Research Article

An Update on Biology, Extent of Damage and Effective Management Strategies of Chickpea Pod Borer (*Helicoverpa armigera*)

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Abstract | *Helicoverpa armigera* is considered as widespread and cosmopolitan insect responsible for drastic decline in chickpea productivity across the world. Management of *H. armigera* is of prime importance to achieve sustainable chickpea yields. Its life cycle passes through egg, larvae, pupae and adult stages in about 4-5 weeks. 1st to 3rd instar larvae generally feed on leaves, twigs and flowers. In later stages larger larvae (4th to 6th instar caterpillars) shift to developing pods by making holes/bores and consume entire developing seeds. Pod borers can cause yield losses up to 90 percent depending upon the insect density and susceptibility of cultivars. Sustainable management of chickpea pod borer involves use of resistant cultivars, manipulation of sowing dates, maintaining low crop density, management of nutrition, use of trap crops (maize, sunflower, sorghum, safflower, pigeon pea, okra and tomato), installing animated bird perches and application of biological control measures (use of plant extracts, virus/bacteria based insecticides). In case of pod borer outbreaks, chemical insecticides remain as last option for farmers. However, management of chickpea pod borer through use of resistant cultivars, adopting recommended cultural practices and biological control measures have been found more effective, economical, sustainable and eco-friendly.

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Introduction

Chickpea (*Cicer arientinum* L.) is exposed to a wide range of insect pests, of which pod borer [*Helicoverpa armigera* (Hubner)] is most common and critical challenge for chickpea productivity around the world (Luckmann and Metcalf, 1975; Ujjan *et al.*, 2019; Jai *et al.*, 2020). In case of outbreaks, yield losses caused by chickpea pod borer range from 10-90 percent depending upon the insect population and susceptibility of genotypes (Sharma *et al.*, 2012). *H. armigera* is widely dispersed throughout the African, Asian, European and Mediterranean regions (Anwar and Shafiq, 1993; EPPO, 2006; Fichetti *et al.*, 2009; Zohary *et al.*, 2012). In Europe *H. armigera* is widespread chickpea pest while limited distribution of pest has been reported in Hungry, France, Italy and Cyprus (Patil *et al.*, 2017). Former reports on extent of damage by pod borer are evident that significant yield losses have been recorded in Southern Asia. Pod damage in unprotected chickpea crops were recorded up to 90 % in Pakistan (Ahmed *et al.*, 1986), in India up to 85 % (Reed, 1983) and 5-15 % in Bangladesh (Pande and Rao, 2000).

H. armigera belongs to insect order Lepidoptera, family Noctuidae. Its life cycle involves four major developmental stages (eggs, larvae, pupae and adult). *H. armigera* completes its life cycle from egg to adult in about 30-34 days at an average temperature of 28 °C (Zalucki *et al*., 1986; Fichetti *et al*., 2009). Under favorable environmental conditions adult insect (Moth) lay eggs which goes through various developmental stages i.e egg changes into Ist to 6th instars caterpillar (larvae) which afterward change into pupa and then adult moth is developed. Ist to 3rd instar larvae generally feed on twigs, leaves and flowers. In later stages larger larvae move to developing pods by making holes/bores and consume entire developing seeds resulting in severe yield losses (Reed and Pawar, 1982).

Pod borer can survive on several host species of crop plants. Pawar *et al*. (1986) reported 182 host species of crop plants for *H. armigera*. 47 species of host plants were reported by Singh and Balan (1986). They also added that gram, tomato and Egyptian clover were most favorable for larval survival. Naresh *et al*. (1989) reported maize, chickpea, sorghum, pigeon pea, okra, tomato and several other crops as preferred host crops for survival of *H. armigera*. Out breaks of pod borer have been observed on chickpea crop due to cultivation of cotton, pigeon pea, maize, tomato, sorghum, cowpeas and okra crops in surroundings because of shift of pest populations to chickpea crop (Reed, 1983; Patil *et al*., 2017). Rotation of common host crops has contributed to lift up the polyphagous insect pest populations like chickpea pod borer (Rivnay, 1962). Irrigation strategies generate new habitats promoting the migration process of some species of pests to the areas that were otherwise away from reach and the insect populations generally develop and migrate to that area (Bhatnagar, 1987).

