25 Host Plant Resistance and Insect Pest Management in Chickpea

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Insect Pest Problems in Chickpea

Chickpea (*C. arietinum* L.) is the third most important legume crop in the world, after dry beans and peas (FAO, 2003). It is cultivated in 42 countries in South Asia, North and Central America, the Mediterranean region, West Asia and North and East Africa. In recent years, it has become an important crop in Australia, Canada and the USA. Nearly 60 insect species are known to feed on chickpea (Reed *et al*., 1987) (Table 25.1). The important insect pests damaging chickpea in different regions are:

- Wireworms: false wireworm – *Gonocephalum* spp.;
- Cutworm: black cutworm – A. ipsilon (Hfn.) and turnip moth – A. segetum Schiff.;
- Termite: *Microtermes obesi* (Holm.) and *Odontotermes* sp.;
- Leaf-feeding caterpillars: cabbage looper – Trichoplusia ni (Hub.), leaf caterpillar – S. exigua (Hub.) and hairy caterpillar – S. oblique Walker;
- Semilooper: *Autographa nigrisignia* Walker;
- Leaf miners: *L. cicerina* (Rondani) and *L. congesta* (Becker);

Table 25.1. *Insect pests feeding on chickpea.*

Common name	Scientific name	Family	Distribution	Nature of damage
Order: *Orthoptera*				
Surface grasshopper	*Chrotogonus trychypterus* Blanch.	Acridiidae	India	Feeds on tender leaves, flowers and tender pods
Grasshopper	*Ailopus simulatrix* Wlk.	Acridiidae	India, Africa	Feeds on tender leaves and flowers
Field cricket	*Liogryllus bimaculatus* De Geer.	Gryllidae	India	Feeds on developing pods and seeds
Order: *Isoptera*				
Termites	*Microtermes obesi* (Holm.) *Odontotermes* sp.	Termitidae	Asia	Damages tap root
Order: *Hemiptera*				
Black aphid	*Aphis craccivora* Koch	Aphididae	Worldwide	Sucks sap from tender leaves, flower stalks and pods
Pea aphid	*Acrythosiphon pisum* (Harris)	Aphididae	Worldwide	Sucks sap from growing tips, flowers and pods
Cow bug	*Tricentrus bicolor* Dist.	Membracidae	India	Sucks sap
Order: *Lepidoptera*				
Cutworms	*Agrotis ipsilon* (Hfn.)	Noctuidae	Worldwide	Cuts the whole plant or growing tips and feeds on the leaves
	A. flammatra Schiff.	Noctuidae	Asia	Cuts the stem and growing tips
	Euxoa spinifera (Hub.) [=*A. spinifera* Hub.]	Noctuidae	Asia	Cuts the plant at ground level
	E. segetum Schiff (=*A. segetum* Dennis and Schiff.)	Noctuidae	Asia	Cuts the plant at ground
Semiloopers	*Autographa nigrisigna* Walker	Noctuidae	Asia	Feeds on leaves and pods
	Plusia orichalcea F.	Noctuidae	Asia	Feeds on leaves pods
	P. signata F.	Noctuidae	Asia	Feeds on leaves pods
	Chrysodeixis chalcites (Esp.)	Noctuidae	Asia	Feeds on leaves flowers
Cabbage looper	*Trichoplusia ni* (Hub.)	Noctuidae	America	Feeds on leaves
Western yellow striped armyworm	*Spodoptera praefica* (Grote)	Noctuidae	America	Feeds on leaves
Tobacco caterpillar	*S. litura* F.	Noctuidae	Asia	Feeds on leaves

