Evaluation of Wild Relatives of Chickpea (*Cicer* spp.) for Resistance to Pod Borer, *Helicoverpa armigera* (Hubner)

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The legume pod borer, *Helicoverpa armigera*, is a major constraint to chickpea production worldwide. The levels of resistance in the cultivated chickpea germplasm are moderate, and therefore, we evaluated 93 accessions of annual wild relatives of chickpea in the field, and 141 accessions under greenhouse conditions for resistance to *H. armigera*. Under field conditions, 24 accessions showed a leaf feeding score of <2.0 compared to 6.0 to 6.5 of the *Cicer reticulatum* accession IG 69975. These accessions also had less than 2 eggs and/or larvae of *H. armigera* and <2 larvae of *Spodoptera exigua* per plant at the flowering/podding stages. Based on leaf feeding, larval survival, and larval weights in the detached leaf assay, 41 accessions showed low leaf feeding, reduced larval weights, and / or low larval survival. Accessions IG 69947, IG 70002, IG 70003, IG 70009, IG 70019, IG 70022, ICC 17125, IG 69979 ICC 17122, ICC 17156, IG 70006, and ICC 17187 (*C. bijugum*), IG 69995 and IG 70030 (*C. judaicum*), and IG 69988, IG 69999 IG 70021, IG 70025, and IG 70028 (*C. pinnatifidum*) showed low leaf feeding, low larval weights, and low host suitability index. These accessions can be exploited for introgressing resistance genes from the wild relatives into the cultivated chickpeas to increase the levels and diversify the basis of resistance to *H. armigera*.

Key Words: *Cicer* spp., *Helicoverpa armiger*, Host plant resistance, pod borer

Chickpea (*Cicer arietinum* L.) is one of the most important grain legumes in Asia, parts of East and North Africa, and the Mediterranean Europe. In recent years, it has gained importance in Australia, Canada, and USA. Pod borer, *Helicoverpa armigera* (Hubner), *Fusarium* wilt, *Aschochyta* blight, *Botrytis* gray mold, and drought are the major constraints limiting the production and productivity of this crop worldwide. Of these, *H. armigera* has been estimated to cause a loss of $325 million annually in the semi-arid tropics (ICRISAT 1992). Because of excessive use of insecticides to control this pest on cotton, grain legumes, vegetables and other high value crops, this pest has developed high levels of resistance to the commonly used insecticides (Kranti *et al.*, 2002). Therefore, there is a need to focus on alternative methods, including host plant resistance for integrated pest management in chickpea (Sharma, 2001). However, only low to moderate levels of resistance are available in the cultivated germplasm of chickpea (Lateef, 1985; Lateef and Sachan, 1990). Therefore, there is a need to identify wild relatives of chickpea with high levels of resistance to this pest. Some of the accessions of wild relatives of chickpea have shown high levels of resistance to cyst nematode, wilt, gray mold, leaf miner and the bruchids (Malhotra *et al.*, 2002). However, there is no information on the relative susceptibility of wild relatives of chickpea to the pod borer, *H. armigera*. Therefore, all the accessions of annual wild relatives of chickpea available at the ICRISAT genebank, were evaluated for resistance to *H. armigera* under field and greenhouse conditions.

Materials and Methods

Evaluation of wild relatives of chickpea for resistance to Helicoverpa armigera under field conditions

To evaluate the relative resistance or susceptibility of annual wild relatives of chickpea to *H. armigera*, 93 accessions were planted in the field during the 2001/02 post-rainy season at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India. However, only 51 accessions germinated or survived in the field. Of these, 20 accessions belonged to *Cicer bijugum*, 1 to *C. cuneatum*, 2 to *C. judaicum*, 11 to *C. pinnnatifidum*, 16 to *C. reticulatum*, and 1 to *C. yamashitae*. Three chickpea cultivars (ICC 506 EB – moderately resistant; ICCV 2 – susceptible Kabuli type, and Annigeri - local check) were included as controls. During the 2002/03 post-rainy season, 93 accessions were planted in the field. Out of the 92 accessions that germinated, 23 accessions belonged to *C. bijugum*, 2 to *C. cuneatum*, 23 to *C. judaicum*, 14 to *C. pinnnatifidum*, 25 to *C. reticulatum*, 3 to *C. yamashitae*, 1 to *C. chorassanicum* and 1 to

C. echinospermum. Each entry was sown in a one-row plot, 2-m long, and there were five plants in each row. There were two replications in a randomized complete block design. The seeds of the wild relatives were scarified at one end with a sharp knife, soaked in water for 24 h, and treated with thiram (3 g per kg of seed) before sowing to enhance water absorption and faster germination. The seeds of cultivated chickpeas were sown without scarification. The trial was planted on ridges 60-cm apart on deep black soils (Vertisols). The seeds were sown in hills at a spacing of 50-cm between the hills at a depth of 5-cm below the soil surface. Normal agronomic practices were followed for raising the crop (basal fertilizer N: P: K :: 50: 60: 40 kg ha^{-1}). Interculture and weeding operations were carried out as needed. The field was irrigated immediately after sowing, and at intervals of one month thereafter. At the flowering stage, data were recorded on eggs and larvae per 5 plants and leaf damage on a 1 to 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged).

