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Review on different biocontrol agents used in control of *Helicoverpa armigera* (Hubner)

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Abstract
H. armigera is a major polyphagous pest for agricultural and horticultural crops. It has wide range of host plants. It is difficult to control due to its polyphagous nature, high fecundity, mobility and diapause. The control of *Helicoverpa armigera* mainly depend on chemicals, but heavy and continuous use of it lead to resistance to different group of insecticides like cyclodienes, pyrethoids, carbamates and organophosphates. To avoid this resistance we should focus on other methods of control like host plant resistance like non-preference, antibiosis and tolerance. Cultural operations like right time of sowing, ploughing, nutrient management, spacing, crop rotation and biological control by using egg parasitoids like *Trichogramma chilonis*, larval parasitoids like *Compolestis chlorideae*, bacteria like *Bacillus thuringensis*, fungi like *Beauveria bassiana* and virus like *HaNPV*.

Keywords: Pod borer, HPR, larval parasitoid, biological control, pesticides

1. Introduction
Helicoverpa armigera is a major pest due to its polyphagous nature, high mobility, short generation duration and high biotic potential (Sharma *et al*., 2005) [46]. It has wide range of host plants causing damage such as tomato, pigeon pea, chickpea, cotton, sorghum, okra, cowpea (Anonymous, 2016) [4]. The caterpillar feed on leaves, floral parts and fruits causing heavy losses (Baghery *et al*., 2013) [7] and can reach up to 95% in chickpea fields (Ahmad *et al*., 2015) [1]. In addition damage to high value crops it also has high reproduction capacity and it can migrate to long distances (Shanower *et al.*, 1999) [43]. The loss due to this pest in difference crops like groundnut, cotton, chickpea, pigeonpea, sorghum, pearl millet, tomato and some other economic importance is about RS10,000 million (Raheja, 1996) [37]. The different species of *Helicoverpa armigera* found worldwide namely *Helicoverpa armigera, Helicoverpa assulta* and *Helicoverpa peltigera* are mainly recorded in India (Singh, 2005) [48]. The level of injury occur in a crop depend on the availability of no. of eggs, no. of larvae, no. of adults, and the no.of caterpillar surviving to the longer, larger will be the damaging due to larval in stars (Kriticos *et al.*,2015) [27]. Majority of insecticides 40% are used to control lepidopteran pest (Srinivasan *et al*., 2006) [50]. To overcome this problem farmers are spraying chemicals such as cypermethrin and chloropyriphos as representative of the pyrethoids, and organophosphate insecticides respectively are most common insecticides on cotton crop in India (Kranthi *et al*., 2002) [26]. Due to excess use of these insecticides *H. armigera* is getting resistant to insecticides such as synthetic pyrethoids (Forrester *et al.*, 1993) [20]. The insecticidal sprays are harmful to the environment and responsible for various human health problems. To overcome this problems the use of bio control agents play important role in such as birds stand supreme in control of insect pest due to their increased efficiency to capture and consume large number of insects (Sweetman,1958).The small wasps *Trichogramma* belonging to the family Trichogrammatidae, *Trichogramma* have great ability as bio-control agents (Bigler *et al*. 2003) [10]. The wasp *Habrobracon hebetor* which is ecto parasitoid is effective against *Helicoverpa armigera* larval parasitoid (Noor-ul-Ane *et al.*, 2018) [34]. *Bacillus thuringiensis* Berliner sub sp. Kurstaki (Btk) is a soil bacterium is effective biological agent against multiple lepidopteran pest, including *H. armigera* (Da silva *et al*.,2018) [17]. *HaNPV* is useful to control *Helicoverpa armigera* on multiple crops, including citrus, (Moore *et al.* 2004) [31] and chickpea (Most-taghi-maleki *et al.*, 2014). *H. armigera* is attacked by different entomopathogenic fungi such as *Beauveria bassiana, Nomuraea rileyi, Metarhizium anisopliae* (Grzywacz *et al.*, 2005) [22]. The management strategies should be started when the *Helicoverpa* larval population reaches one larva per meter row length in chickpea plants in

order to prevent reaching to economic injury level (Zahid *et al*., 2008) [58]. So I will discuss few application methods of different biocontrol agents in control of *H. armigera.*