Continued

Table 25.1. *Continued*

Common name	Scientific name	Family	Distribution	Nature of damage
Leaf caterpillar	*S. exigua* (Hub.)	Noctuidae	Asia, America	Feeds on leaves
Pod borers	*Helicoverpa armigera* (Hub.)	Noctuidae	Asia, Africa, Australia,	Feeds on leaves flowers and bores holes on the pod and eat away the seeds
	H. punctigera (Wallengren)	Noctuidae	Australia	Feeds on leaves, flowers and pods
	H. zea (Boddie.)			
	Heliothis virescens (Fab.)			
	H. assulta Cn.	Noctuidae	Asia	Feeds on leaves, flowers and pods
Noctuid caterpillar	*Rhyacia herwlea* C&D	Noctuidae	Asia	Feeds on leaves
Green leaf caterpillar	*Anticarisisa irrorata* (F.)	Noctuidae	Asia	Feeds on leaves
Fig moth	*Caudra cautella* (Wlk.)	Phycitidae	Asia	Feeds on stored grain
Bihar hairy caterpillar	*Diacrisia obliqua* (L.)	Arctiidae	Asia	Feeds on leaves
Order: *Diptera*				
Gram stem miner	*Ophiomyia cicerivora* Spencer	Agromyzidae	Asia	Feeds on the stem
Leaf miner	*Chromatomyia horticola* (Goureau)	Agromyzidae	Asia	Larvae mine leaves and feed on green matter
Pea leaf miner	*Phytomyza articornis* (Meig.)	Agromyzidae	Asia	Larvae mine leaves and feed on mesophyll
Chickpea leaf miner	*Liriomyza cicerina* (Rondani)	Agromyzidae	North Africa Asia	Larvae mine leaves and feed on mesophyll
Order: *Coleoptera*				
False wireworms	*Gonocephalum* spp.	Tenebrionidae	Asia	Damages the seedlings
Gujhia weevil	*Tanymecus indicus* F.	Curculionidae	Asia	Damages the seedlings
Pea leaf weevil	*Sitona lineatus* (L.)	Curculionidae	America	Adults feed on seedlings
Pumpkin beetle	*Aulacophora foveicolis* (Lucas)	Chrysomelidae	Asia	Feeds on leaves
Bruchids	*Callosobruchus chinensis* L.	Bruchidae	Worldwide	Feeds on stored seed
	C. maculatus (F.)	Bruchidae	Worldwide	Feeds on stored seed
	C. phaseolli (Gylh.)	Bruchidae	Worldwide	Feeds on stored seed
	C. analis (F.)	Bruchidae	Worldwide	Feeds on stored seed
	Acanthoscelides obtectus (Say)	Bruchidae	Worldwide	Feeds on stored seed

- Aphids: *A. craccivora* Koch and *Acyrthosiphon pisum* (Harris);
- Nodule-damaging fly: *Metopina ciceri* Disney;
- Pod borers: cotton bollworm – H. armigera (Hub.), native budworm – H. punctigera (Wallengren) and corn earworm – H. zea (Boddie.);
- Bruchids: Chinese bruchid – Callosobruchus chinensis L., bean bruchid – Acanthoscelides obtectus (Say), pulse weevil – C. analis F. and pulse bruchid – C. phaseoli (Gylh.).

The pod borer, *H. armigera* and the aphid, *A. craccivora* are the major pests of chickpea in the Indian Subcontinent. In the Mediterranean region, the most important pest is the leaf miner, *L. cicerina*. The black aphid, *A. craccivora* is important as a vector of the chickpea stunt disease, while *C. chinensis* is the most dominant species in storage.

In Australia, the major pests of chickpea are the two pod borers, *H. armigera* and *H. punctigera* (Knights and Siddique, 2002). Chickpea has a few pest problems in the USA (Miller *et al.*, 2002; Margheim *et al.*, 2004; Glogoza, 2005). Occasional pests in the Pacific Northwest are the western yellow striped armyworm, *S. praefica* (Grote) (Clement, 1999), pea leaf weevil, *Sitona lineatus* (L.) (Williams *et al.*, 1991), pea aphid, *A. pisum* and cowpea aphid, *A. craccivora* (Clement *et al.*, 2000). The potential pests are early season cutworms, loopers, corn earworm (*H. zea*), wireworms, aphids, grasshoppers and an agromyzid leafminer. Larvae of the agromyzid fly mine the chickpea leaves, but the impact of damage has not been established (Miller *et al.*, 2002; Margheim *et al.*, 2004). The major pest problems in chickpea and their management options are discussed below.