Evaluation of Wild Relatives of Chickpea for Resistance to H. armigera under Greenhouse Conditions

During the 2002 postrainy season, 141 accessions of annual chickpea wild relatives, along with three cultivated chickpea genotypes (ICC 506 – moderately resistant, ICCV 10 commercial check, and Annigeri – susceptible local landrace) were evaluated for resistance to *H. armigera* under no-choice conditions using the detached leaf assay (Sharma *et al.,* 2002b). The plants were grown in plastic pots (30-cm diameter, 30-cm deep) in the greenhouse. The pots were filled with a potting mixture of black soil (Vertisols), sand, and farmyard manure (2: 1: 1). The seeds were scarified at one end, treated with thiram (3 g per kg of seed) and placed in a Petri dish containing agar-agar (0.5%) for germination. After germination, the plants were transplanted into the soil and watered immediately. One seedling was transplanted in each pot, and the plants were watered as needed. There were five plants for each accession. The pots were arranged in a completely randomized design. The greenhouse was cooled by desert coolers to maintain the temperature at 27 ± 5°C, and relative humidity >65%. Additional lighting was provided (14 h photoperiod) to induce flowering and pod formation.

Detached Leaf Assay

The accessions grown under field and/or greenhouse conditions were tested for resistance to *H. armigera* at the vegetative stage (50 days after germination) using the detached leaf assay. Terminal branches (2 to 3 fully expanded leaves and a bud) of chickpea seedlings were used to measure genotypic resistance to *H. armigera* (Sharma *et al.,* 2002b). The chickpea branches were cut with scissors, and immediately planted in a slanting manner into 3% agar-agar medium in a 250 ml plastic cup. There were five replications for each accession in a completely randomized design. Ten neonate larvae of *H. armigera* raised in the laboratory (Sharma *et al.,* 2001) were released on the chickpea leaves with a camel hairbrush. The cups were kept in the laboratory at 27±2° C, and 45 to 75% relative humidity. Observations were recorded 5 days after releasing the larvae on the leaves, when the differences between the resistant and susceptible checks were maximum. First, the plants were scored for leaf feeding on a 1 to 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged). The number of larvae surviving after the feeding period were recorded, and placed in 25 ml plastic cups. The weights of larvae were recorded 4 h after separating them from the food. The data were expressed as percentage larval survival and mean weight of the larvae. Data on leaf damage rating, larval survival and larval weights were used to compute host suitability index (resistance index) for each accession.

Resistance (host suitability) index = Larval weight/ damage rating x larval survival) (low values indicating high levels of resistance, and high values denoting low resistance/high susceptibility).

Statistical Analysis

Data were subjected to analysis of variance using GENSTAT release 5.0. The significance of differences between the treatments was measured by *F*-test at *P* 0.05. The treatment means were compared using least significant difference (LSD) at $P \leq 0.05$.

Results

Reaction of different accessions of wild relatives of chickpea to Helicoverpa armigera under field conditions

Under field conditions, 24 accessions showed a leaf damage rating of <2.0 compared to 6.0 to 6.5 of the *Cicer reticulatum* accession IG 69975 (Table 1). These accessions also had less than 2 eggs and larvae of *H. armigera* and *S. exigua* per plant at the flowering stage. High egg and larval numbers were recorded on IG 69975, IG 70020, IG 72937, IG 72942, IG 72938, IG 72944,

Table 1. Screening of wild chickpea accessions for *Helicoverpa armigera* in the field (ICRISAT, Patancheru, 2002/03 post-rainy season)

Accession	Alternate accession identifier	Species	Damage rating*		*Helicoverpa armigera*	*Spodoptera exigua*
			2001/02	2002/03	Eggs + larvae per plant	Larvae per plant
IG 69942	ILWC 3	*C. yamashitae*	*	2.3	1.0	1.7
IG 69946	ILWC 7	*C. bijugum*	3.0	4.0	4.0	5.0
IG 69947	ILWC 8	*C. bijugum*	5.4	3.0	3.0	1.7
IG 69959	ILWC 20	*C. judaicum*	*	1.0	0.0	1.0
IG 69960	ILWC 21	*C. reticulatum*	6.0	2.3	3.0	1.0
IG 69968	ILWC 29	*C. pinnatifidum*	1.1	2.0	1.0	0.0
IG 69969	ILWC 30	*C. judaicum*	*	1.3	2.0	0.0
IG 69970	ILWC 31	*C. judaicum*	*	2.0	1.0	0.0
IG 69972	ILWC 33	*C. pinnatifidum*	1.5	–	*	*
IG 69974	ILWC 35	*C. echinospermum*	*	2.0	2.3	1.0
IG 69975	ILWC 36	*C. reticulatum*	6.5	6.0	8.0	0.0
IG 69976	ILWC 37	*C. cuneatum*	*	1.5	3.0	1.0
IG 69977	ILWC 38	*C. judaicum*	*	1.0	0.0	0.0
IG 69979	ILWC 40	*C. cuneatum*	1.0	1.0	0.0	1.0
IG 69980	ILWC 41	*C. judaicum*	*	1.0	2.0	0.0
IG 69981	ILWC 42	*C. bijugum*	*	3.3	3.7	2.5
IG 69982	ILWC 43	*C. judaicum*	*	1.3	3.0	1.0
IG 69986	ILWC 47	*C. judaicum*	*	3.0	2.0	0.0
IG 69987	ILWC 48	*C. judaicum*	*	1.0	5.3	1.0
IG 69988	ILWC 49	*C. pinnatifidum*	2.0	3.3	0.0	1.5
IG 69989	ILWC 50	*C. judaicum*	*	2.0	0.0	0.0
IG 69990	ILWC 51	*C. pinnatifidum*	1.0	3.3	0.0	1.0
IG 69992	ILWC 53	*C. yamashitae*	*	3.3	2.7	1.5
IG 69993	ILWC 54	*C. judaicum*	*	4.0	3.0	1.0
IG 69994	ILWC 55	*C. yamashitae*	0.4	2.0	4.0	2.0
IG 69995	ILWC 56	*C. judaicum*	*	1.0	2.0	1.0
IG 69996	ILWC 57	*C. judaicum*	*	1.5	1.0	0.0
IG 69997	ILWC 58	*C. judaicum*	*	2.0	0.0	3.0
IG 69998	ILWC 59	*C. judaicum*	*	3.5	1.0	0.0
IG 69999	ILWC 60	*C. pinnatifidum*	*	2.3	3.0	1.5
IG 70000	ILWC 61	*C. judaicum*	*	1.0	1.0	1.0
IG 70001	ILWC 62	*C. bijugum*	*	2.7	5.0	2.0
IG 70002	ILWC 63	*C. bijugum*	2.5	2.7	5.7	2.7
IG 70003	ILWC 64	*C. bijugum*	2.5	2.7	2.0	3.3
IG 70004	ILWC 65	*C. bijugum*	2.5	3.0	12.0	2.0
IG 70005	ILWC 66	*C. bijugum*	4.1	2.5	3.0	0.0
IG 70006	ILWC 67	*C. bijugum*	3.5	3.3	4.0	2.7
IG 70007	ILWC 68	*C. bijugum*	3.0	3.0	5.0	2.0
IG 70008	ILWC 69	*C. bijugum*	2.5	3.5	3.0	1.0
IG 70009	ILWC 70	*C. bijugum*	3.5	3.3	4.0	1.0
IG 70010	ILWC 71	*C. bijugum*	3.0	2.3	5.0	1.5
IG 70011	ILWC 72	*C. bijugum*	4.5	3.0	0.0	2.5
IG 70012	ILWC 73	*C. bijugum*	4.1	2.7	5.0	4.5
IG 70013	ILWC 74	*C. bijugum*	3.5	2.7	7.5	2.0
IG 70014	ILWC 75	*C. bijugum*	3.1	2.7	3.0	3.7
IG 70015	ILWC 76	*C. bijugum*	2.5	3.0	5.0	2.0
IG 70016	ILWC 77	*C. bijugum*	2.4	2.7	6.0	3.5