Management of *H. armigera* is of prime importance to achieve sustainable chickpea yields. Integrated pest management strategies have been emphasized by several researchers to minimize the pest populations which include use of resistant cultivars, adoption of recommended cultural practices and use of biological and chemical control measures (Navi *et al*., 2018; Ujjan *et al*., 2019). Uses of pod borer resistant cultivars guarantee a pest free crop and incur almost no further charge to chickpea growers (Rajesh *et al*., 2017). Similarly, early sowing of chickpea crop, optimum plant density, installing insectivorous bird perches and intercropping with trap crops is also helpful in pest management. Several natural pathogens, insect parasitoids, predators and plant materials are being extensively utilized for biological management of pod borer (Bhatnagar, 1987). In case of insect outbreaks, insecticides remain as last option for farmers. Several insecticide groups (pyrethroids, hydrocarbons, carbamates, organophosphates) have been introduced for chemical control of pod borer (Schulten, 1987).

Life cycle of helicoverpa armigera

Helicoverpa armigera completes its life cycle (from egg to adult) in 4-5 weeks at an average temperature of 28 °C (Zalucki *et al*., 1986; Patil *et al*., 2017; Jai *et al*., 2020). Egg, larva, pupa and adult are four major stages of its life cycle (Figure 1). Adult insects having stout bodies with broad thorax are named as Moth. A female moth can lay up to 3000 eggs. Eggs are generally laid on leaves, pods and flowers. Oviposition period may last for 5-24 days and egg incubation occurs in 3-5 days depending upon temperature and host plant. Color of freshly laid eggs is yellowish-white that change into shady brown prior to hatching (Ali *et al*., 2009). After hatching larvae are released having six distinct instars (1-6 instars caterpillar). Initially larvae feed on leaves, younger twigs and flowers but in later stages they enter into the developing pods by making holes from the pod basis (Singh and singh, 2007). Pre-pupa period lasts for 1-4 days. Generally, the pupal period ranges from 10-16 days however it depends on temperature by taking 6 days at 35 °C and up to 30 days on 15°C. Under very low temperature (in winter) and very high temperature (in summer) it exhibits a facultative diapause to stay alive under unfavorable environmental conditions. Pupae exposed to exceeding 30°C temperatures produce pale colored adults (Patil *et al*., 2017). Male and female adults have distinguished color pattern showing greenish-grey and orange brown respectively. Pearson (1958) reported that female moths generally live longer than male.

Management approaches for chickpea pod borer

Sustainable management approaches for chickpea pod borer include varietal resistance, adoption of recommended cultural practices, and use of biological and integrated pest management measures.

Varietal resistance

Several characteristics antixenosis, pod thickness, length, density and pods plant^{-1} significantly contribute towards resistance against chickpea pod borer (Ujagir and Khere, 1987; Rajesh *et al*., 2017). Trichome types, length, density and orientation are associated with reduced pod damage. The association among pod borer damage and pod wall thickness exhibit negative correlation therefore genotypes having more wall thickness are generally less damaged. Similarly, pod length, area and breadth have also a considerable effect on pod borer resistance showing a negative association among the extent of damage, pod length and area. However, positive associations among pod borer damage and the pods plant^{-1} have been reported (Jeffree, 1986; Peter *et al*., 1995).

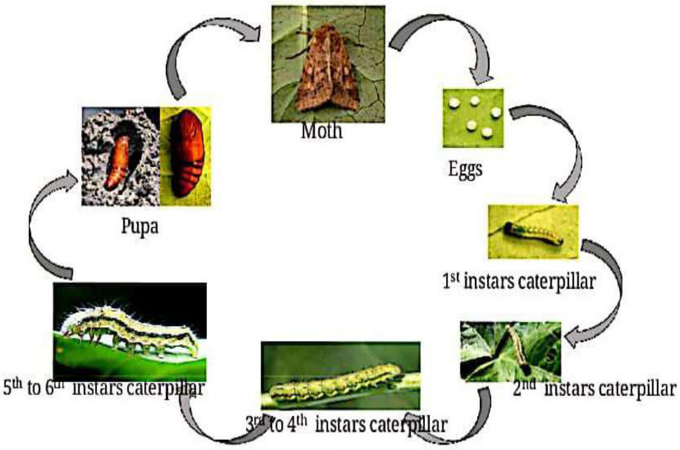

Figure 1: *Life cycle of Helicoverpa armigera.*

Development and utilization of pod borer resistant cultivars serves as the most efficient and sustainable control method for chickpea pod borer. Utilization of resistant varieties is most effective method and incurs no extra charge to the growers. Hence, the breeding objective must be to identify and utilize the genetic resistance sources to chickpea pod borer. Development of genetically advanced varieties having improved pod borer resistance is feasible provided that a good source of resistance is available. The selection procedures like mass selection, bulk and pedigree selection approaches can be utilized for the development of chickpea pod borer resistant varieties. Recurrent selection procedure has been found more efficient to accumulate the desired alleles in a single genotype and to break the undesired blocks (Singh *et al*., 1991; Sharma, 2005). These schemes require characterization of large populations, repeated selections and inter crossing among selected parents. Mutation breeding can also be utilized for creation genetic variation in performance of various traits having positive influence on resistance for pod borer damage. Singh *et al*., 1991 reported that the parents ICC 10619, ICCL 84205 and ICC 506 with low borer damage were found resistant to pod borer damage.