Pod Borers: *Helicoverpa armigera* and *Helicoverpa punctigera*

Chickpea production is severely threatened by increasing difficulties in controlling the pod borers, *H. armigera* and *H. punctigera* (Matthews, 1999). The extent of losses due to *H. armigera* in chickpea have been estimated to be over $328 million in the semi-arid tropics (ICRISAT, 1992). Worldwide, losses due to *Heliothis/Helicoverpa* in cotton, legumes, vegetables, cereals, etc. may exceed $2 billion, and the cost of insecticides used to control these pests may be over $1 billion annually (Sharma, 2005). Field surveys in the early 1980s indicated that less than 10% of the farmers used pesticides to control *H. armigera* in chickpea in India (Reed *et al.*, 1987). However, the shift from subsistence to commercial production and the resulting increase in prices have provided the farmers an opportunity to consider application of pest management options for increasing chickpea production (Shanower *et al.*, 1998).

Population monitoring and forecasting

Efforts have been made to develop a forewarning system for *H. armigera* on cotton, pigeonpea and chickpea in India (Das *et al.*, 1997; Puri *et al.*, 1999).

A thumb rule has been developed to predict *H. armigera* population using surplus/deficit rainfall in different months in South India (Das *et al.*, 2001). A combination of surplus rains during the monsoon and deficit rainfall during November indicated low incidence, while deficit rains during the monsoon and surplus rains during November (A–, B+) indicated severe attack. Additional information on November rainfall gives precise information on the level of attack (low, moderate or severe). In Australia, population monitoring with sex pheromone-baited traps is used to detect the onset of immigration or emergence from local diapause. Abundance of *H. armigera* and *H. punctigera* as measured by light traps showed that seasonal rainfall and local crop abundance gave a reasonable prediction of the timing of population events and the size of subsequent generations (Maelzer and Zalucki, 1999; Zalucki and Furlong, 2005). Timing of control is determined by field monitoring of larval densities in crops through the period of crop susceptibility. Control is only recommended when larval populations in post flowering crops exceed the threshold of 2–4 larvae per metre row (Lucy and Slatter, 2004).

Host-plant resistance

The development of crop cultivars resistant or tolerant to *H. armigera* has a major potential for use in integrated pest management, particularly under subsistence farming conditions in the developing countries (Fitt, 1989; Sharma and Ortiz, 2002). More than 14,000 chickpea germplasm accessions have been screened for resistance towards *H. armigera* at ICRISAT, Hyderabad, India, under field conditions (Lateef and Sachan, 1990). Several germplasm accessions (ICC 506EB, ICC 10667, ICC 10619, ICC 4935, ICC 10243, ICCV 95992 and ICC 10817) with resistance to *H. armigera* have been identified, and varieties such as ICCV 7, ICCV 10 and ICCL 86103 with moderate levels of resistance have been released for cultivation (Gowda *et al.*, 1983; Lateef, 1985; Lateef and Pimbert, 1990) (Table 25.2). Pedigree selection appears to be effective in selecting lines with resistance to *Helicoverpa*. However, most of these lines are highly susceptible to fusarium wilt. Therefore, concerted efforts are being made to break the linkage by raising a large population of crosses between *Helicoverpa* and wilt resistant parents.

Wild relatives of chickpea are an important source of resistance to leaf miner, *L. cicerina* and the bruchid, *C. chinensis* (Singh *et al.*, 1997). Based on leaf feeding, larval survival and larval weights, accessions belonging to *C. bijugum* (ICC 17206, IG 70002, IG 70003, IG 70006, IG 70012, IG 70016 and IG 70016), *C. judaicum* (IG 69980, IG 70032 and IG 70033), *C. pinnatifidum* (IG 69948) (Sharma *et al.*, 2005a) and *C. reticulatum* (IG 70020, IG 72940, IG 72948 and IG 72949, and IG 72964) (Sharma *et al.*, 2005b) showed resistance to *H. armigera*. With the use of interspecific hybridization, it would be possible to transfer resistance genes from the wild relatives to cultivated chickpea. Some of the wild relatives of chickpea may have different mechanisms of resistance than those in the cultivated types, which can be used in crop improvement to diversify the bases of resistance to this pest.

