Exploitation of Wild *Cicer reticulatum* Germplasm for Resistance to *Helicoverpa armigera*

H. C. SHARMA,[1, 2] G. PAMPAPATHY,[1] S. K. LANKA,[1] AND T. J. RIDSDILL-SMITH[3]

J. Econ. Entomol. 98(6): 2246–2253 (2005)

ABSTRACT In the absence of high levels of resistance to *Helicoverpa armigera* (Hübner) in the cultivated germplasm of chickpea, we evaluated accessions of *Cicer* spp. mostly *Cicer reticulatum* Ladzinsky, for resistance to this important pest. Under multichoice conditions in the field, 10 accessions showed lower leaf damage and lower numbers of eggs, larvae, or both of *H. armigera*. Of these, IG 69960, IG 72934, and IG 72936 showed significantly lower leaf feeding than the cultivated genotypes or other accessions at the vegetative and reproductive stages. Larval weight was lower or comparable with that on *C. bijugum* (IG 70019) and *C. judaicum* (IG 70032) in *C. reticulatum* accessions IG 72933, IG 72934, IG 72936, and IG 72953 at the seedling stage and on IG 69960 and IG 72934 at the flowering stage. The accessions showing resistance to *H. armigera* in the field and laboratory conditions were placed in different groups, indicating the presence of diversity in *C. reticulatum* accessions for resistance to this pest. Less than seven larvae survived on IG 70020, IG 72940, IG 72948, and IG 72949, and IG 72964 compared with 12 on ICC 506. Larval and total developmental periods were prolonged by 6–15 and 3–8 d, respectively, *on C. reticultatum* accessions compared with those on ICCC 37. Less than five larvae pupated on the *C. reticulatum* accessions (except IG 72958 and ICC 17163) compared with 11 in ICCC 37. Accessions showing lower leaf feeding and adverse effects on the survival and development can be used in increasing the levels and diversifying the basis of resistance to *H. armigera* in chickpea.

KEY WORDS *Cicer reticulatum*, chickpea, wild relatives of chickpea, host plant resistance, *Helicoverpa armigera*

CHICKPEA, *Cicer arietinum* L., is a major grain legume in Asia and parts of North Africa, North America, and Australia. Chickpea yields in Asia have remained stagnant for the past two to three decades, due largely to biotic and abiotic stress factors. *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) is one of the most important constraints to chickpea production in Asia, Africa, and Australia. *H. armigera* has been estimated to cause more than U.S. $2 billion loss to field crops in the semiarid tropics, despite $500 million worth of pesticides applied to control this pest (Sharma 2001). In chickpea, it causes $325 million loss annually in the semiarid tropics (ICRISAT 1992). Intensification of agriculture has exacerbated the *H. armigera* problem, and farmers are resorting to frequent use of toxic insecticides. As a result, *H. armigera* has developed considerable levels of resistance to conventional insecticides (Armes et al. 1996, Kranthi et al. 2002). For pest problems as intractable as *H. armigera*, the presumption is that no single tactic will suffice in itself to contain this pest. Therefore, there is a need to explore the possibility of deploying cultivars with resistance to this pest in integrated pest management programs.

It has long been recognized that plant resistance perhaps is the most effective and economic option for pest management, particularly under subsistence farming conditions in the semiarid tropics. However, thus far, the levels of resistance in the chickpea germplasm have been found to be low to moderate (Lateef 1985, Lateef and Sachan 1990, Sharma 2001).

Wild relatives of crops are a useful source of genes for resistance to biotic and abiotic stress factors (Stalker 1980, Muehlbauer 1987, Croser et al. 2003). In chickpea, the wild species in the primary and secondary gene pool are crossable with the cultigen by conventional techniques (Ladizinsky and Adler 1976, Pundir and Mangesha 1995). Therefore, there is a potential for exploiting the wild relatives of chickpea with different mechanisms of resistance to increase the level and diversify the basis of resistance to *H. armigera.*

The genus *Cicer* comprises of 43 species, of which 34 are perennial and eight annual wild species, and one annual cultivated species (Ladizinsky and Adler 1976). Most of the studies have indicated that *Cicer reticulatum* Ladzinsky is probably the wild progenitor of the cultivated species, *C. arietinum* (Ladizinsky and

[1] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India.
[2] Corresponding author, e-mail: h.sharma@cgiar.org.
[3] Commonwealth Scientific and Industrial Research Organization (CSIRO), Entomology, Private Bag 5, Wembley 6913, Western Australia, Australia.

