (2010). Economic thresholds for *Helicoverpa* and other pests in summer pulses-challenging our perceptions of pest damage. In *Proceedings of the 1st Australian summer grains conference*, 21-24.

Bueno, A. F., Carvalho, G. A., Santos, A. C., Sosa-Gómez, D. R. and Silva, D. M. (2017). Seletividade de agrotóxicosnosinimigosnaturais: Desafios e restrições para a pesquisa e recomendações de campo. *Ciência Rural*, *47*

CABI international: https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.26757

Cameron, P. J., Walker, G. P., Herman, T. J. B. and Wallace, A. R. (2001). Development of economic thresholds and monitoring systems for *Helicoverpa armigera* (Lepidoptera: Noctuidae) in tomatoes. *Journal of economic entomology*, *94*(5), 1104-1112.

Carneiro, E., Silva, L. B., Silva, A. F., Santos, V. B., Almeida, M. L. S., Carvalho, G. S. and Veras, M. (2016). Toxicity and sublethal effects of insecticides on *Helicoverpa armigera*Hubner (Lepidoptera: Noctuidae). *African Journal of Agricultural Research*, *11*, 1966–1972.

Cunningham, J. P., Zalucki, M. P. and West, S. A. (1999). Learning in *Helicoverpa armigera* (Lepidoptera: Noctuidae): A new look at the behaviour and control of a polyphagous pest. *Bulletin of Entomological Research*, 89, 201–207.

Deshmukh, S. G., Sureja, B. V., Jethva, D. M. andChatar, V. P. (2010). Estimation of yield losses by pod borer *Helicoverpa armigera* (Hubner) on chickpea. *Legume Research*, 33(1), 67- 69.

Dhandapani, N. U., Shekhar, R. andMurugan, M. (2003). Bio-intensive pest management (BIPM) in major vegetable crops: An Indian perspective. *Journal of Food, Agriculture and Environment*, *1*, 333-339.

Fitt, G. P. (1989). The ecology of Heliothis Species in relation to agroecosystems. *Annual Review of Entomology*, *34*, 17–53.

Fitt, G. P. and Forrester, N. W. (1987). Overwintering of *Heliothis*: the importance of stubble cultivation. *Australian Cottongrower*, *8*, 7-8.

Garcia, F. M. (2006). Analysis of the Spatio–temporal Distribution of *Helicoverpa armigera* Hb. in a Tomato Field using a Stochastic Approach. *Biological systems engineering*, *93*(3), 253-259.

Genç, H. and Yücel, S. (2017). Observation of *Helicoverpa armigera* Hübner (Lepidoptera: Noctuide) Infestation on *Gladiolus grandiflorus* (Iridaceae) in Çanakkale. ÇOMÜ Zir. Fak. Derg., *5*(1), 105–114.

Gonçalves, R. M., Mastrangelo, T., Rodrigues, J. C. V., Paulo, D. F., Omoto, C., Corrêa, A. S. and de Azeredo-Espin, A. M. L. (2019). Invasion origin, rapid population expansion, and the lack of genetic structure of cotton bollworm (*Helicoverpa armigera*) in the Americas. *Ecology and Evolution*, *9*, 7378–7401.

Haile, F., Nowatzki, T. and Storer, N. (2021). Overview of Pest Status, Potential Risk, and Management Considerations of *Helicoverpa armigera* (Lepidoptera: Noctuidae) for U.S. Soybean Production. *Journal of Integrated Pest Management*, *12*(1), 1–10.

Hakeem, S. A., Wani, R. A., Baba, J. A., Allie, B. A., Dar, N. A., Bashir, S., Nissa, S. U., Zaffer, G., Dar, S. A. and Sofi, M. A. (2017). Evaluation of different insecticides against pod borer (*Helicoverpa armigera*) in Lentil. *International Journal of Current Microbiology and Applied Sciences*, *6*, 681–685.

Hardwick, D. F. (1965). The corn earworm complex. *The Memoirs of the Entomological Society of Canada*, *97*(S40), 5-247.

Herald, K. P., andTayde, A. R. (2018). Biology and morphology of tomato fruit borer, *Helicoverpa armigera* (Hubner) under Allahabad conditions. *Journal of Entomology Zoology*, *6*, 1734–1737.

Jallow, M. F. and Matsumura, M. (2001). Influence of temperature on the rate of development of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae). *Applied Entomology and Zoology*, *36*(4), 427-430.