Table 25.2. Identification and utilization of host plant resistance to *Helicoverpa armigera*.

Genotypes	Remarks	Reference
Desi: short-duration		
ICC 506, ICCV 7 (ICCX 730041-1-1P-BP), ICC 10667, ICC 6663, ICC 10619, ICC 10817, ICCL 861992, ICCL 86103, ICCX 73008-8-1-IP-BP-EB, ICCX 730162-2-IP-B-EB, ICCX 730213-9-1-3HB, C 10, PDE 2, PDE 5, DPR/CE 72, DPR/CE 1-2, DPR/CE 3-1 and DPR/CE 2–3	DR < 3.8 compared to 6.0 in Annigeri	Lateef and Sachan (1990)
Desi: medium-duration		
ICC 4935-E-2793, ICCX 730094-18-2-IP-BP-EB, BDN 9-3, ICCX 730185-2-4- H1-EB, ICCX 730190-12-1H-B-EB, ICCX 730025-11-3-IH-EB, ICC 3474-4EB, ICC 5800, S 76, N 37 and PDE 1	DR < 4.6 compared to 8.5 in ICC 3137	
ICCL 86101, ICCL 86102, ICCL 86103 and ICCL 86104		
Desi: long-duration		
ICC 10243, ICCX 730020-11-1-1H-B-EB, GL 1002, Pant G 114 and PDE 7	DR 4.3 compared to 6.0 in H 208	
Kabuli: - medium-duration		
ICC 10870, ICC 5264-E10, ICC 8835, ICC 4856, ICC 7966, ICC 2553-3EB, ICC 2695-3EB, ICC 10243 and ICCX 730244-17-2-2H-EB	DR < 5.4 compared to 6.0 in L 550	
GL 645, Dhulia, 6–28, GGP Chaffa, P 1324-11, P 1697, P 6292 and selection 418	Suffered <5% pod damage compared to 16.1 to 36% damage in G 130 and L 550	Chhabra *et al*. (1990)
ICC 506EB, ICC 2397, ICC 6341, ICC 4958 and ICC 8304	Suffered <12% pod damage compared to 42% in ICC 14665	Bhagwat *et al*. (1995)
PDE 2-1, IC 16, Annigeri, BGM 42 and C 21–79	These lines had 6–9 larvae per meter row compared to 32 larvae in H 86-18	Chauhan and Dahiya (1994)
BG 372, B 390, GNG 469, PDE 2-1 and PDE 3-2	Performed better than H 82-2 based on pod damage and grain yield	
DHG 84-11, P 240, DHG 88-20, ICP 29, DHG 86-38, SG 90-55, KBG 1, H 83-83, NP 37, DHG 87-54, GNG 669 and SG 89-11	These varieties were better or on par with the commercial cultivars 240, P 256, C 235 and BR 77	Singh and Yadav (1999 a,b)
ICC 12475, ICC 12477, ICC 12478, ICC 12479, ICC 14876, ICCV 96782, ICCL 87316, ICCL 87317 and ICCV 95992	Stable resistance to pod borer across seasons	Sreelatha (2003); Lakshminarayanamma (2005)

Molecular marker-assisted selection (MAS) can be used to accelerate the introgression of desirable genes into improved cultivars (Sharma *et al.*, 2002). Preliminary results on development of molecular markers for resistance to *H. armigera* have been reported in chickpea (Lawlor *et al.*, 1998) based on bulk segregant analysis with amplified fragment length polymorphism (AFLP) analysis of F_2 and F_4 generations. Recombinant inbred lines (RILs) derived from ICCV2 × JG 62 cross have shown considerable variation for susceptibility to *H. armigera*. A skeletal molecular map is already available from this mapping population (Cho *et al.*, 2002). Another mapping population derived from ICC 506EB × Vijay is being currently evaluated for resistance to pod borer (H.C. Sharma, 2005, India, unpublished data). A susceptible *C. arietinum* variety (ICC 3137) has been crossed with a *C. reticulatum* accession (IG 72934) resistant to *H. armigera*, and the F_2 plants have been screened for resistance to *H. armigera*. Significant progress has been made over the last decade in introducing foreign genes into plants, providing opportunities to modify crops to increase yields, impart resistance to biotic and abiotic stresses and improve nutritional quality (Sharma *et al.*, 2004). Kar *et al.* (1997) developed transgenic chickpea plants with *cry1Ac* gene. Efforts are underway at ICRISAT and elsewhere to develop transgenic plants of chickpea with *Bacillus thuringiensis* (Bt) and soybean trypsin inhibitor (SBTI) genes for resistance to *H. armigera* (Sharma *et al.*, 2004). Efficient tissue culture and transformation methods by using *Agrobacterium tumefaciens* have been standardized at ICRISAT (Jayanand *et al.*, 2003).

