Exploiting host plant resistance for pest management in chickpea

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Abstract: Nearly 60 insect species are known to feed on chickpea, of which cutworm, *Agrotis* spp., beet armyworm, *Spodoptera exigua* leaf miner, *Liriomyza cicerina*), aphid, *Aphis craccivora*, pod borer, *Helicoverpa armigera*, and bruchid, *Callosobruchus chinensis* are the major pests worldwide. Low to moderate levels of resistance have been identified in the cultivated germplasm. Wild relatives of chickpea have high levels of resistance to *H. armigera*. Efforts are also underway to utilize molecular techniques to increase the levels of resistance to pod borer. Transgenic chickpea plants with *cryIIa* gene have also been developed. Synthetic insecticides, agronomic practices, nuclear polyhedrosis virus (NPV), and natural plant products have been evaluated as components of pest management in chickpea.

Key words: chickpea, host plant resistance pest management, wild relatives, transgenic plants

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Introduction

Nearly 60 insect species are known to feed on chickpea, of which. cutworms (black cutworm - *Agrotis ipsilon* (Hfn.) and turnip moth - *Agrotis segetum* Schiff.), leaf feeding caterpillars (beet armyworm, *Spodoptera exigua* (Hub.)), leaf miners (*Liriomyza cicerina* (Rondani) and *L . congesta* (Becker)), pea leaf weevil (*Sitona lineatus* (L.)), aphids (*Aphis craccivora* Koch), pod borers (cotton bollworm - *Helicoverpa armigera* (Hub.) and native budworm - *Helicoverpa punctigera* (Wallengren)), and bruchids (Chinese bruchid - *Callosobruchus chinensis* L.) are the major pests (2). 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*. *A. craccivora* is important as a vector of the chickpea stunt disease, while *C. chinensis* is the most dominant pest species in storage. In India, insect pests cause an average of 30% loss in pulses, which at times can be 100%. *H. armigera* – the single largest yield reducing factor in food legumes, causes an estimated loss of 328 million USD in chickpea. Globally, it causes an estimated loss of over 2 USD billion annually, despite over 1 USD billion worth of insecticides used to control this pest (6).

Host-plant resistance

Development of chickpea cultivars resistant or tolerant to insects has a major potential for use in integrated pest management, particularly under subsistence farming conditions in the semi-arid tropics. Resistant varieties derived through conventional plant breeding, marker assisted selection, introgression of genes from wild relatives into cultivated chickpea, or developed through genetic transformation will provide an effective weapon for pest management in chickpea, particularly against the pod borers. Screening for resistance to insects under natural conditions is a long-term process because of the variation in insect density across seasons and locations, and staggered flowering of the test material. Knowledge concerning the periods of maximum insect abundance and hot-spots is the first step to initiate work on screening and breeding for resistance to *H. armigera*. Delayed plantings of the crop and use of infester rows of a sus-ceptible cultivar of the same or of a different species can be used to increase *H. armigera* infestations under natural conditions (6). Artificial infestation with laboratory-reared insects can be used to overcome some of the difficulties encountered in screening the test material under natural infestation. Caging the test plants with larvae in the field or greenhouse is another dependable method of screening for resistance to *H. armigera* (7). Chickpea plants infested with 10 neonate or three third-instars per plant at the flowering stage can be used to screen for resistance to this pest. For valid comparison, resistant and susceptible checks of appropriate maturity should also be included, and infested at the same time as the test genotypes. Detached leaf assay can be used to evaluate a large number of lines for resistance to *H. armigera*.

Pod borer. More than 14,000 chickpea germplasm accessions have been screened for resistance to *H. armigera* at ICRISAT, India, under field conditions. 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 (3, 6), and varieties such as ICCV 7, ICCV 10, and ICCL 86103 with moderate levels of resistance have been released for cultivation (6). However, most of these lines are highly susceptible to *Fusarium* wilt. Therefore, concerted efforts have been made to break the linkage by raising a large population of crosses between the lines with resistance to *H. armigera* and the lines resistant to wilt. Inheritance of resistance to damage by *H. armigera* is largely governed by additive gene action, while dominance genetic variation is predominant in governing the inheritance of antibiosis component of resistance (larval survival and larval weight) and grain yield. Further studies on mechanisms and inheritance of resistance and use of morphological, biochemical, and molecular markers will be useful for increasing the levels and diversifying the basis of resistance to *H. armigera* in chickpea (8).