Accession	Alternate accession identifier	Species	Damage rating*		*Helicoverpa armigera*	*Spodoptera exigua*
			2001/02	2002/03	Eggs + larvae per plant	Larvae per plant
IG 70017	ILWC 78	*C. pinnatifidum*	0.9	2.0	0.0	2.0
IG 70018	ILWC 79	*C. bijugum*	5.0	2.7	2.5	2.3
IG 70019	ILWC 80	*C. bijugum*	3.5	3.0	1.5	2.0
IG 70020	ILWC 81	*C. reticulatum*	4.0	2.3	12.0	17.0
IG 70021	ILWC 82	*C. pinnatifidum*	*	2.0	0.0	2.0
IG 70022	ILWC 83	*C. bijugum*	*	3.0	1.5	1.0
IG 70023	ILWC 84	*C. bijugum*	3.5	3.3	10.0	3.0
IG 70024	ILWC 85	*C. pinnatifidum*	1.9	2.0	1.0	3.0
IG 70025	ILWC 86	*C. pinnatifidum*	1.5	1.5	2.0	1.0
IG 70026	ILWC 87	*C. pinnatifidum*	1.0	1.3	2.0	1.0
IG 70027	ILWC 88	*C. pinnatifidum*	*	2.7	0.0	0.0
IG 70028	ILWC 89	*C. pinnatifidum*	1.1	2.3	1.5	1.5
IG 70029	ILWC 90	*C. chorassanicum*	*	2.0	0.0	1.0
IG 70032	ILWC 93	*C. judaicum*	0.4	1.3	3.0	0.0
IG 70033	ILWC 94	*C. judaicum*	*	1.0	5.0	0.0
IG 70034	ILWC 95	*C. judaicum*	*	2.0	1.5	2.0
IG 70035	ILWC 96	*C. pinnatifidum*	*	2.0	1.5	0.0
IG 70036	ILWC 97	*C. pinnatifidum*	1.1	2.0	1.0	1.5
IG 70037	ILWC 98	*C. judaicum*	*	1.3	1.0	0.0
IG 70038	ILWC 99	*C. judaicum*	*	1.0	2.0	2.0
IG 70039	ILWC 100	*C. pinnatifidum*	*	3.0	3.5	0.0
IG 72930	ILWC 101	*C. judaicum*	*	1.0	5.0	1.0
IG 72931	ILWC 102	*C. judaicum*	1.4	1.5	6.5	1.0
IG 72932	ILWC 103	*C. judaicum*	*	1.3	1.0	2.0
IG 72933	ILWC 104	*C. reticulatum*	*	2.3	1.7	2.0
IG 72934	ILWC 105	*C. reticulatum*	*	2.0	2.0	1.0
IG 72935	ILWC 106	*C. reticulatum*	*	2.0	4.0	1.0
IG 72936	ILWC 107	*C. reticulatum*	*	3.0	2.5	1.0
IG 72937	ILWC 108	*C. reticulatum*	3.0	2.0	11.0	33.0
IG 72938	ILWC 109	*C. reticulatum*	*	2.7	5.3	0.0
IG 72939	ILWC 110	*C. reticulatum*	*	3.0	3.5	2.0
IG 72940	ILWC 111	*C. reticulatum*	3.5	2.0	3.7	2.0
IG 72941	ILWC 112	*C. reticulatum*	4.5	2.3	1.3	1.5
IG 72942	ILWC 113	*C. reticulatum*	5.5	2.0	5.7	1.0
IG 72943	ILWC 114	*C. reticulatum*	*	2.7	2.5	2.0
IG 72944	ILWC 115	*C. reticulatum*	4.0	2.7	9.5	2.0
IG 72945	ILWC 116	*C. reticulatum*	4.0	2.5	1.5	0.0
IG 72946	ILWC 117	*C. reticulatum*	5.5	1.0	7.0	1.0
IG 72948	ILWC 119	*C. reticulatum*	*	2.3	3.7	6.0
IG 72949	ILWC 120	*C. reticulatum*	7.0	3.3	3.0	2.0
IG 72951	ILWC 122	*C. reticulatum*	3.5	3.3	2.0	4.0
IG 72952	ILWC 123	*C. reticulatum*	6.0	2.7	3.3	5.7
IG 72953	ILWC 124	*C. reticulatum*	5.5	2.0	3.0	1.5
IG 72955	ILWC 126	*C. reticulatum*	5.1	3.0	1.0	2.0
IG 72958	ILWC 129	*C. reticulatum*	*	3.0	7.0	1.0
IG 72959	ILWC 130	*C. reticulatum*	4.5	2.0	2.0	2.0
Mean				2.3	3.1	2.0
SE				±0.73	±2.84	±2.29