Cultural manipulation of the crop and its environment

A number of cultural practices such as time of sowing, spacing, fertilizer application, deep ploughing, interculture and flooding have been reported to reduce the survival of and damage by *Helicoverpa* spp. (Lal *et al.*, 1980, 1985; Reed *et al.*, 1987; Murray and Zalucki, 1990; Shanower *et al.*, 1998; Romeis *et al.*, 2004). Intercropping or strip-cropping with marigold, sunflower, linseed, mustard and coriander can minimize the extent of damage to the main crop. Strip-cropping also increases the efficiency of chemical control. Hand-picking of large-sized larvae can also be practised to reduce *Helicoverpa* damage. However, the adoption of cultural practices depends on the crop husbandry practices in a particular agro-ecosystem. Rotations do not help manage these polyphagous and very mobile insects, although it has been noted that some crops (e.g. lucerne) are more attractive to the moths, and susceptible crops should not be planted too close to the main crop. Habitat diversification to enhance pest control has been attempted in Australia. An area-wide population management strategy has been implemented in regions of Queensland and New South Wales to contain the size of the local *H. armigera* population, and chickpea trap crops have played an important role in this strategy (Ferguson and Miles, 2002; Murray *et al.*, 2005b). Chickpea trap crops are planted after the commercial crops to attract *H. armigera* as they emerge from winter diapause. The emergence from diapause typically occurs when commercial chickpea has senesced, and before summer crops (sorghum, cotton and mung bean) are attractive to moths (October to November). However, moths are diverted to weeds for oviposition (including wheat, *Triticum aestivum*) when they grow above the chickpea crop canopy (Sequeira *et al*., 2001). Trap crops are managed in the same way as commercial crops, but destroyed by cultivation before larvae begin to pupate. The trap crops reduce the size of the local *H. armigera* population before it can infest summer crops and start to increase in size. As a result, the overall *H. armigera* pressure on summer crops is reduced, resulting in greater opportunity for the implementation of soft control options, reduced insecticide use and greater natural enemy activity.

Biological control

The importance of both biotic and abiotic factors on the seasonal abundance of *H. armigera* is poorly understood. Low activity of parasitoids has been reported from chickpea because of dense layer of trichomes and their acidic exudates (Jalali *et al*., 1988; Murray and Rynne, 1994; Romeis *et al*., 1999). The ichneumonid, *Campoletis chlorideae* (Uchida), is probably the most important larval parasitoid on *H. armigera* in chickpea in India. *Carcelia illota* (Curran), *Goniophthalmus halli* Mesnil and *Palexorista laxa* (Curran) have also been reported to parasitize up to 54% larvae on chickpea (Yadava *et al*., 1991; King, 1994; Romeis and Shanower, 1996), although Bhatnagar *et al*. (1983) recorded only 3% parasitism on chickpea. Predators such as *Chrysopa* spp., *Chrysoperla* spp., *Nabis* spp., *Geocoris* spp., *Orius* spp. and *Polistes* spp. are the most common in India. Provision of bird perches or planting of tall crops that serve as resting sites for insectivorous birds such as myna and drongo helps reduce the numbers of caterpillars.