Lateef, 1985 and Sharma, 2005 found several accessions of germplasm (ICC-10817, ICCV -95992, ICC-10243, ICC-10667, ICC-10619, ICC-4935 and ICC-506EB resistant to chickpea pod borer while the genotypes like ICCL-86103, ICCV-10, ICCV-7 were found moderately resistant to chickpea pod borer. Several studies on genetic resistance and use of molecular markers were conducted by different researchers to identify the tolerant and resistant sources. The tolerant/ resistant sources against pod borer have been given in the (Table 1).

Cultural practices

Sowing time: Chickpea productivity is greatly influenced by the sowing time of crop. Environmental factors, like humidity, temperature, sunshine hours, and wind speed affect the pod borer populations. Kumar and Bisht, 2013, reported that temperature is positively correlated with the pod borer larval population, whereas rainfall and relative humidity reduce the larval population. Late sown crop is generally more affected by pod borer than early sown crop (Akhtar *et al*., 2014). Singh *et al*., 2002 concluded that in delayed sowing less grain yield indicated the direct correlation of yield to pod damage. Parmar *et al*. (2015) recorded low pod borer larval population and less pod damage percentage in early sown crop.

Generally, crop sown during October suffers least in comparison to late sown crop under Pakistan and Indian condition (Patil *et al*., 2017). The early instars generally appear in early April which remain restricted on leaves for food. However, the later instars, responsible for considerable pod damage, usually appear in late April. At that time, the pods are fully developed and mature enough that a limited damage can take place. Consequently, the early-sown chickpea crop escapes this period.

Plant density: Plant density and planting geometry also affects the extent of pod damage. Qadeer and Singh, 1989, reported that a denser chickpea crop favors enhanced pod damage. Anil *et al*., 2011 concluded that denser crops generally harbored higher larval population resulting in yield loss. Thinning may be recommended to reduce the plant density, because in some cases chickpea growers have a limited opportunity to minimize seed rate due to adverse physical soil conditions and unreliable seed germination.

Table 1: *Resistant sources to chickpea pod borer (H. armigera).*

Country	Tolerant genotypes	References
Pakistan	Pb-91	Shahzad *et al*., 2005
	C-27	Sarwar *et al*., 2009
	CM-72	Khan *et al*., 2009
	CH 07/02, CH 20/02 , CH 84/02 and CM 188/01	Shafique *et al*., 2009
	CH 4/02, CH 9/02, B 8/02 and B 8/03	Nadeem *et al*., 2010
	CH 73/02	Nadeem *et al*., 2011
	CH-53/99, CC-94/99, CM-24-2/02 and CM-210/01	Sarwar, 2013
	K-70005	Shabbir *et al*., 2014
	NIFA-2005, DG-89 and DG-92	Hafeez *et al*., 2018
Myanmar	ICC-506 and ICCX-730008	Ahmed *et al*.,1990
Nepal	GLK-88341, ICCV-88102, ICCX-860043-BP, ICCX-900239-BP and ICCV-95991	Thakur, 1998
India	Chaffa	Bhatt and Patel, 2001
	C-727	Rajput *et al*., 2003
	ICCV-2, ICC-87311	Sanap and Jamadagni, 2005
	ICCV-7, JG-74, , JG-130, JG-315 and BG-256	Ahmad and Rai, 2005
	IPC 96-3	Kaur *et al*., 2005
	ICC-16374	Patil *et al*., 2007
	ICC-12478, ICC-12479 and ICC-506 EB	Lakshmi Narayanamma *et al*., 2007
	Avrodhi , Vijay, BG-372, HC-1 and SAKI-9516	Deshmukh *et al*., 2010
	Vishal , Vijay, ICPL 88034 and ICCV 10	Sharma *et al*., 2014
	CSJD-884 and RSG-931	Choudhary *et al*.,2015
	BG-256 and KPG-59	Rajesh *et al*., 2017
Bangladesh	BCX-91042-3, BCX-91040-3, ICCV-95138, ICCV-98939, ICCV-96020 and ICCV-97004	Hossain (2009)
Kenya	ICC-3362, ICC-2580, ICC-7272, ICCV-92311, ICCV-95311, ICC 506, ICCVX 906183-1 and EC-583311	Mulwa *et al*. (2010)
	EC583250, EC583264, EC58318, EC583260 ICC14831 and ICCV10	Ruttoh *et al*. (2013)
Sudan	Flip03-139c and Atmore	Mansour and Mohamed, 2014