* Damage rating (1 = <10% leaf area damaged, and 9 >80% leaf area damaged).

IG 72946 and IG 72958 (*C. reticulatum*), IG 69987, IG 70033 and IG 72930, (*C. judaicum*), and IG 7004, IG 70007, IG 70010, IG 70012, IG 70013, IG 70015, IG 70016 and IG 70023 (*C. bijugum*). Since cultivated chickpeas matured much earlier than the wild relatives, no data were recorded on them for comparison with the wild relatives.

Reaction of wild relatives of chickpea grown under field conditions for resistance to neonate larvae of H. armigera– detached leaf assay

In the plants grown under field conditions, leaf damage rating varied from 2.4 in ICC 506 to 9.0 in IG 69968, and five accessions showed a leaf damage rating of <5.0, compared to 2.4 and 3.0 in ICC 506, and 5.5 and 6.2 in Annigeri in the first and second experiments, respectively (Table 2). The larval weights varied from 1.20 to 6.59 mg in the first experiment, and 1.47 to 6.07 mg in the second experiment. The larval weights of *H. armigera* were less than half on IG 69947, IG 70002, IG 70006, IG 70009, IG 70010, IG 70013, and IG 70016 (*C. bijugum*), IG 69979 (*C. cuneatum*), and IG 70017 (*C. pinnatifidum*) as compared to larval weights on the cultivated chickpea, ICCC 37 (first experiment) or ICCV 2 (second experiment). The larval survival varied from 52 to 95% in the first experiment, and 70 to 98% in the second experiment. Based on resistance index, accessions IG 69947, IG 70006, IG 70016, IG 70003, and IG 70008 (*C. bijugum*), IG 69979 (*C. cuneatum*), and IG 70025, IG 70028, IG 70036, and IG 70017 (*C. pinnatifidum*) showed evidence for high levels of resistance to *H. armigera*. The leaf damage ratings in general were greater in the detached leaf assay than those observed under natural field conditions. It may be because of low levels of infestation in the field, and/or existence of oviposition non-preference as one of the components of resistance to *H. armigera*.

Reaction of wild relatives of chickpea grown under greenhouse conditions for resistance to H. armigera

The accessions were tested in five sets of 30-35 accessions, along with the resistant and susceptible checks of the cultivated chickpeas to maintain precision and timely observations (Table 3). In the first experiment, the leaf feeding scores ranged from 3.8 in IG 69947 to 9.0 in IG 70031, IG 70021 and IG 70035 in the wild relatives, compared to 6.6 in ICCC 37 and 5.0 in Annigeri (Table 3). The larval weights were <1.50 mg on 16 accessions of the wild relatives compared to 2.45 mg on ICCV 10 (moderately resistant check) and 4.23 mg on ICCC 37 (susceptible check). The resistance index of these genotypes was <1.5 compared to 2.93 of ICCV 10 and 6.28 of ICCC 37. Larval survival ranged from 54% on IG 69990 to 98% on ICCC 37. Accessions IG 69947 and IG 70002 (*C. bijugum*), and IG 69988 (*C. pinnatifidum*) showed low leaf feeding, low larval weights, and low host suitability index.

In the second experiment, 10 accessions showed leaf damage rating of <5.2 compared to 7.6 in ICC 506, and 8.8 in ICCV 10. The larval weights on these accessions were <1.34 mg compared to 2.63 mg on ICC 506, and 3.39 mg on ICCV 10. Larval survival was 56 to 68% on 7 accessions of the wild relatives compared to 72% on ICC 506 and ICCV 10, and 82% on Annigeri. Accessions IG 70003 (*C. bijugum*), IG 69995 and IG 70030 (*C. judaicum*), IG 69999 IG 70021, IG 70025, and IG 70028 (*C. pinnatifidum*) showed high resistance (resistance index <1.5 compared to 2.43 of Annigeri, and 2.49 of ICC 506).

In the third experiment, five accessions showed leaf-feeding scores of <5.0 compared to 9.0 in ICC 506 and 8.5 on Annigeri. Larval weights were <1.5 mg on 13 accessions compared to 3.93 mg on ICC 506 and ICCC 37, and 5.61 mg on Annigeri. Larval survival was <60% on eight accessions compared to 90% on IG 69994, 76% on ICC 506, and 88% on Annigeri. Accessions IG 70009, IG 70019, and IG 70022, (*C. bijugum*) showed evidence for low leaf feeding and reduced larval weights. Host suitability index was poor (<1.47 compared to 3.32 on ICC 506 and 5.78 on Annigeri) on 12 accessions, of which IG 70009, IG 70019, and IG 70022 (*C. bijugum*) suffered low leaf damage, and the larval weights and larval survival were also very low.