2. Biology of pod borer: The eggs are spherical in shape with white colour having 0.4 to 0.6mm in diameter. The color of eggs changes from white to darkened greyish brown prior to hatching. The eggs apical area was smooth and remaining surface sculptured in the form of longitudinal ribs. The incubation period is 3 to 4 days. The larval period of pod borer completed through six different instars. The color of first and second instar larva are dark brown to black head capsule and remaining larval body with yellowish-white to redish-brown in color (Ali *et al*.,2009) [2]. The color of first and second instars larva are more same and movement is very small. The abdominal legs or prolegs developed during third instar stage on 3,4,5,6 and 10th abdominal segments (Bhatt *et al*., 2001) [9]. The completely grown larva was straw yellow to green with lateral brown strips. Spiracles and tubercles of the larva were brown to black indicating then a spotted appearance (Cunningham *et al*., 1999) [16]. The larval period is 24 to 34days in winter and in summer 17 to 24days. The pupa is brown color with obtect types; the surface of pupa is smooth with round anterior side and posterior with two parallel spines. The pupal period with 10 days minimum and 14 days maximum (Ali *et al*., 2009) [2] Pupa commonly found in soil, the length pupa measured from 18.9mm to19.4 mm, and breadth ranged from 4.9 mm to 5.3 mm (Baikar, 2016) [8]. The body of *H. armigera* is stout with broad thorax. A series of dots can be seen on the margins of forewings. The hindwings were lighter in color with apical end having abroad dark brown color. Males were greenish-grey in colour, whereas females were orange-brown in colour with tuft of hair on the tip of abdomen. The length of female moth ranged from 18.5 mm to 20.4 mm (average 19.34 ± 0.75 mm) and breadth (with wing expanded) is 39.2 mm to 41.5 mm (average 40.20 ± 0.84 mm), respectively.

3. *Helicoverpa armigera* resistant to different insecticides: Due to excess and repeated use of different compound like organophosphatetes (monocrotophos), cyclodienes (endosulfan), pyrethoids (fenvalerate, cypermethrin)the *Helicoverpa armigera* lost its susceptibility to those insecticides and become resistance to those insecticides (Chaturvedi, 2007) [13].

3.1Resistance mechanism of pyrethoids in *Helicoverpa armigera*

In *H. armigera*, the nerve insensitivity mechanism was associated with enzymatic detoxification of pyrethoids, which cause resistance to pyrethoids (Chaturvedi, 2007) [13]. In Indian strains of *Helicoverpa armigera*, the enzyme Glutathione S-transferases are also involved in resistance to pyrethoids. Deltamethrin was resistant to *Helicoverpa armigera* due to suppressible by the Piperonyl butoxide (PBO) (Martin *et al*., 2000) [30]. The esterase which is a hydrolyses enzyme is also involved in detoxifying or resistance to pyrethoids (Martin *et al*., 2000) [30].

3.2 Resistance of *Helicoverpa armigera* to carbamates: The resistance to methomyl may be caused to monoxygenase and esterase detoxification (Gunning *et al*.,1992) [23].

3.3 Resistance of *Helicoverpa armigera* to organophosphates: Resistance to the phosphate type of organophosphates is caused due to insensitive AChE mechanism. Resistance to quinolphos and is due to the fact that the phosphorathionate insecticide (quinolphos) mainly act as AChE inhibitor through an oxidative transformation catalyzed by mixed function oxidases (Armes *et al*.,1996) [6].