Nutrient management: Coaker (1987) narrated that application of nutrients to crop exhibit direct effect on pest attacks. Increased application of NPK enhances the plant growth which and crop becomes more attractive to chickpea pod borer. Hossain *et al*. (2009) concluded that the bushy plant types provide better refuge for insects, resulting in more pod damage while low doses of NPK resulted in less pod damage. Similarly, Anilkumar *et al*. (2011) reported that increased phosphorous levels significantly minimized insect incidence and increased the chickpea seed production. Fertilizer applications change the plant physiology and makes it active host for pod borer (Coaker, 1987). Application of inorganic fertilizers to chickpea crop showed higher pest population in comparison to the organic manures (Singh and Singh, 2007). Ramakrishnan *et al*. (1983) also studied the fertilizer effect on pod borer population and cited that nitrogenous fertilizers have direct effect on pod damage. Therefore, reduced NPK doses may be recommended to control the pod borer population.

Use of trap crops: The crops cultivated to lure insect pests away from the commercial crops are generally known as trap crop. Insects are either prohibited to enter the crop or trapped in other crops away from the major crop. Method of trap cropping depends on pest species as well as on stage of crop. Certain plants produce chemicals that catch the attention of insects for pollination, which make them fit trap crop. Various species of crop plants produce different degrees of volatiles, permitting certain species of insects and have been found suitable for trap cropping (Naresh *et* *al*., 1989; Sarwar *et al*., 2009).

When insect population is concentrated in a trap crop, they may be easily managed by applying recommended treatments techniques in specific area instead of treating the whole crop. Such treatments are less expensive and most effective to control insect populations. The crops like maize, sunflower, sorghum, safflower, pigeon pea, okra and tomato have been found as host crops and may be exploited as trap crops on borders or repeated in rows with a ratio of 10:3 (Chickpea: Trap crop rows respectively) across the field. A study involving sunflower and marigold as trap crops with a ratio of 7:1 resulted in 34-40% reduced pod damage (Anonymous, 2009).

Intercropping or mixed cropping: Intercropping with several other crops provides insurance in the farming ecosystem against the insect pest. Intercropping of common host crops has also contributed to lift up the populations of polyphagous insect pests like *H. armigera* therefore intercropping of non host crops resulted in reduced larval populations (Rivnay, 1962). Intercropping manipulates the crop geometry and the cropping system and inhibits the larval population of insects to migrate from a certain location of crop to another. Pimbert (1990) reported that intercropping of chickpea with certain crops do not offer same kind of stimuli and companionship for the pod borer therefore less extent of damages were revealed.

Ahmad (2003) concluded that chickpea intercropped with mustard, wheat, linseed and non host crops revealed considerably less pod injury in comparison to the sole chickpea crop. Similarly, 38.3% less pod borer damage was recorded by Ali *et al*. (2009) in wheat + chickpea mixed cropping than chickpea solitary cropping. Intercropping effect of chickpea + linseed was investigated by Borah *et al*. (2010) who found reduced incidence along with delayed pod borer attack. Tripathi *et al*. (2008) studied chickpea + mustard intercropping and narrated highest chickpea grain yield and reduced larval population followed by chickpea + barley intercropping. Similarly studies on intercropping of chickpea with coriander, sunflower and safflower also resulted in low yield loss and reduced pod damage (Pattar *et al*., 2012).

Biological control

Biological control agents serve as more efficient alternative of chemical, eco-friendly, sustainable and economical. These agents provide reliable control of chickpea pod borer incurring no extra cost to farmers. Sources of such agents are generally living organisms and their products or by products. Biological managements often rely on parasitism, herbivory, and predation or other natural mechanisms.

Plants and animal based extracts have been found safer, benign and cost effective in comparison to the chemical insecticides (Kamanula *et al*., 2011; Jai *et al*., 2020). Azadirachtin is a common plant extract isolated from neem plant. Roy and Dureja (1998) cited that Azadirachtin has growth-retarding and can cause death of insects by interfering the neuroendocrine control during metamorphosis. Zhu *et al*. (2001) reported that mixture of neem and garlic extract has repellent, toxic and anti oviposition effect on insects. Mishra *et al*. (2013) cited that vitex leaf extract, vermiwash, neem oil, pongamia leaf extract and animal urine have insect repellent properties and reported significant reduction in pod damage. Application of neem seed extracts was investigated by Hussain *et al*., 2016 who also found notable decline in pod borer population.