The use of microbial pathogens including *H. armigera* nuclear polyhedrosis virus (HaNPV), entomopathogenic fungi, Bt, nematodes and natural plant products such as neem, custard apple and karanj (*Pongamia*) kernel extracts have shown some potential to control *H. armigera* (Sharma, 2001). HaNPV has been reported to be a viable option to control *H. armigera* in chickpea (Rabindra and Jayaraj, 1988; Cowgill and Bhagwat, 1996; Butani *et al*., 1997; Ahmad *et al*., 1999; Cherry *et al*., 2000). Jaggery (0.5%), sucrose (0.5%), egg white (3%) and chickpea flour (1%) are effective in increasing the activity of HaNPV (Sonalkar *et al*., 1998). In Australia, the efficacy of HaNPV in chickpea has been increased by the addition of milk powder, and more recently the additive Aminofeed® (Anonymous, 2005). Spraying Bt formulations in the evening results in better control than spraying at other times of the day (Mahapatro and Gupta, 1999). Entomopathogenic fungus, *Nomuraea rileyi* (10^6 spores per ml), results in 90–100% larval mortality, while *Beauveria bassiana* (2.68×10^7 spores per ml) resulted in 6% damage in chickpea compared to 16.3% damage in the untreated control plots (Saxena and Ahmad, 1997). In Australia, specific control of *H. armigera* and *H. punctigera* on chickpea is being achieved using the commercially available HaNPV, with an additive that increases the level of control. Bt formulations are also used as a spray to control *Helicoverpa*.

Chemical control

Management of *Helicoverpa* in India and Australia in chickpea and other high-value crops relies heavily on insecticides. There is substantial literature on the comparative efficacy of different insecticides against *Helicoverpa*. Endosulfan, cypermethrin, fenvalerate, thiodicarb, profenophos, spinosad and indoxacarb have been found to be effective for *H. armigera* control on chickpea in Australia (Murray *et al.*, 2005a). Spray initiation at 50% flowering has been found to be most effective (Sharma, 2001). The appearance of insecticide resistance in *H. armigera,* but not in *H. punctigera* is considered to be related to the greater mobility of the later species (Maelzer and Zalucki, 1999, 2000). However, *H. armigera* populations in the northern Australia are largely resistant to pyrethroids, carbamates and organophosphates. Introduction of new chemistry, notably indoxacarb and spinosad, is being managed to minimize the development of resistance in *H. armigera* through a strategy that takes into account its use in all crops throughout the year (Murray *et al.*, 2005a). Consequently, the use of indoxacarb in chickpea is limited to one application with a cut-off date for application to ensure that one generation of *H. armigera* is not exposed to the product in any crop before the commencement of its use in summer crops (cotton and mung bean).

Leaf Miner: *Liriomyza cicerina*

The leaf miner, *L. cicerina,* is an important pest of chickpea in the Mediterranean region and eastern Europe (Weigand *et al.*, 1994). It has also been reported from North India (Naresh and Malik, 1986). Efforts are currently underway at ICARDA, Aleppo, Syria, to breed lines that combine leaf miner resistance and high yield. Spraying with neem seed kernel extract is relatively effective, but the persistence is limited (Weigand *et al.*, 1994). Studies in Syria have also identified a parasitic wasp (*Opius* sp.) that feeds on the leaf miner larvae, but further research is required before this insect can be used for biological control in the field. *Opius monilicornis* Fischer parasitizes the larvae of *L. cicerina* in May and June in chickpea fields (M. El Bouhssini, 2006, Syria, unpublished data). It was observed that *L. cicerina* parasitism was 0–23.91%. Early-sown crops usually escape leaf miner damage.