In the fourth experiment, ICC 17125, IG 69979, ICC 17198, and ICC 17211 showed leaf damage rating of <5.4 compared to 8.5 on Annigeri. Larval weights were <1.5 mg on 19 accessions, as compared to 5.61 on Annigeri. Thirteen accessions showed poor host suitability index (<1.55 compared to 3.32 of ICC 506 and 5.78 of Annigeri), of which ICC 17125 and IG 69979 (*C. bijugum*) also showed evidence for low leaf feeding and low larval weights.

In the fifth experiment, leaf-feeding scores ranged from 4.6 on ICC 17122 to 9.0 on ICC 17212, ICC 17126, ICC 17152, ICC 17153, ICC 17155, and ICC 17209 as compared to 5.4 on ICC 506 and 8.8 on ICCC 37.

Table 2. Relative susceptibility of wild relatives of chickpea grown under field conditions to *Helicoverpa armigera* – detached leaf assay (ICRISAT, Patancheru, India 2002 post-rainy season)

Accession	Species	Damage rating*	Larval weight (mg)	Larval survival (%)	Resistance index
Ist experiment					
IG 69946	*C. bijugum*	5.8	2.13	86	3.16
IG 69947	*C. bijugum*	7.8	1.51	68	1.32
IG 70002	*C. bijugum*	6.2	1.78	86	2.47
IG 70006	*C. bijugum*	4.4	1.20	56	1.53
IG 70007	*C. bijugum*	6.6	2.36	88	3.15
IG 70009	*C. bijugum*	4.8	1.72	88	3.15
IG 70010	*C. bijugum*	6.8	1.74	92	2.35
IG 70011	*C. bijugum*	7.0	1.94	90	2.49
IG 70013	*C. bijugum*	5.2	1.86	88	3.15
IG 70016	*C. bijugum*	5.8	1.66	82	2.35
IG 70018	*C. bijugum*	4.2	2.03	92	4.45
IG 70023	*C. bijugum*	6.6	1.94	98	2.88
IG 69979	*C. cuneatum*	5.8	1.62	72	2.01
IG 72931	*C. judaicum*	7.4	2.31	88	2.75
IG 70032	*C. judaicum*	7.8	2.61	70	2.34
IG 70025	*C. pinnatifidum*	8.8	2.93	52	1.73
IG 69975	*C. reticulatum*	4.4	3.65	76	6.30
IG 72937	*C. reticulatum*	5.9	4.85	82	6.74
IG 72941	*C. reticulatum*	6.4	2.88	68	3.06
IG 72944	*C. reticulatum*	5.6	6.59	90	10.59
IG 72946	*C. reticulatum*	5.0	5.00	92	9.20
IG 72949	*C. reticulatum*	6.4	3.74	92	5.38
IG 72951	*C. reticulatum*	5.4	4.83	86	7.69
IG 72953	*C. reticulatum*	7.2	3.89	78	4.21
IG 72959	*C. reticulatum*	7.2	4.76	86	5.69
IG 69994	*C. yamashitae*	8.5	3.85	95	4.30
Cultivated chickpea					
ICC 506 EB	*C. arietinum*	2.4	3.27	72	9.81
ICCC 37	*C. arietinum*	2.8	3.82	62	8.46
Annigeri	*C. arietinum*	5.5	3.74	69	4.69
SE		±0.56	±0.33	±7.14	
LSD		2.13	1.21	19.7	

Accession	Species	Damage rating*	Larval weight (mg)	Larval survival (%)	Resistance index
IInd Experiment					
IG 70003	*C. bijugum*	4.2	2.92	92	6.40
IG 70004	*C. bijugum*	8.0	2.80	96	3.36
IG 70005	*C. bijugum*	8.8	3.54	84	3.38
IG 70008	*C. bijugum*	6.2	3.06	86	4.24
IG 70012	*C. bijugum*	5.8	2.73	94	4.42
IG 70014	*C. bijugum*	7.0	3.26	98	4.56
IG 70015	*C. bijugum*	7.8	3.33	98	4.18
IG 70019	*C. bijugum*	8.0	2.45	78	2.39
IG 69961	*C. pinnatifidum*	8.6	2.22	88	2.27
IG 69968	*C. pinnatifidum*	9.0	3.57	88	3.49
IG 69972	*C. pinnatifidum*	8.8	3.14	74	2.64
IG 69988	*C. pinnatifidum*	8.8	4.06	92	4.24
IG 69990	*C. pinnatifidum*	8.8	3.14	86	3.07
IG 70017	*C. pinnatifidum*	9.0	1.47	76	1.24
IG 70024	*C. pinnatifidum*	8.8	3.70	92	3.87
IG 70026	*C. pinnatifidum*	8.4	4.08	94	4.57
IG 70028	*C. pinnatifidum*	7.2	3.94	80	4.38
IG 70036	*C. pinnatifidum*	7.6	3.01	84	3.33
IG 69960	*C. reticulatum*	7.6	5.21	90	6.17
IG 70020	*C. reticulatum*	5.5	4.90	96	8.55
IG 72940	*C. reticulatum*	6.8	4.55	88	5.89
IG 72942	*C. reticulatum*	7.6	4.50	94	5.57
IG 72945	*C. reticulatum*	8.4	5.66	94	6.33
IG 72952	*C. reticulatum*	8.2	6.07	84	6.22
IG 72955	*C. reticulatum*	7.6	5.42	90	6.42
Cultivated chickpea					
ICC 506	*C. arietinum*	3.0	2.40	70	5.60
ICCV 2	*C. arietinum*	4.3	4.06	74	6.99
Annigeri	*C. arietinum*	6.2	2.37	80	3.06
SE		±1.20	±0.93	±15.64	
LSD		16.4	25.6	17.9	

*Damage rating (1 = <10% leaf area consumed, and 9 = >80% leaf area consumed).