Adler 1976; Singh and Ocampo 1993, 1997). High levels of resistance to cyst nematode, wilt, gray mold, leaf miner, and bruchids have been reported (Malhotra et al. 2002). Several attempts have been made to transfer resistance genes from the wild to the cultivated chickpea (Singh et al. 1990; Verma et al. 1990, 1995; Pundir and Mangesha 1995; Singh et al. 1999; Malhotra et al. 2002). The possibilities for gene transfer from *C. reticulatum* and *Cicer echinospermum* P. H. Davis to the cultivated chickpea are very high (Pundir and van der Maesen 1983).

Accessions belonging to *Cicer bijugum* Rechinger, *C. pinnatifidum* Jaubert & Spach, and *C. echinospermum* have been reported to be resistant to the leafminer *Liriomyza cicerina* (Rondani) and the bruchid *Callosobruchus chinensis* L. (Singh et al. 1990, 1997, 1998). Low numbers of *H. armigera* larvae have been observed on a few accessions belonging to *C. echinospermum*, *C. judaicum*, *C. pinnatifidum*, and *C. reticulatum* (Kaur et al. 1999). However, all the accessions belonging to *C. reticulatum*, which can be easily crossed with the cultivated chickpea, have not been evaluated for resistance to *H. armigera.* Also, there is no information on the mechanisms of resistance in accessions of *C. reticulatum* showing resistance to *H. armigera.* Therefore, we evaluated all the accessions of *C. reticulatum* in the genebank at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India, for resistance to *H. armigera* under greenhouse and field conditions.

Materials and Methods

Field Reaction of *C. reticulatum* Accessions *to H. armigera.* Twenty-five accessions of *C. reticulatum* were evaluated for resistance to *H. armigera* along with three cultivated chickpea genotypes (ICC 506, resistant check, Lateef 1985; ICCC 37, susceptible check, Sharma et al. 2002b; and Annigeri, local check) during the 2001/02 and 2002/03 postrainy seasons (January–May) at ICRISAT, Patancheru, Andhra Pradesh, India. Each entry was sown in a one-row plot, 2 m in length, and there were five plants in each row. There were two replications in a randomized complete block design. The seeds were soaked in water for 24 h and treated with thiram (2 g/kg seed) before sowing to enhance germination. The trial was planted on ridges 60 cm apart on deep black Vertisol soil. The seeds were sown in hills at a spacing of 30 cm between the hills at a depth of 5 cm below the soil surface. Normal agronomic practices were followed with basal fertilizer of diammonium phosphate (100 kg/ha). The field was irrigated immediately after sowing, and at 1-mo intervals thereafter. Data were recorded on eggs and larvae of *H. armigera* in five plants selected at random in each replication at the flowering stage. The plots also were rated visually for leaf feeding by the *H. armigera* larvae on a 1–9 damage rating scale (1, <10% leaf area damaged and 9, >80% leaf area damaged) (Sharma et al. 2002b).

Reaction of *C. reticulatum* Accessions to *H. armigera* under No-Choice Conditions. Twenty-four accessions of *C. reticulatum* along with one accession each of *C. bijugum*, IG 70019 and *C. judaicum*, IG 70032, which previously have shown resistance to *H. armigera* (Sharma et al. 2002b), and three chickpea genotypes (ICC 506, ICCC 37, and Annigeri) were evaluated under no-choice conditions. The test material was grown under greenhouse conditions and screened for resistance to neonate larvae of *H. armigera* at 30 and 60 d after seedling emergence by using the detached leaf assay (Sharma et al. 2002b). The plants were raised in the greenhouse in plastic pots (30 cm in diameter, 30 cm in depth) filled with a steam-sterilized potting mixture of black soil (Vertisols), sand, and farmyard manure (2:1:1). The seeds were scarified, soaked in water for 24 h, treated with thiram (2 g/kg seed) and sown 5–7 cm in depth in the soil and watered immediately. One seedling was retained in each pot at 15 d after seedling emergence. The plants were watered as needed. Greenhouse conditions were 27 ± 3°C, >65% RH, and a photoperiod of 10:14 (L:D) h.