Black Cutworm: *Agrotis ipsilon*

The black cutworm is a pest of chickpea, pea, lentil, potato and other crops in North India (Ahmad, 2003). It cuts the plants and drags them into cracks between soil clods. Dry weather during April–May affects the cutworms adversely. *A. flammatra* Schiff and *A. spinifera* (Hub.) are of minor importance. Heavy damage by cutworms occur in areas that remain flooded during the rainy season. *A. ipsilon* has four generations in North India. Chaudhary and Malik (1983) reported up to 9.5% plant damage at 40 days after crop emergence. Eggs are laid on earth clods, and on the chickpea plants. The pre-oviposition and oviposition periods vary from 3.9 to 5.5 and 5.8 to 8.3 days, respectively. A female may lay as many as 639–2252 eggs, and the egg incubation, larval and pupal periods vary from 2.7 to 5.1, 18.2 to 39.5 and 31.4 to 69.8 days, respectively. Larval mortality is as high as 70% during the early instars. In summer, it survives on the weeds in wastelands. It has been suggested that it may migrate to hills during the summer. Ploughing the fields before planting and after crop harvest reduces cutworm damage. The plants at times are able to recover from cutworm damage. Endosulfan dusts or sprays (Chaudhary and Malik, 1981; Kumar *et al.*, 1983) and endosulfan bait have been found to be effective for cutworm control. In India, the braconids such as *Microgaster* sp., *Bracon kitcheneri* (Will.) and *Fileanta ruficanda* (Cam.) parasitize the cutworm larvae, while *Broscus punctatus* (Klug.) and *Liogryllus bimaculatus* (DeGeer) are common predators (Nair, 1975).

Aphid: *Aphis craccivora*

The black aphid, *A. craccivora* causes substantial damage to chickpea in North India. This aphid is capable of transmitting a number of viral diseases in chickpea (Kaiser *et al.*, 1990). The most important is a strain of the bean leaf roll luteovirus, the incitant of chickpea stunt disease, which has assumed economic importance (Nene and Reddy, 1976). It is transmitted in a persistent manner. Chickpea chlorotic dwarf, a monogeminivirus (Horn *et al.*, 1995), is transmitted in a persistent, non-propagative and circulative manner by the leafhopper, *Orosius orientalis* (Matsumura) (Horn *et al.*, 1994). In Australia, lucerne mosaic virus, subterranean clover red leaf virus, beet western yellow virus, cucumber mosaic virus and bean leaf roll virus infect chickpea (Knights and Siddique, 2002). Aphids transmit many of these viruses, and may require chemical sprays (Loss *et al.*, 1998). Both nymphs and adults suck the sap from the leaves and the pods, causing depletion of photosynthates. In case of severe infestation, the leaves and shoots are deformed, and the plants become stunted. Life cycle from nymph to adult stage is completed in 8–10 days. Varieties with low trichome density or devoid of trichomes are highly susceptible to aphid damage. The aphids are active throughout the year (Bakhetia and Sidhu, 1977). A gravid female can produce over 100 nymphs in 15 days (Talati and Bhutani, 1980). The aphid incidence is greater under drought conditions. Nymphs undergo four molts. There are three population peaks on chickpea at Hisar, Haryana, India (Sithanantham *et al.*, 1984). Early sowing leads to early canopy closure, which also helps reduce virus spread in chickpea. Aphid infestation is greater under wider spacing. The genotypes, H 75-35 and H 2184, are less susceptible (Lal *et al.*, 1989). Additionally, Mushtaque (1977) observed that the lines H 6560, H 6576 and H 424 were less susceptible to aphid damage. *Coccinella septempunctata* L., *C. transversalis* (F.), *C. nigritis* (F.), *Cheilomenes sexmaculatus* (F.), *Brumus suturalis* (F.), *Chrysoperla* spp. and *Ischiodan javana* (Weid.) are common predators, while *Trixys indicus* (Subbarao & Sharma) and *Lipolexix scutellaris* Mackaur are important parasitoids (Singh and Tripathi, 1987). Generally, there is no need for aphid control on chickpea in India, but chemical control may become necessary to prevent secondary spread of the chickpea viruses (Reed *et al*., 1987). A number of insecticides such as methomyl, oxy-demeton methyl and monocrotophos are effective for aphid control. *Aphis craccivora* has also developed resistance to some commonly used insecticides (Dhingra, 1994).