Jing, Y. A. N. G., and Han, Z. J. (2014). Efficiency of different methods for dsRNA delivery in cotton bollworm (*Helicoverpa armigera*). *Journal of Integrative Agriculture*, *13*(1), 115-123.

Kambrekar, D. (2016). Management of legume podborer, *Helicoverpa armigera* with host plant resistance. *Legume Genomics and Genetics*, *7*, 1–19.

Karim, S. (2000). Management of *Helicoverpa armigera*: A review and prospectus for Pakistan. *Pakistan Journal of Biological Sciences*, *3*, 1213–1222.

Kassi, A. K., Javed, H. and Mukhtar, T. (2018). Screening of okra cultivars for resistance against *Helicoverpa armigera*. *Pakistan Journal of Zoology*, *50*, 91–95.

Khanam, U., Hossain, M., Ahmad, N., Uddin, M. and Hussain, M. (2003). Varietal screening of tomato-to-tomato fruit borer, *Helicoverpa armigera* (Hub.) and associated tomato plant characters. *Pakistan Journal of Biological Sciences*, *6*, 413–421.

Kriticos, D. J., Ota, N., Hutchison, W. D., Beddow, J., Walsh, T., Tay, W. T., Borchert, D. M., Paula-Moraes, S. V., Czepak, C. andZalucki, M. P. (2015). The potential distribution of invading *Helicoverpa armigera* in North America: Is it just a matter of time? *PLoS One*, *10*, e0133224.

Lal, S., Singh, S., Srivastava, P. andPhogat, K. (1999). Screeding of tomato hybrids for resistance against fruit borer, *Helicoverpa armigera* in Kumaon Hills. *Indian Journal of Entomology*, *61*, 48–50

Mahmood, M. T. (2021). An Update on Biology, Extent of Damage and Management Strategies of Chickpea pod borer (*Helicoverpa armigera*). *Pakistan Journal of Agricultural Research*, *34*(1), 2021/91-101.

Mantzoukas, S. (2019). The effect of *Metarhizium robertsii* and *Bacillus thuringiensis* against *Helicoverpa armigera*(Hübner) (Lepidoptera : Noctuidae). *Advances in Ecological and Environmental Research*, *4*, 136–146.

Mapuranga, R., Chapepa, B. and Mudada, N. (2015). Strategies for integrated management of cotton bollworm complex in Zimbabwe : A review. *International Journal of Agronomy and Agricultural Research*, *7*(1), 23–35.

McCaffery, A. R. (1998). Resistance to insecticides in heliothine Lepidoptera: a global view. Philosophical Transactions of the Royal Society of London. Series B: *Biological Sciences*, *353*(1376), 1735-1750.

Mehta, K. S., Patyal, S. K., Rana, R. S.and Sharma, K. C. (2010). Ecofriendly techniques for the management of *Helicoverpa armigera* (Hubner) in tomato. *Journal of Biopesticides*, *3*(1), 296–303.

Mironidis, G. K., andSavopoulou- Soultani, M. (2014). Development, sur vivorship, and reproduction of *Helicoverpa armigera* (Lepidoptera: Noctuidae) under constant and alternating temperatures. *Environmental Entomology*, *37*, 16– 28.

Murúa, M. G., Scalora, F. S., Navarro, F. R., Cazado, L. E., Casmuz, A., Villagrán, M. E., & Gastaminza, G. (2014). First record of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Argentina. *Florida Entomologist*, *97*(2), 854-856.

Nasreen, A. and Mustafa, G. (2000). Biology of *Helicoverpa armigera* (Hubner) reared in laboratory on natural diet. *Pakistan Journal of Biological Sciences*, *3*, 1668–1669.

Patil, S. B., Goyal, A., Chitgupekar, S. S. and Kumar, S. (2017). Sustainable management of chickpea pod borer. A review. *Agronomy for Sustainable Development*, *37*(20), 1–17.

Prakash, G. and Srivastava, A. K. (2008). Statistical elicitor optimization studies for the enhancement of azadirachtin production in bioreactor Azadirachta indica cell cultivation. *Biochemical Engineering Journal*, *40*(2), 218-226.

Pratissoli, D., Lima, V. L., Pirovani, V. D. and Lima, W. L. (2015). Occurrence of *Helicoverpa armigera* (Lepidoptera: Noctuidae) on tomato in the Espírito Santo state. *Horticulturabrasileira*, *33*, 101-105.

Queiroz- Santos, L., Casagrande, M. M. and Specht, A. (2018). Morphological characterization of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae: Heliothinae). *Neotropical Entomology*, *47*, 517–542.