At 30 and 60 d after seedling emergence, terminal branches (two to three fully expanded leaves and a bud) were bioassayed for resistance to neonate larvae of *H. armigera* by using the detached leaf assay. The chickpea branches were cut with scissors and immediately planted in a slanting manner in 3% agar-agar medium in a 10-cm-diameter plastic cup (250-ml capacity). 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's-hair brush. The cups were kept in the laboratory at 27 ± 2°C, and 45–65% RH. Observations were recorded at 6 d after initiating the experiment (when the differences between the test genotypes were most apparent) for branches bioassayed at 30 d after seedling emergence and at 5 d after initiating the experiment at the reproductive stage. The plants were rated for leaf feeding (1, <10% leaf area damaged and 9, >80% leaf area damaged) (Sharma et al. 2002b). The number of larvae surviving after 5 d were counted and placed in 25-ml plastic cups. The weights of larvae were recorded 4 h after separating them from the food. The data are expressed as percentage of larval survival and mean weight of the larvae. Data on leaf damage rating, larval survival, and larval weights were used to compute resistance index as follows: resistance index = leaf damage rating × larval weight/(100 − percentage survival).

Survival and Development of *H. armigera* Larvae on *C. reticulatum* Accessions. To gain a better understanding of the antibiosis mechanism of resistance to *H. armigera*, we studied the survival and development of neonate larvae on 21 accessions of *C. reticulatum* under laboratory conditions. The plants were grown in the greenhouse as described above, and the larvae (15 on each accession) were reared individually. Tender branches of the plants were offered to the larvae as food. The branches were embedded in agar-agar to

keep them in a turgid condition. Food was changed on alternate days. Larval weights were recorded at 10 and 15 d after initiating the experiment. Data were also recorded on percentage pupation and adult emergence, and duration of larval and pupal periods. Weights of the pupae were recorded 1 d after pupation.

Statistical Analysis. Data were subjected to analysis of variance (ANOVA) by using GENSTAT release 6.0 (Genstat 2002). The significance of differences between the treatments was measured by F-test at $P < 0.05$, and treatment means were compared using the least significant difference (LSD) at $P < 0.05$. Data on *H. armigera* leaf damage rating in the field and detached leaf assay, egg and larval density in the field, larval survival, and larval weights were subjected to similarity matrix (NTSYSpc version 2.10d, Applied Biostatistics, Inc. 1986–2000) analysis to assess the diversity in *C. reticulatum* accessions for their reaction to *H. armigera.*

Results

Field Reaction of *C. reticulatum* accessions to *H. armigera.* There was significant variability in the susceptibility of *C. reticulatum* accessions to *H. armigera* (Table 1). Phenological asynchrony precluded the comparison of cultivated types with the *C. retilculatum,* because the cultivated chickpea genotypes matured nearly 30 d earlier than the wild type. Leaf damage rating varied from 3.0 to 7.0 and from 1.0 to 6.0 during the 2001–2002 and 2002–2003 postrainy seasons, respectively. Numbers of eggs and larvae of *H. armigera* were significantly different on the accessions tested at the flowering stage. During the 2003 season, accessions IG 69960, IG 72933, IG 72934, IG 72935, IG 72936, IG 72940, IG 72941, IG 72 945, IG 72953, and IG 72959 showed lower leaf damage as well as lower numbers of eggs, larvae, or both of *H. armigera* compared with IG 69975.

Reaction of *C. reticulatum* Accessions to *H. armigera* under No-Choice Conditions. There were significant differences in leaf feeding by the neonate larvae of *H. armigera* among the genotypes tested (Table 2). At 30 d after seedling emergence, *C. reticulatum* accessions IG 72933, IG 72934, IG 72936, and IG 72953 showed a leaf damage rating of <3.4 compared with 4.9 of ICC 506 (resistant check), and 6.4 of ICCC 37 (susceptible check). Of these, IG 72934 and IG 72936 also showed lower leaf damage at the flowering stage. Larval survival ranged from 72 (IG 72936) to 98% (IG 69960) in different accessions of *C. reticulatum* compared with 94% on ICCC 37 at the vegetative stage; and 64–100% during the flowering stage compared with 79.6% survival of on ICCC 37. Larval weights were 1.802–2.231 mg on IG 72933, IG 72934, IG 72936, and IG 72953 compared with 4.996 mg on ICCC 37 at the vegetative stage. At the flowering stage, lower larval weights (<3.0 mg) were recorded on IG 69960 and IG 72934 compared with 6.291 mg on ICCC 37. Resistance index based on leaf feeding, larval survival, and larval weight indicated that IG 72936, IG 72934, IG 70019, and IG 70032 had high levels of resistance at the vegetative and reproductive stages (Fig. 1).