Table 3. Relative susceptibility of wild relatives of chickpea grown under greenhouse conditions to *Helicoverpa armigera* – detached leaf assay (ICRISAT, Patancheru, India 2002)

Accession	Species	Damage rating*	Larval weight (mg)	Larval survival (%)	Resistance index
Ist experiment					
IG 69947	*C. bijugum*	3.8	0.72	78	1.48
IG 69981	*C. bijugum*	6.0	1.02	86	1.46
IG 70002	*C. bijugum*	5.2	1.07	86	1.77
IG 70009	*C. bijugum*	8.4	1.13	90	1.21
IG 69976	*C. cuneatum*	6.8	1.54	70	1.59

Accession	Species	Damage rating*	Larval weight (mg)	Larval survival (%)	Resistance index
IG 69943	*C. judaicum*	7.6	1.75	84	1.93
IG 69980	*C. judaicum*	7.0	1.80	82	2.11
IG 69982	*C. judaicum*	7.8	1.83	80	1.88
IG 69948	*C. pinnatifidum*	8.2	1.32	76	1.22
IG 69968	*C. pinnatifidum*	8.6	1.20	68	0.95
IG 69972	*C. pinnatifidum*	8.6	0.98	70	0.80

Accession	Species	Damage rating*	Larval weight (mg)	Larval survival (%)	Resistance index
IG 69988	*C. pinnatifidum*	5.4	1.64	90	2.73
IG 69990	*C. pinnatifidum*	8.8	1.98	54	1.22
IG 69999	*C. pinnatifidum*	8.8	0.75	66	0.56
IG 70021	*C. pinnatifidum*	9.0	1.04	74	0.86
IG 70026	*C. pinnatifidum*	8.0	1.45	62	1.12
IG 70027	*C. pinnatifidum*	8.4	1.08	76	0.98
IG 70031	*C. pinnatifidum*	9.0	1.12	58	0.72
IG 70035	*C. pinnatifidum*	9.0	0.94	70	0.73
IG 69960	*C. reticulatum*	6.2	1.26	80	1.63
IG 69975	*C. reticulatum*	6.2	1.60	68	1.75
IG 72933	*C. reticulatum*	6.4	1.33	72	1.50
IG 72934	*C. reticulatum*	7.4	1.76	72	1.71
IG 72941	*C. reticulatum*	7.7	1.75	62	1.41
IG 72942	*C. reticulatum*	7.2	1.92	72	1.92
IG 72943	*C. reticulatum*	8.0	1.40	74	1.30
IG 72949	*C. reticulatum*	8.2	2.19	80	2.14
IG 69942	*C. yamashitae*	8.4	2.32	78	2.15
IG 69992	*C. yamashitae*	8.2	1.51	74	1.36
Cultivated chickpea					
Annigeri	*C. arietinum*	5.0	3.83	86	6.59
ICCV 10	*C. arietinum*	7.2	2.45	86	2.93
ICCC 37	*C. arietinum*	6.6	4.23	98	6.28
SE		±1.30	±0.45	±6.61	
LSD at 5%		2.14	0.75	18.5	
II[nd] experiment					
IG 70003	*C. bijugum*	2.8	0.57	72	1.47
IG 70004	*C. bijugum*	3.8	1.15	78	2.36
IG 70007	*C. bijugum*	4.0	1.13	64	1.81
IG 70008	*C. bijugum*	5.0	1.2	80	1.92
IG 70010	*C. bijugum*	4.4	1.30	76	2.25
IG 69995	*C. judaicum*	7.8	1.39	78	1.39
IG 69998	*C. judaicum*	5.4	2.18	62	2.50
IG 70000	*C. judaicum*	3.8	1.33	78	2.73
IG 70030	*C. judaicum*	6.4	0.99	86	1.33
IG 70034	*C. judaicum*	7.0	1.62	82	1.90
IG 69999	*C. pinnatifidum*	7.8	0.92	56	0.66
IG 70021	*C. pinnatifidum*	8.2	1.32	66	1.06
IG 70025	*C. pinnatifidum*	8.2	1.51	64	1.18
IG 70028	*C. pinnatifidum*	7.2	0.89	70	0.87
IG 72936	*C. reticulatum*	4.2	1.34	74	2.36
IG 72937	*C. reticulatum*	3.0	0.90	82	2.46
IG 72939	*C. reticulatum*	6.4	1.95	70	2.13
IG 72944	*C. reticulatum*	5.6	2.16	66	2.55
IG 72945	*C. reticulatum*	6.2	2.32	72	2.69
IG 72952	*C. reticulatum*	5.4	1.97	80	2.92
IG 72953	*C. reticulatum*	5.0	1.31	68	1.78
IG 72955	*C. reticulatum*	6.0	1.68	84	2.35
IG 72958	*C. reticulatum*	5.0	1.22	80	1.95
IG 72959	*C. reticulatum*	5.2	1.24	80	1.91