Rahman, A. Z., Haque, M., Alam, S., Begum, K. andSarker, D. (2016). Development of integrated pest management approaches against *Helicoverpa armigera* (Hubner) in tomato. *Bangladesh Journal of Agricultural Research*, *41*, 287–296.

Rahoo, A. M., Mukhtar, T., Gowen, S. R., Rahoo, R. K. andAbro, S. I. (2017). Reproductive potential and Host Searching Ability of Entomopathogenic nematode, *Steinernemafeltiae*. *Pakistan Journal of Zoology*, *49*(1), 229–234.

Rajapakse, C. N. K. and Walter, G. H. (2007). Polyphagy and primary host plants: oviposition preference versus larval performance in the lepidopteran pest *Helicoverpa armigera*. *Arthropod-Plant Interactions*, *1*, 17-26.

Razaq, M., Suhail, A., Arif, M. J., Aslam, M. and Sayyed, A. H. (2007). Effect of rotational use of insecticides on pyrethroids resistance in *Helicoverpa armigera* (Lep.: Noctuidae). *Journal of Applied Entomology*, *131*(7), 460-465.

Razmjou, J., Naseri, B. and Hemati, S. A. (2014). Comparative performance of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) on various host plants. *Journal of Pest Science*, *87*, 29-37.

Reddy, C. N., Yeshbir Singh, Y. S., and Singh, V. S. (2001). Economic injury level of gram pod borer (*Helicoverpa armigera*) on pigeonpea, 381-387.

Rizvi, S. A. H. and Jaffar, S. (2015). Efficacy of some selected chemical insecticides and bio-pesticides against tomato fruit worm, (*Helicoverpa armigera*) under the agro climatic condition of Gilgit Baltistan, Pakistan. *Pakistan Journal of Entomology Zoology Studies*, *15*, 4.

Rogers, D. J. and Brier, H. B. (2010). Pest-damage relationships for *Helicoverpa armigera* (Hübner)(Lepidoptera: Noctuidae) on vegetative soybean. *Crop Protection*, *29*(1), 39-46.

Safuraie-Parizi, S., Fathipour, Y., and Talebi, A. A. (2014). Evaluation of tomato cultivars to *Helicoverpa armigera* using two-sex life table parameters in laboratory. *Journal of Asia-Pacific Entomology*, *17*(4), 837-844.

Saraf, N., Makhija, S. K. and Kachole, M. (2015). Developmental stages in the life cycle of *Helicoverpa armigera* (hubner) under laboratory conditions. *Journal of Quality Assurance and Pharma Analysis*, *1*(1), 142-145.

Sarate, P. J., Tamhane, V. A., Kotkar, H. M., Ratnakaran, N., Susan, N., Gupta, V. S., and Giri, A. P. (2012). Developmental and digestive flexibilities in the midgut of a polyphagous pest, the cotton bollworm, *Helicoverpa armigera*. *Journal of Insect Science*, *12*(1), 42.

Sarode, S. (1999). Sustainable management of *Helicoverpa armigera* (Hubner). *Pestology*, *13*, 279–284.

Sarwar, M., Ahmad, N. and Tofique, M. (2011). Identification of susceptible and tolerant gram (*Cicer arietinum* L.) genotypes against gram pod borer (*Helicoverpa armigera*) (Hubner). *Pakistan Journal of Botany*, *43*, 1265–1270.

Sarwar, M., Ahmad, N. and Toufiq, M. (2009). Host plant resistance relationships in chickpea (*Cicer arietinum* L.) against gram pod borer (*Helicoverpa armigera* Hubner). *Pakistan Journal of Botany*, *41*, 3047–3052.

Selvanarayanan, V. (2000). Host plant resistance in tomato against fruit borer, *H. armigera* (Hub.). Annamalai University.

Shahzaman, S., Inam-ul-Haq, M., Mukhtar, T. and Naeem, M. (2015). Isolation, identification of antagonistic rhizobacterial strains obtained from chickpea (*Cicer arietinum* L.) field and their in-vitro evaluation against fungal root pathogens. *Pakistan Journal of Botany*, *47*, 1553–1558

Sharma, H. (2005). Heliothis/Helicoverpa management: Emerging trends and prospects for future research. Oxford& IBH Publishing Co.