Table 1. Reaction of *C. reticulatum* accessions to *H. armigera* under multichoice conditions in the field

Accession	Alternate accession identifier	DR[a]		*Helicoverpa* eggs and larvae plant^{-1} 2002/03
		2001/02	2002/03	
IG 69960	ILWC 21	6.0	2.3	3.0
IG 69975	ILWC 36	6.5	6.0	8.0
IG 70020	ILWC 81	4.0	2.3	12.0
IG 72933	ILWC 104	—[b]	2.3	1.7
IG 72934	ILWC 105	—	2.0	2.0
IG 72935	ILWC 106	—	2.0	4.0
IG 72936	ILWC 107	—	3.0	2.5
IG 72937	ILWC 108	3.0	2.0	11.0
IG 72938	ILWC 109	—	2.7	5.3
IG 72939	ILWC 110	—	3.0	3.5
IG 72940	ILWC 111	3.5	2.0	3.7
IG 72941	ILWC 112	4.5	2.3	1.3
IG 72942	ILWC 113	5.5	2.0	5.7
IG 72943	ILWC 114	—	2.7	2.5
IG 72944	ILWC 115	4.0	2.7	9.5
IG 72945	ILWC 116	4.0	2.5	1.5
IG 72946	ILWC 117	5.5	1.0	7.0
IG 72948	ILWC 119	—	2.3	3.7
IG 72949	ILWC 120	7.0	3.3	3.0
IG 72951	ILWC 122	3.5	3.3	2.0
IG 72952	ILWC 123	6.0	2.7	3.3
IG 72953	ILWC 124	5.5	2.0	3.0
IG 72955	ILWC 126	5.1	3.0	1.0
IG 72958	ILWC 129	—	3.0	7.0
IG 72959	ILWC 130	4.5	2.0	2.0
SE		±1.2	±0.52	±1.79
$LSD_{(p = 0.05)}$		NS	1.49	5.11
Fp (df = 53)		0.181[c]	0.002	<0.001

[a] Damage rating (1, <10% leaf area damaged and 9, >80% leaf area damaged.
[b] No germination.
[c] df = 31; NS, not significant.

Dendrogram based on similarity index analysis placed the accessions into three groups (similarity coefficient <0.89) (Fig. 2). The cultivated chickpea genotypes ICC 506 and ICCC 37 were placed along with *C. reticulatum* accessions IG 69990, IG 72949, IG 72935, IG 72953, and IG 72941. The landrace chickpea 'Annigeri' was grouped along with 10 other *C. reticulatum* accessions and *C. bijugum* (ICC 70019) and *C. judaicum* (IG 700032). The remaining accessions were placed in the third group. The three cultivars showing resistance to *H. armigera* in the field and laboratory conditions were placed in different groups, indicating the presence of diversity among the resistance sources.

Survival and Development of *H. armigera* Larvae on *C. reticulatum* Accessions. Larval weights were lower at 10 d (<50 mg per larva compared with 225.0 mg on ICCC 37) and 15 d (<100.3 mg per larva compared with 300.9 mg on ICCC 37) after initiating the experiment on ICC 17160, IG 72945, IG 72953, IG 72937, 72933, IG 72944, and IG 70037 (Fig. 3a and b). Larval survival (out of 15) was less than seven and pupation less than one on IG 72949, IG 72948, IG 70020, and IG 72940 compared with 11 on ICCC 37 (Table 3). On *C. reticulatum* accessions, either there was no pupation or the larvae took >22.3 d to com-

Table 2. Reaction of *Cicer* spp. accessions to *H. armigera* in detached leaf assay under no-choice conditions