Accession	Species	Damage rating*	Larval weight (mg)	Larval survival (%)	Resistance index
Cultivated chickpea					
ICC 506	*C. arietinum*	7.6	2.63	72	2.49
ICCV 10	*C. arietinum*	8.8	3.39	72	2.77
Annigeri	*C. arietinum*	7.8	2.31	82	2.43
SE		±1.2	±0.81	±14.28	
LSD at 5%		1.9	1.34	23.65	
III[rd] experiment					
IG 69946	*C. bijugum*	5.4	0.99	74	1.36
IG 70009	*C. bijugum*	3.8	0.69	70	1.27
IG 70011	*C. bijugum*	6.2	1.20	74	1.43
IG 70012	*C. bijugum*	4.6	1.07	74	1.72
IG 70013	*C. bijugum*	6.2	1.25	72	1.45
IG 70014	*C. bijugum*	5.2	1.22	84	1.97
IG 70015	*C. bijugum*	5.0	1.49	66	1.97
IG 70018	*C. bijugum*	5.6	1.37	78	1.91
IG 70019	*C. bijugum*	4.2	0.89	50	1.06
IG 70022	*C. bijugum*	4.4	0.63	52	0.74
IG 70023	*C. bijugum*	5.6	2.61	52	2.42
IG 70029	*C. chorassanicum*	8.6	1.45	52	0.88
IG 69974	*C. echinospermum*	8.2	2.41	78	2.29
IG 69970	*C. judaicum*	7.0	1.69	70	1.69
IG 69977	*C. judaicum*	7.4	3.13	54	2.28
IG 69987	*C. judaicum*	7.8	1.63	78	1.63
IG 70032	*C. judaicum*	6.4	1.74	70	1.90
IG 70033	*C. judaicum*	7.6	1.54	76	1.54
IG 70038	*C. judaicum*	8.2	1.63	74	1.47
IG 69961	*C. pinnatifidum*	7.8	1.33	60	1.02
IG 70024	*C. pinnatifidum*	8.4	1.63	62	1.20
IG 70036	*C. pinnatifidum*	8.8	1.85	50	1.05
IG 70039	*C. pinnatifidum*	8.2	1.13	54	0.74
IG 70020	*C. reticulatum*	7.6	2.00	80	2.11
IG 72940	*C. reticulatum*	7.2	1.76	74	1.81
IG 69994	*C. yamashitae*	7.8	1.81	90	2.09
Cultivated chickpea					
ICC 506	*C. arietinum*	9.0	3.93	76	3.32
ICCC 37	*C. arietinum*	7.6	3.93	68	3.52
Annigeri	*C. arietinum*	8.5	5.61	87.5	5.78
SE		±1.10	±0.55	±14.89	
LSD at 5%		1.83	0.92	24.72	
IV[th] experiment					
ICC 17125	*C. bijugum*	5.0	0.97	80	1.55
IG 69979	*C. cuneatum*	5.2	1.25	76	1.83
ICC 17148	*C. judaicum*	7.1	1.08	78	1.19
ICC 17149	*C. judaicum*	6.0	1.35	80	1.80
ICC 17150	*C. judaicum*	6.2	1.40	68	1.54
ICC 17191	*C. judaicum*	8.4	1.39	82	1.36
ICC 17192	*C. judaicum*	7.6	1.58	96	2.00
ICC 17193	*C. judaicum*	6.2	1.25	60	1.21

Accession	Species	Damage rating*	Larval weight (mg)	Larval survival (%)	Resistance index
ICC 17195	*C. judaicum*	7.4	1.18	92	1.47
ICC 17197	*C. judaicum*	5.6	1.05	80	1.50
ICC 17198	*C. judaicum*	5.4	1.57	78	2.27
ICC 17199	*C. judaicum*	7.8	1.90	72	1.75
ICC 17204	*C. judaicum*	8.0	1.15	76	1.09
ICC 17205	*C. judaicum*	6.6	1.17	82	1.45
ICC 17208	*C. judaicum*	8.0	1.49	86	1.60
ICC 17211	*C. judaicum*	4.4	1.18	86	2.31
IG 70032	*C. judaicum*	7.2	1.20	70	1.17
IG 70033	*C. judaicum*	6.4	1.50	62	1.45
IG 70034	*C. judaicum*	7.4	1.38	66	1.23
IG 70038	*C. judaicum*	7.0	1.01	64	0.92
IG 72931	*C. judaicum*	7.4	0.88	76	0.90
ICC 17200	*C. pinnatifidum*	8.4	2.05	68	1.66
ICC 17201	*C. pinnatifidum*	6.4	2.23	82	2.86
ICC 17203	*C. pinnatifidum*	8.4	2.07	68	1.68
ICC 17121	*C. reticulatum*	7.0	2.07	82	2.42
ICC 17123	*C. reticulatum*	7.8	3.26	56	2.34
ICC 17124	*C. reticulatum*	7.0	2.09	66	1.97
ICC 17163	*C. reticulatum*	5.8	1.94	84	2.81
ICC 17117	*C. yamashitae*	8.2	1.49	86	1.56
Cultivated chickpea					
ICC 506	*C. arietinum*	9.0	3.93	76	3.32
ICCC 37	*C. arietinum*	7.6	3.93	68	3.52
Annigeri	*C. arietinum*	8.5	5.61	88	5.78
SE		±1.28	±0.06	±15.23	
LSD at 5%		2.11	1.05	25.2	
V[th] experiment					
ICC 17122	*C. bijugum*	4.6	0.77	90	1.51
ICC 17156	*C. bijugum*	4.8	1.32	82	2.26
ICC 17157	*C. bijugum*	8.4	2.58	82	2.52
ICC 17187	*C. bijugum*	5.4	1.01	86	1.61
IG 70001	*C. bijugum*	8.6	1.17	86	1.17
IG 70005	*C. bijugum*	6.6	1.16	90	1.58
IG 70006	*C. bijugum*	5.4	1.00	92	1.70
IG 70016	*C. bijugum*	7.0	0.82	84	0.98
ICC 17162	*C. cuneatum*	8.0	1.28	88	1.41
ICC 17151	*C. judaicum*	8.8	2.25	70	1.79
ICC 17188	*C. judaicum*	8.0	1.48	66	1.22
ICC 17189	*C. judaicum*	8.6	2.08	80	1.93
ICC 17190	*C. judaicum*	8.8	1.92	76	1.66
ICC 17194	*C. judaicum*	8.8	1.66	70	1.32
ICC 17196	*C. judaicum*	8.4	1.92	72	1.65
ICC 17207	*C. judaicum*	8.6	1.67	88	1.71
ICC 17212	*C. judaicum*	9.0	1.93	80	1.72
IG 69959	*C. judaicum*	8.8	2.12	90	2.17
IG 69969	*C. judaicum*	8.8	2.82	86	2.76
IG 72932	*C. judaicum*	8.8	1.85	78	1.64
ICC 17126	*C. pinnatifidum*	9.0	2.10	76	1.77
ICC 17152	*C. pinnatifidum*	9.0	1.48	90	1.48
ICC 17153	*C. pinnatifidum*	9.0	1.46	82	1.33
ICC 17155	*C. pinnatifidum*	9.0	1.94	86	1.85
ICC 17209	*C. pinnatifidum*	9.0	2.72	78	2.36
ICC 17210	*C. pinnatifidum*	8.6	1.55	80	1.44
IG 70039	*C. pinnatifidum*	8.6	1.60	84	1.56
ICC 17160	*C. reticulatum*	7.2	1.50	94	1.96
IG 70037	*C. reticulatum*	8.6	1.99	90	2.08
IG 72943	*C. reticulatum*	8.2	1.67	94	1.91
IG 72951	*C. reticulatum*	8	2.81	82	2.88
IG 72964	*C. reticulatum*	8.4	2.88	82	2.81
ICC 17116	*C. yamashitae*	8.6	2.75	82	2.62
Cultivated chickpea					
Annigeri	*C. arietinum*	8.4	5.83	82	5.69
ICC 506E	*C. arietinum*	5.4	4.12	90	6.87
ICCC 37	*C. arietinum*	8.8	6.25	92	6.53
SE		±0.95	±0.75	±13.29	
LSD at 5%		1.06	1.25	21.94	