Virus and bacteria based insecticides have also been found most efficient in controlling pod borer outbreaks. Jai *et al*. (2020) reported that species specific nuclear polyhedrosis viruses (NPVs) have significant degrees of infestation to chickpea pod borer. Sharma *et al*. (1997) investigated NPV and a chemical insecticide Endosulfan in and found that NPV reduced pod damage up to 78 % while 70 % with Endosulfan. Bacteria based insecticide also provide an eco-friendly and effective control against chickpea pod borer. Chemical insecticides have hazardous and toxic effects on soil, environment, mammals and birds while the microbial insecticides have no residual effects and are considered as eco-friendly alternatives (Ahmed *et al*., 2012). Bacteria based (Bt) insecticides have been found more effective IPM tool for the pod borer. Utilization of Bt-based insecticides with DiPel, Delfin, BioBit in combination with NPV found most efficient with reduced pod damage (Hussain *et al*., 2016).

Numerous species of predatory birds feed on several insects, which may reduce the insect population up to 84 % (Chakravarthy, 1988). Among these insectivorous birds, house sparrows, black drogue, rosy pastor, blue jays, mynah and cattle egret and

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are common predators which feed on several insect pests including chickpea pod borer (Gokhale and Ameta, 1991). The sunflower provides sitting place for the predatory birds and its intercropping in chickpea reduces the larval population within a short time. Gopali *et al*. (2009) studied the sowing of sunflower and sorghum intercropped with chickpea crop and recorded higher chickpea grain yield when intercropped with sunflower due to bird perches. Ali and Dillon (1983) narrated that the beneficial role of insectivorous birds is the rich heritage of the nature in plant protection scenario. Bird perches are eco-friendly measure to control the insect populations rather than using the chemical insecticides.

Chemical control

In case of pod borer outbreaks, insecticides remain as last option for farmers. Several researchers have investigated the efficacy of certain insecticides and made recommendation of different insecticides for effective management of chickpea pod borer. Rashid *et al*. (2003) investigated the effect of insecticides i.e. Chlorpyrifos, Endosulfan, Indoxicarb, profenofos and spinosad along with untreated check against gram pod borer (*H. armigera*) and concluded that Indoxicarb and spinosad were found most effective with significant reduction of pod borer in chickpea crop. Ahmed *et al*. (2004) studied efficacy of various insecticides to chickpea pod borer and reported that spinosad was found most useful for management of chickpea pod borer followed by indoxacarb.

Similarly, the insecticides; cyperthrine 10 % EC, deltamethrine 2.8% EC, emamectin benzoate 5 % SC, endosulfan 35 % EC, flubendiamide 480 % EC, fenvalenrate 20 % EC, indoxicarb 15 % EC, lambda cyhalothrine 5 % EC, quinalphos 25 % EC, thiacloprid 240 % SC and spinosad 45 % have also been found effective for control of *H. armigera* in various former research studies (Narayana and Rajasri, 2006; Gowda *et al*., 2007).

Conclusions and Recommendations

Chickpea pod borer can be effectively managed by integration of measures such as use of resistant varieties, adaptation of recommended cultural practices and use of biological and chemical insecticides. Less plant density and intercropping with trap crops (mustard, coriander, marigold, sunflower, sorghum and linseed) and installing animated bird perches also help to attain enhanced chickpea productivity. However, in case of insect outbreaks generally chemical insecticides remain as the only solution. Due to harmful residual effects of pesticides for the food chain, soil and the natural balance, application of chemicals should be avoided. Sustainable management of pod borer can't be attained by applying any single measure therefore an integrated management approach following all the recommendations/ principles required to safeguard the crop is necessary. In view of this, it can be concluded that integration of all measures must be practiced to manage chickpea pod borer and to attain sustainable crop productivity.

Novelty Statement

This review covers salient former research outcomes and includes most recent accomplishments pertaining to the biology and efficient management of chickpea pod borer (*Helicoverpa armigera*). This novel review will help researchers and chickpea growers to potentially enhance chickpea yield in affected agro-ecologies.

Author's Contributions

MTM, MA, MS and IR studied former research findings and collected necessary information. MTM wrote the article. IR, MA, ZA remained involved in review and necessary revisions.

Conflict of Interest

The authors have no conflict of interest.

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