Entry	DR[a](V)	DR(R)	Larval survival (%)(V)	Larval survival (%)(R)	Larval wt. (mg)(V)	Larval wt. (mg)(R)
C. reticulatum						
IG 69960	4.0	4.7	98.0	84.0	3.616	2.983
IG 69975	4.8	6.0	92.0	84.0	4.355	5.134
IG 70020	4.4	5.4	88.0	80.0	3.853	5.025
IG 72933	3.0	7.0	90.0	84.0	1.802	4.742
IG 72934	3.0	3.8	92.0	64.0	2.005	2.967
IG 72935	4.2	6.4	92.0	76.0	3.361	6.013
IG 72936	3.4	4.5	72.0	76.0	2.231	5.366
IG 72937	5.4	6.3	82.0	92.0	4.916	4.754
IG 72938	5.4	7.8	82.0	82.0	3.886	3.648
IG 72939	4.6	7.7	92.0	98.0	3.095	6.197
IG 72940	5.0	6.4	90.0	84.0	3.358	5.132
IG 72941	5.0	6.6	96.0	76.0	4.208	5.211
IG 72942	6.6	7.6	94.0	100.0	4.583	5.700
IG 72943	5.8	7.3	94.0	90.0	4.449	3.223
IG 72944	4.2	6.9	82.0	76.0	3.088	6.140
IG 72945	6.8	6.0	84.0	88.0	5.778	4.868
IG 72946	6.4	5.5	92.0	85.7	5.517	4.976
IG 72948	5.0	6.5	86.0	94.0	2.747	5.313
IG 72949	6.0	6.9	94.0	80.3	5.204	5.465
IG 72951	5.6	5.4	84.0	88.0	4.082	3.635
IG 72953	3.0	6.9	94.0	78.0	1.989	6.558
IG 72955	5.2	7.9	90.0	90.0	4.714	5.584
IG 72958	4.4	6.2	94.0	66.4	3.475	5.594
IG 72959	3.8	7.4	90.0	84.0	3.799	5.209
C. bijugum						
IG 70019	4.2	5.4	90.0	86.0	1.856	2.959
C. judaicum						
IG 70032	3.4	4.6	94.0	84.7	1.797	1.261
C. arietinum						
Annigeri	4.4	4.8	76.0	74.0	4.065	4.675
ICC 506	4.9	3.0	80.0	67.2	3.385	4.696
ICCC 37	6.4	4.8	94.0	79.6	4.996	6.291
SE	±0.57	±0.52	±4.95	±6.49	±0.40	±0.54
$LSD_{(P = 0.05)}$	1.59	1.46	13.88	18.21	1.13	1.51
P (df = 28)	<0.001	<0.001	0.044	0.020	<0.001	<0.001

[a] Damage rating (1, <10% leaf area damaged and 9, >80% leaf area damaged); V, vegetative stage; R, reproductive stage.

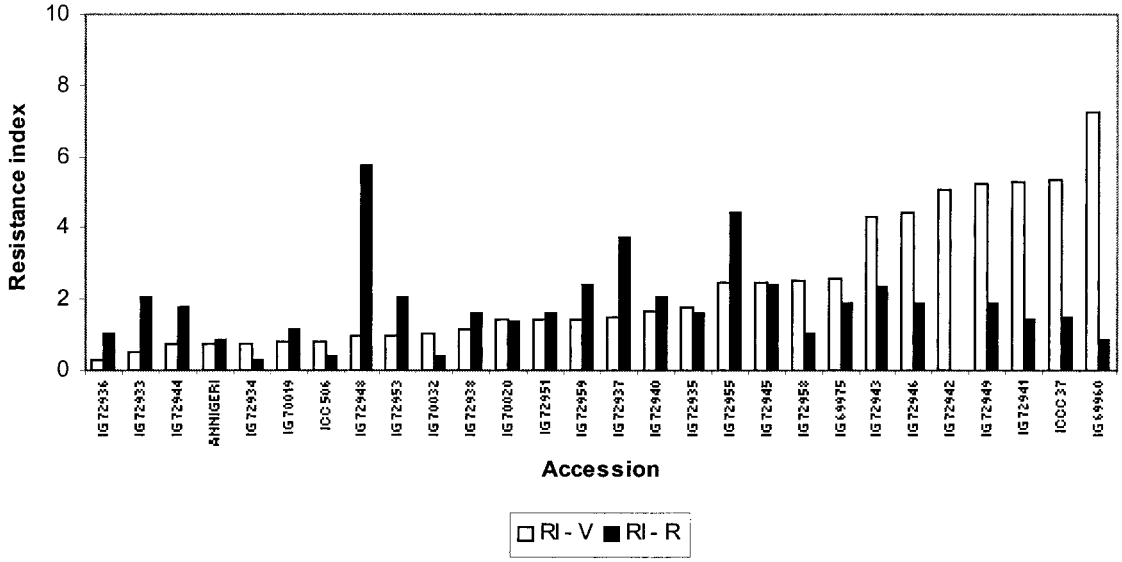

Fig. 1. Resistance index of 23 accessions of *C. reticulatum*, one accession each of *C. bijugum* (IG 70019) and *C. judaicum* (IG 70032) and three cultivated chickpea genotypes (ICC 506, ICCC 37, and Annigeri) at the vegetative (V) and reproductive (R) stages to *H. armigera*. Resistance index = damage rating × larval weight/larval mortality.