Semilooper: *Autographa nigrisigna*

The semilooper, *A. nigrisigna* occasionally damages chickpea in North India in January. The larvae feed on leaf buds, flowers and the young pods. The young larvae scratch the leaf, which becomes whitish. The larvae of *A. nigrisigna* feed on the whole pod, leaving the peduncle behind. The egg, larval and pupal stages last for 3–6, 8–80 and 5–13 days, respectively (Mahmood *et al*., 1984). Males live for 4–5 days, while the females survive for 7–9 days. One generation is completed in 18–52 days. Its populations increase under high humidity. Endosulfan, phosalone, dichlorvos and malathion have been recommended for controlling this pest (Rizvi and Singh, 1983; Mahmood *et al*., 1984; Chhabra and Kooner, 1985). Bt formulations have also been found to be effective against this pest (Saxena and Ahmad, 1997).

Bruchids: *Callosobruchus* spp.

In India, bruchid infestation levels approaching 13% have been reported (Mookherjee *et al*., 1970; Dias and Yadav, 1988). Total losses have been reported from the Near East (Weigand and Tahhan, 1990). Extensive screening of kabuli type chickpea has not shown any acceptable level of resistance (Weigand and Pimbert, 1993). However, high levels of resistance have been observed in desi type chickpea (Raina, 1971; Schalk *et al*., 1973; Weigand and Tahhan, 1990). Lines showing resistance to bruchids usually have small seeds with a rough seed coat. Such grain is not acceptable to the consumers (Reed *et al*., 1987). Chickpea seed that is split for *dhal* is unattractive to ovipositing bruchid females (Reed *et al*., 1987). Chemical insecticides are little used in chickpea storage in India (Srinivasu and Naik, 2002). Biological control of bruchids has not really been exploited in India. For more information, see Van Huis (1991) for a comprehensive review of biological control of bruchids in the tropics.

Need for Future Research

Insect-resistant chickpea cultivars will form the backbone of integrated pest management in future. The development and deployment of chickpea plants with resistance to insects would offer the advantage of allowing some degree of selection for specificity effects, so that pests, but not the beneficial organisms, are targeted.

Deployment of insect-resistant chickpea will result in decreased use of chemical pesticides and increased activity of natural enemies, and thus, higher yields. For pest management programmes to be effective in future, there is a need for:

- In-depth understanding of the population dynamics of insect pests in chickpea growing areas to develop appropriate control strategies;
- Combined resistance to insects with resistance to important diseases and cold tolerance;
- Utilization of wild relatives of chickpea to diversify the genetic basis, and thus increase the levels of resistance to the target insect pests;
- Identification of quantitative trait loci (QTLs) associated with resistance to insects to increase the levels of resistance through gene pyramiding;
- Development of insect-resistant varieties through genetic transformation using genes with diverse modes of action;
- Insecticide resistance management, development of biopesticides with stable formulations and strategies for conservation of natural enemies for integrated pest management.

Conclusion

Nearly 60 insect species are known to feed on chickpea, of which cutworms (black cutworm – *Agrotis ipsilon* and turnip moth – *A. segetum*), leaf-feeding caterpillars (leaf caterpillar – *Spodoptera exigua* and hairy caterpillar – *Spilarctia oblique*), leaf miners (*Liriomyza cicerina*), aphids (*Aphis craccivora*), pod borers (cotton bollworm – *Helicoverpa armigera* and native budworm – *H. punctigera*) and the bruchids (*Callosobruchus* spp.) are the major pests worldwide. The pod borer, *H. armigera* and aphids, *A. craccivora* (as a vector of chickpea stunt virus) are the major pests in the Indian subcontinent; while the leaf miner, *L. cicerina* is an important pest in the Mediterranean region. Bruchids, *Callosobruchus* spp. cause extensive losses in storage all over the world. Low to moderate levels of resistance have been identified in the germplasm, and a few improved varieties with resistance to pod borer and high grain yield have been developed. Germplasm accessions of the wild relatives of chickpea (*Cicer bijugum*, *C. judaicum* and *C. reticulatum*) can be used to increase the levels and diversify the bases of resistance to *H. armigera*. Efforts are also underway to utilize molecular techniques to increase the levels of resistance to pod borer. Synthetic insecticides, agronomic practices, nuclear polyhedrosis virus (NPV), entomopathogenic fungi, bacteria and natural plant products have been evaluated as components of pest management in chickpea.

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