Leaf miner. Varieties with larger leaflets are preferred by the leaf miner than those with small leaflets. Oxalic acid content in chickpea leaves has been reported to be correlated with the level of resistance to leafminer. ILWC 39, ILC 3800, ILC 5901, and ILC 7738 are resistant to leafminer damage (2). Seven lines (FLIP 2005-1C, FLIP 2005-2C, FLIP 2005-3C, FLIP 2005-4C, FLIP 2005-5C, FLIP 2005-6C, and FLIP 2005-7C) have good agronomic background, seed size, and plant type, and have been distributed to national programs for evaluation under local conditions.

Aphid. Varieties with low trichome density or devoid of trichomes are highly susceptible to aphid, *A. craccivora* damage. The glabrous mutant of chickpea devoid of trichomes, is highly susceptible to aphid damage (Sharma, HC, Unpublished). A number of genotypes/lines were reported to be less susceptible to aphid damage (3).

Figure 1. Chickpea pods damaged by pod bore

Bruchid. High levels of resistance have been observed in desi type chickpeas to bruchids, *Callosobruchus* spp. The chickpea genotypes CPI 29973, CPI 29975, CPI 29976, NCS 960003, K 902, CM 72, CMN 122, and BG 372 have been reported to be resistant to *C. maculatus*. Apart from the cultigens, wild relatives of several grain legumes have shown high levels of resistance to bruchids (3). Lines showing resistance to bruchids usually have small seeds with a rough seed coat. However, such grain is not acceptable to the consumers. Chickpea seed that is split for *dhal* is unattractive to ovipoisiting bruchid females, and therefore, processing the chickpea into split peas or flour immediately after crop harvest can minimize the losses due to these.

Exploitation of wild relatives of chickpea for insect resistance

Based on leaf feeding, larval survival, and larval weights, accessions belonging to *C. bijugum* (ICC 17206, IG 70002, IG 70003, IG 70006, 70012, IG 70016, and IG 70016), *C. judaicum* (IG 69980, IG 70032, and IG 70033), *C. pinnatifidum* (IG 69948), and *C. reticulatum* (IG 70020, IG 72940, IG 72948, and IG 72949, and IG 72964) (6) showed resistance to *H. armigera*. With the use of inter-specific 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 than those in the cultivated types, which can be used in crop improvement to diversify the bases of resistance to this pest. Accessions of *C. reticulatum* have been used in the crossing program at ICRISAT, and interspecific derivatives evaluated under unprotected field conditions for resistance to pod borer. Many interspecific derivatives showed resistance levels better than the cultivated check, ICCV 10 (4). Wild relatives of chickpea are an important source of resistance to leaf miner, *Liriomyza ciceri* and the bruchid, *Collasobruchus chinensis*.Two accessions of *Cicer cuneatum* (ILWC 40 and ILWC 187) and 10 accessions of *C. judaicum* have been found to be highly resistant to leafminer damage.Accessions belonging to *C. bijugum, C. pinnatifidum* and*C. echinospermum* have shown resistance to the bruchid, *Collasobruchus chinensis*.

Table 1. Population dynamics of *Helicoverpa armigera* on a susceptible (ICCC 37), a moderately-resistant (ICCV 2), and a resistant (ICC 506) chickpea cultivars - A hypothetical example based on the model proposed by Knipling (1979)

Generation		No. of *Helicoverpa armigera* moths ha^{-1}		
		ICCC 37	ICCV 2	ICC 506
Parent generation	P_1	10	10	10
First generation	F_1	4250	3250	3000
Second generation	F_2	903125	528125	450000
Third generation	F_3	191914063	85820313	67500000
Population ratio in relation to the resistant check (ICC 506)		2.84	1.27	1.00

It has been assumed that each female moth lays an average of 500 eggs, and the sex ratio is 1:1. There are three generations in a cropping season. The *Helicoverpa armigera* population at the beginning of the season is assumed to be 10 female moths ha^{-1}. In each generation, the larval mortality is 15% in ICCC 37, 35% on ICCV 2, and 40% on ICC 506.

Transgenic chickpea for resistance to *Helicoverpa armigera*

Genetic transformation as a means to enhance crop resistance or tolerance to biotic constraints has shown considerable potential to achieve a more effective control of target insect pests for sustainable food production (5). The δ-endotoxin genes from the bacterium, *Bt* have been deployed in several crops for pest management. Transgenic plants expressing *cryIIa* have shown high levels of resistance to *H. armigera,* and are currently under testing in confined field trial at ICRISAT (1). Once released for commercialization, these will prove to an effective weapon for management of pod borers in chickpea.