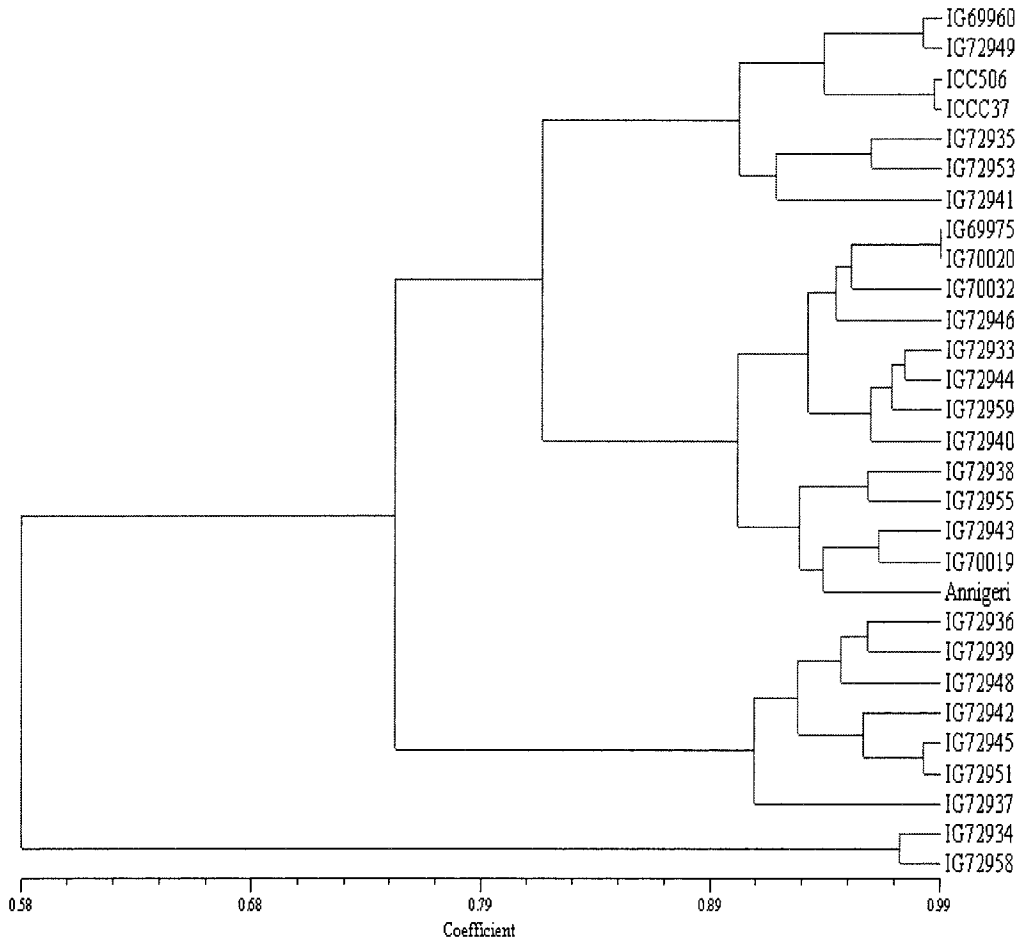

Fig. 2. Dendrogram depicting genetic similarity between 24 accessions of *C. reticulatum* and one accession each of each of *C. bijugum* (IG 70019) and *C. judaicum* (IG 70032), and three cultivated chickpea genotypes (ICC 506, ICCC 37, and Annigeri).

plete development compared with 16–17 d on cultivated chickpea genotypes. There was a marked effect on pupal weight when the larvae were reared on *C. reticulatum* accessions. Less than one adult emerged on *C. reticulatum* accessions (except on IG 72958) compared with 11 adults on ICCC 37. *C. reticulatum* accessions suffering low leaf damage and also exhibiting adverse effects on *H. armigera* survival and development can be used in chickpea improvement for resistance to *H. armigera.*