Sharma, K. C., Bhardwaj, S. C., & Gaurav Sharma, G. S. (2011). Systematic studies, life history and infestation by *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) on tomato in semi-arid region of Rajasthan. *Biological Forum — An International Journal*, *3*(1), 52–56

Souza, T. D., Fernandes, F. O., Sanches, A. C. & Polanczyk, R. A. (2020). Sublethal effects of different fungal isolates on *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Egyptian Journal of Biological Pest Control*, *30*, 1-12.

SreeLatha, E. and Sharma, H. (2018). Antixenosis mechanism of resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn.). *International Journal of Current Microbiology and Applied Sciences*, *7*, 1233–1238.

Stark, J. D., & Banks, J. E. (2003). Population-level effects of pesticides and other toxicants on arthropods. *Annual review of entomology*, *48*(1), 505-519.

Su, H. H., Song, B., Li, L., Lu, Y. W. and Yang, Y. Z. (2012). Resistance of Spodoptera exigua to insecticides and mechanisms of resistance. *Chinese Journal of Applied Entomology*, *49*, 1659–1663.

Tay, W. T., Walsh, T. K., Downes, S., Anderson, C., Jermiin, L. S., Wong, T. K. F., Piper, M. C., Chang, E. S., Macedo, I. B., Czepak, C., Behere, G. T., Silvie, P., Soria, M. F., Frayssinet, M. and Gordon, K. H. J. (2017). Mitochondrial DNA and trade data support multiple origins of *Helicoverpa armigera* (Lepidoptera, Noctuidae) in Brazil. *Scientific Reports*, *7*, 45302.

Thakur, P., Rana, R. and Kumar, A. (2017). Biophysical characters of tomato varieties in relation to resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner). *Journal of Entomology and Zoology Studies*, 5, 108–112.

Thia, J. A., Hoffmann, A. A. and Umina, P. A. (2021). Empowering Australian insecticide resistance research with genetic information: The road ahead. *Austral Entomology*, *60*(1), 147–162.

Toffa, J., Loko, Y. L. E., Kpindou, O. K. D., Zanzana, K., Adikpeto, J., Gbenontin, Y. and Adandonon, A. (2021). Endophytic colonization of tomato plants by

Beauveria bassiana Vuillemin (Ascomycota: Hypocreales) and leaf damage in *Helicoverpa armigera* (Hübner)(Lepidoptera: Noctuidae) larvae. *Egyptian Journal of Biological Pest Control*, *31*(1), 82.

Tripathi, S.R. and Sharma, S.K. 1985. Population dynamics of Helicoverpa armigera (Hub.) (Lepidoptera, Noctuidae) on gram in the Terai belt of NEUP. *GiarnaleItalianadi Entomologia, 2*(10), 347-352.

Vinutha, J. S., Bhagat, D. and Bakthavatsalam, N. (2013). Nanotechnology in the management of polyphagous pest *Helicoverpa armigera. Journal of academia and industrial research*, *1*(10), 606–608.

Wu, K. M. (2007). Regional management strategy for cotton bollworm *Helicoverpa armigera* in China. In AreaWide Control of Insect Pests. Springer, Dordrecht, 559-565.

Yadav, S. P. S., Bhattarai, S., Ghimire, N. P. and Yadav, B. (2022). A review on ecology, biology, and management of a detrimental pest, *Tutaabsoluta* (Lepidoptera: Gelechiidae). *Journal of agriculture and applied biology*, *3*(2), 77-96.

Yadav, S. P. S., Lahutiya, V. and Paudel, P. (2022). A review on the biology, ecology, and management tactics of *Helicoverpa armigera* (Lepidoptera: noctuidae). *Turkish Journal of Agriculture-Food Science and Technology*, *10*(12), 2467-2476.

Yadav, S. P. S., Sharma, R., Ghimire, N. and Yadav, B. (2022). Chapter-2 Sterile Insect Technology (SIT) in New World Screwworm. *Advances in Agricultural Entomology*. AkiNik Publications, 15-34.

Yongming, R. and Kunjun, W. (2001). Performances of the cotton boll worm, *Helicoverpa armigera* on different food plants. Kun Chong xue bao. *Acta Entomologica Sinica*, *44*, 205–212.

Yücel, S. andHanife, G. (2018). Laboratory rearing of cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) wild colony on different artificial diets. *Journal of Applied Biological Sciences*, 12, 26–32.

Zahid, M., Islam, M., Reza, M., Prodhan, M. and Begum, M. R. (2008). Determination of economic injury levels of *Helicoverpa armigera* (Hubner) in chickpea. *Bangladesh Journal of Agricultural Research*, *33*, 555–563.

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