*Damage rating (1 = <10% leaf area consumed, and 9 = >80% leaf area consumed).

Larval weights were <1.5 mg on 13 accessions of the wild relatives compared to 4.1 mg on ICC 506 and 5.83 mg on Annigeri. Larval survival ranged from 66% on ICC 17188 to 92% on ICCC 37 as compared to 90% on ICC 506 and 82% on Annigeri. Ten accessions showed poor host suitability index, of which ICC 17122, ICC 17156, IG 70006, and ICC 17187 showed low leaf feeding, low larval weights, and/or poor host suitability index.

Discussion

Several genotypes have been found to be less susceptible to *H. armigera* in the cultivated germplasm of chickpea (Lateef, 1985). However, the expression of resistance varies over seasons and locations. Therefore, wild relatives of chickpea can be exploited as useful sources of genes to increase the stability of resistance to this pest. Accessions belonging to *C. bijugum*, *C. pinnatifidum*, and *C. echinospermum* have shown resistance to leaf miner (*Liriomyza cicerina* Rondani) and bruchids (*Callosobruchus chinensis* L.) (Singh *et al.*, 1990, 1997, 1998). Numbers of pod borer larvae have been found to be lower on the annual species *C. echinospermum*, *C. judaicum*, *C. pinnatifidum* and *C. reticulatum* as compared to *C. arietinum* (Kaur *et al.*, 1999; Sharma *et al.*, 2002b).

Accessions IG 69947, IG 70002, IG 70003, IG 70009, IG 70019, IG 70022, ICC 17125, IG 69979, ICC 17122, ICC 17156, IG 70006, and ICC 17187 (*C. bijugum*), IG 69995 and IG 70030 (*C. judaicum*), and IG 69988, IG 69999 IG 70021, IG 70025, and IG 70028 (*C. pinnatifidum*) showed high levels of resistance to *H. armigera*. The major component of resistance to *H. armigera* in the wild relatives of chickpea is antibiosis, which could be because of the poor nutritional quality of the food or the presence of secondary metabolites. Leaf feeding and larval survival, in general, were greater on the wild relatives than on the cultivated chickpeas, while the larval weights on many wild relatives were much lower than those on the cultivated chickpeas, indicating existence of antibiosis effect on *H. armigera* in wild relatives of chickpea. Several isoflavones have been identified from wild relatives of chickpea (Stevenson and Veitch, 1996, 1998), which have shown antifeedant and antibiotic activity towards the larvae of *H. armigera* (Simmonds and Stevenson, 2001). Developing seeds of wild relatives of chickpea have also shown a significant variation in trypsin inhibitors for the *H. armigera* gut proteinases (Patankar *et al.*, 1999). Therefore, there is a possibility of introgressing diverse resistance genes from the wild relatives of chickpea into the cultivated genotypes for increasing the levels and diversifying the basis of resistance to *H. armigera*.

There has been little success in introgressing resistance genes from the tertiary gene pool into the cultigen. The possibility of gene transfer from *C. reticulatum* and *C. echinospermum* to the cultigen is quite high (Singh and Ocampo 1993, 1997; Badami *et al.*, 1997; Sheila *et al.*, 1992), and the accessions of these species showing resistance to *H. armigera* can be exploited to increase the levels and diversify the basis of resistance to this pest. Since use of wild relatives for introgression of useful genes into the cultivated types will result in the transfer of a number of undesirable traits, marker assisted selection may be useful to improve the efficiency for selection of the desirable traits (Sharma *et al.*, 2002a). Since there is limited polymorphism in the cultigen, lines derived through wide hybridization may be more useful for construction of genetic linkage maps. Development of techniques to overcome compatibility barriers and chromosome engineering may lead to increased utilization of wild relatives of chickpea for resistance to *H. armigera*.

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