Marker assisted selection for resistance to *Helicoverpa armigera*

Mapping complex traits such as resistance to pod borer, *H. armigera* in chickpea is only just beginning. A mapping population of 126 F_{13} RILs of ICCV 2 x JG 62, has been evaluated for resistance to *H. armigera*. The overall resistance score (1 = < 10 leaf area and/or pods damaged, and 9 = > 80% leaf area and/or pods damaged) varied from 1.7 to 6.0 in the RIL population compared to 1.7 in the resistant check, ICC 506EB, and 5.0 in the susceptible check, ICCV 96029. The results indicated that there is considerable variation in this mapping population for susceptibility to *H. armigera*. Another RIL mapping population from the cross between Vijay (susceptible) × ICC 506EB (resistant) has also been evaluated for resistance to *H. armigera*. Efforts are also underway to develop interspecific mapping populations based on the crosses between ICC 3137 (*C. arietinum*) × IG 72933 (*C. reticulatum*) and ICC 3137 × IG 72953 (*C. reticulatum*) for resistance to pod borer and to identify QTLs linked to various components of resistance to *H. armigera* (8).

Host plant resistance in IPM

Chickpea cultivars with resistance to insects can play major role in integrated pest management, particularly under subsistence farming (Table 1). Varieties such as Vijay, Vishal, ICCV 10, ICPL 88034, and ICCL 86103 with low to moderate levels of resistance to pod borers can be cultivated in India. Varieties with resistance to leaf miner and aphids have also been identified for use in West Asia. High levels of resistance have been observed in desi type chickpeas to bruchids, *Callosobruchus* spp. Early plantings generally suffer low damage due to leaf miner, and *Sitona* species in West Asia. Early sowing leads to early canopy closure, which also helps to reduce virus spread in chickpea. Therefore, early sowing and optimum planting densities can be used to minimize aphid infestation. Ploughing the fields before sowing and after crop harvest and flooding reduces the infestation and population carryover of pod borers and soil dwelling insects. Intercropping or stripped cropping of chickpea with marigold, sunflower, mustard, and coriander can minimize the extent of *H. armigera* damage to the main crop (6).

Parasitism by the egg parasitoid, *Trichogramma* spp. is very low on chickpea because of acidic glandular exudates. The ichneumonid parasitoid, *Campoletic chlorideae* Uchidaisthe most important larval parasitoid on *H. armigera*, while *Chrysoperla, Nabis, Geocoris, Orius,* and *Polistes* are the common predators attacking *Helicoverpa* on chickpea and other crops. Provision of bird perches or planting of tall crops such a sorghum and sunflower that serve as resting sites for insectivorous birds such as Myna and Drongo helps to reduce the numbers of caterpillars. A number of natural enemies have been reported on case of cutworms, *Sitona*, aphids, and other foliage feeders. However, except for aphids, natural enemies are not very effective in reducing insect damage under field conditions. HaNPV (nuclear polyhedrosis virus) and *Bacillus thuringiensis* can be used forminimizing the damage by *Helicoverpa*, and possibly other lepidopteran insects (*Spodoptera* spp.). Neem oil (1%) and neem seed kernel extract (NSKE, 10 kg/ha) are also effective against lepidopteran insects, leaf miner and the aphids. However, because of lower bioefficacy and nonpersistent nature, their use has not been widely adopted by the farmers. Cypermethrin, fenvalerate, methomyl, thiodicarb, profenophos, spinosad, and indoxacarb are effective against pod borers and other leaf feeding insects, particularly on cultivars with some degree of resistance/tolerance to pod borers.

Conclusions

Insect-resistant cultivars will form the backbone of integrated pest management in future. The development and deployment of cultivars 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. For pest management programs to be effective in future, there is a need for in-depth understanding of the population dynamics of insect pests to develop appropriate control strategies, combine resistance to insects with resistance to important diseases and cold tolerance, utilization of wild relatives 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, develop insect-resistant varieties through genetic transformation using genes with diverse modes of action, and insecticide resistance management. Development of bio-pesticides with stable formulations, and strategies for conservation of natural enemies is essential for integrated pest management. ■

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