3.4 Host plant resistance to *Helicoverpa armigera*: Host plant resistance is the ability of the crop to withstand attack by another organism. But the original definition of Host plant resistance given by Painter 1951, the relative amount of heritable qualities possessed by the plant which influences the ultimate degree of damage done by insect. varying degrees of resistance shown by chickpea to *Helicoverpa armiger* have been used successfully by the farmers (Reed and Lateef, 1990, Sharma *et al.*,1999) [39, 45]. In chickpea different type of resistance (Antibiosis, Non-preference, Tolerance) observed (Clement *et al.*, 1994) [15]. The factors responsible for chickpea resistance to *Helicoverpa armigera*, are the acids with high concentration of malic acid produced from leaves, stems and pods of glandular hairs (Rembold, 1981) [40]. Some of the resistant varieties in chickpea are Genotype F 378 and C 235 (Srivastava *et al*.,1975) [51], H75-58, ICCC18 and Kanpur, Gondah and Mirzapur locals (Dias *et al*.,1983) [19] ICCV7, ICC506EB, ICC6663, ICC10619; ICC10667 (Singh, 1997) [47]. In pigeonpea the genotypes with smaller pods, deep constriction between the seeds and pod wall connected tightly to the seeds are less susceptible to *Helicoverpa armigera* (Nanda *et al*.,1996) [33]. The highest level of antibiosis noticed when the larva were nurture on leaves and pod so *Cicer acutifolicus* (ICPW1), *C. sericeus* (ICPW160), *C. cajanifolicus* (ICPW29), *C. scarabaeoides* and *C. albicans* (Sujana, *et al*., 2008) [53]. In pigeonpea the genotypes ICP7203-1, T21, ICPL187-1, ICPL 332 and ICPL84060 used as a Antixenosis (Non-preference) mechanism of resistance to *H. armigera* list in Table 1. (Kumari *et al*., 2006) [29].

4. Cultural practices for management of *Helicoverpa armigera*: Cultural operations like time of sowing, deep ploughing, nutrient management, spacing, intercultural and flood have been described to decrease the survival and injury by *Helicoverpa spp* (Lal *et al.*,1985; Murray and zalucki, 1990; Shanower *et al.*,1998) [19, 43]. Strip cropping or intercropping with marigold, sunflower, mustard, linseed, and coriander can decrease the extent of damage to main crop (Sequeira *et al*. 2001) [42]. The main crop damage has been decreased by strip cropping or intercropping with sunflower, linseed, marigold coriander and mustard. Large sized larva can be picked by hand to control *Helicoverpa armigera* because of its polyphagous nature, crop rotation do not help to manage the pest (Kambrekar and Demanna 2016) [25]. Trap crop of chickpea have been grown after the commercial crop to attract Helicoverpa armigera as they emerge from winter diapause, so that the Helicoverpa armigera incidence on summer crop is reduced, which help in reduced insecticidal use and greater natural enemy activity (Kambrekar and Demanna, 2016) [25].

5. Biological control: *Trichogramma chilonis* which is a small wasp, egg parasitoid used to control *Helicoverpa armigera* in red gram and sorghum. (Romeis *et al.*,1999) [41]. The larval parasitoid *Ichneumonoid, Compoletis chlorideae* (uchida) is used in control of *Helicoverpa armigera* (Kambrekar and Demanna., 2016) [25]. The larval parasitoid braconid wasp *Meteorus laphygmarum* observed to having parasitism (31%) in *Helicoverpa armigera* of cotton (Streito and Nibouche,1997) [52]. The microbial pesticides used to control *Helicoverpa armigera* are entomopathogenic fungi, *HaNPV*, *Bacillus thuringensis* and natural products from neem, pongamia, custard apple shown some ability to control (Sharma, 2001) [44]. The entomopathogenic fungi *Metarhizium anisopliae* infecting the larva turning to herbage green on the body, *Beauveria bassiana* will also infect the larva of *Helicoverpa armigera* help in control of larva (Kumar and Chowdary, 2004) [28]. *HaNPV* is used to control *Helicoverpa armigera* in chickpea fields (*Cherry et al*., 2001) [14], and its effectiveness is increased by adding sucrose (0.5%), jiggery (0.5%), egg white (3%) and chickpea flour (1%) (Sonalkal *et al.*, 1998) [49]. The entomopathogenic bacteria *Bacillus thuringiensis* is used in control of defoliating lepidopteran pest (Frankenhuyzen, 1993) [21]. *Bacillus thuringiensis* is a gram positive, aerobic, facultative bacterium, forming endospores, during vegetative and stationary phase it produce a wide range of virulence factors while contribute to insecticidal activity (Chapple *et al*., 2000) [12]. The toxin produced by the bacteria will bind the midgut receptors thus triggering a pore forming process, that help to change of the permeability of epidermal membrane permeability with continuous distribution of intestinal barrier functions and bacterial leading to death of death of insect due to bacterial septicemia (Bravo *et al*., 2007) [11]. The *Bacillus thuringiensis* dose 1.5kg/ha in pigeonpea is effective against control of *Helicoverpa armigera* (Tagger *et al.*, 2014).

Bacillus thuringensis var. kurstaki (spic-Bio Reg.)@2.5lit/ha was effective treatment for control of larval population of *Helicoverpa armigera*. In India, solutions of Bt based insecticides Delfin, Biobit, Dipel along simultaneously with *NPV* exhibited minimum pod damage (4.2 to 16.7%) as compared to control (12.4 to 38.6%)(Aynonymous1997). The Efficacy of *Bt. kurstaki* was found to increase with the decrease in particle size, against larvae of *H. armigera* (Devi and Vineela, 2015) [18].

5. Efficacy of pesticides against *Helicoverpa armigera*:

The highest mortality of egg was observed in flubendiamide and thiodicarb followed by emamectin benzoate and chlorantraniliprole. The 1st 2nd and 3rd instar larva can be controlled effectively by using Chloropyriphos (Ravi and Verma, 1997) [38]. The action of Spinosyn inducing allosteric activation of nicotinic acetylcholine receptor causing death of insects (Perry *et al.*, 2011) [36]. Fipronil was effective in control of Helicoverpa armigera. Among different insecticides the lowest mean larval population was observed in flubendiamide 480 SC (0.70LARVA/Plant), Chlorantraniliprole18.5 SC (0.73larva/plant), cyantraniliprole 10.26OD (0.80larva/plant), spinosad45SC (0.87larva/plant) and indoxacarb14.5SC (0.24larva/plant) were observed (Thakkar *et al.*,2019). It was found that highest larval decrease in percent was observed in chlorantraniprole1.5SC(73%),flubendiamide480SC (72.6%), emamectin benzoate 5%SG(71.6%), cyantraniprole 10.26 OD (69), Spinosad 45SC (68%),Indoxacarb14.5SC (64.66%), Profenophos50EC (68%),indoxacard14.5SC (64.66%), profenophos 50EC(60.66%) and Azadiractin 1EC(60%) in okra (Thakkar *et al.*,2019). In chickpea Chlorantrailiprole @0.15lit/ha is effective in control of *Helicoverpa armigera* (Anandhi *et al.*, 2001) [3].

Table 1: Characters associated to *Heliothis/ Helicoverpa armigera* in chickpea.

Crop	Mechanism	Characters
Chick pea	Non- preference	Pod shape, pod wall thickness, foliage color and gloriousness.
	Antibiosis	Malic acid, oxalic acid, crude fiber, non- reducing sugars, low starch, cellulose, hemicelluloses, lignin in the pod wall, trypsin inhibitors and HG proteinase inhibitor.
	Escape	Earliness and cold tolerance

6. Conclusion

Now-a-days the use of insecticides is increasing to control *Helicoverpa armigera*, but it is developing resistant to different insecticides. To avoid this resistance the research should focus on different biological control methods.

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