Discussion

Under multichoice field conditions, there was considerable variability in the relative susceptibility of *C. reticulatum* accessions, with 10 accessions showing lower leaf damage as well as lower numbers of eggs, larvae, or both of *H. armigera.* Under no-choice conditions in the detached leaf assay, IG 72934 and IG 72936 of *C. reticulatum* showed lower leaf feeding than the cultivated genotypes or other accessions tested at both the growth stages. Larval weight was lower or comparable with that on *C. bijugum* (IG 70019) and *C. judaicum* (IG 70032) on the *C. reticulatum* accessions such as IG 72933, IG 72934, IG 72936, and IG 72953 at the seedling stage, and on IG 69960 and IG 72934 at the flowering stage. Similarity index analysis placed the accessions into different groups, suggesting the presence of diversity in the reaction of *C. reticulatum* accessions for resistance/susceptibility to *H. armigera.* The accessions showing resistance to *H. armigera* in the field and laboratory conditions were placed in different groups, indicating the presence of diversity in *C. reticulatum* accessions for resistance to this pest.

Acid exudates such as malic acid and oxalic acid on the leaves are responsible for resistance to *H. armigera* in cultivated chickpea (Cowgill and Lateef 1996). However, isoflavones [judaicin, judaicin 7-*O*-glucoside, and judaicin 7-*O*-(6″-*O*-malonylglucoside], and pterocarpans [maakiain 3-*O*-glucoride and maackiain 3-*O*-(6′-*O*-malonyl glucoride] (Stevenson and Veitch 1998), and 2-arylbenzofuran (Stevenson and Veitch 1998) have been isolated from the roots of wild chickpea, *C. bijugum*

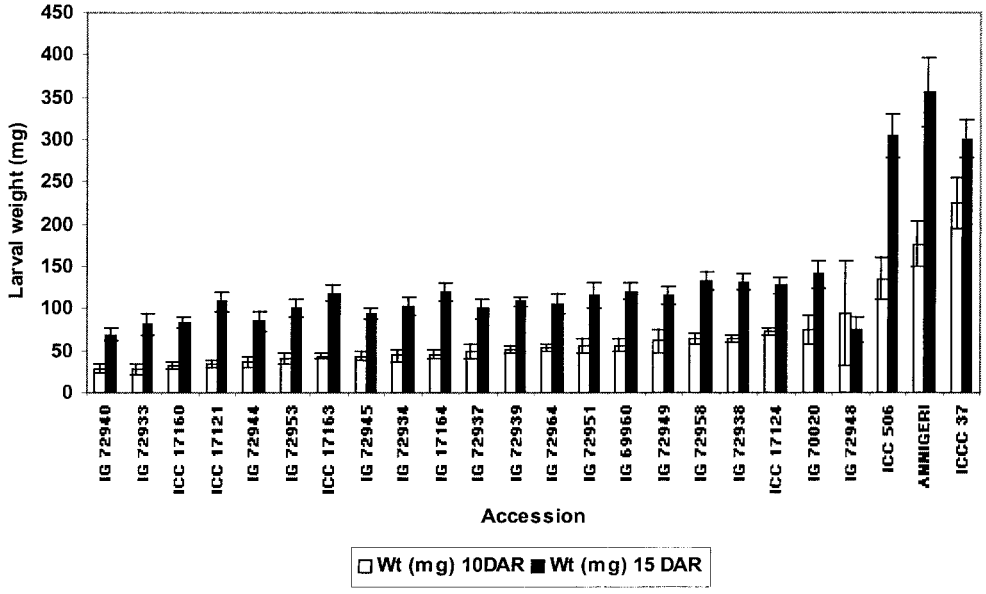

Fig. 3. Weights of *H. armigera* larvae at 10 (a) and 15 (b) days after releasing (DAR) the larvae on the leaves of 24 accessions of *C. reticulatum*, one accession each of *C. bijugum* (IG 70019) and *C. judaicum* (IG 70032), and three cultivated chickpea genotypes (ICC 506, ICCC 37, and Annigeri).

and *C. judaicum.* These compounds confer resistance to Fusarium wilt (Stevenson and Veitch 1996, Stevenson et al. 1997) and Botrytis gray mold (Stevenson and Haware 1999). The flavonoids judaicin 7-*O*-glucoside, two methoxy judaicin, judaicin, and maakiain have shown antifeedant activity toward the larvae of *H. armigera* (Simmonds and Stevenson 2001). Judaicin and maakiain showed greater antifeedant activity in combination with chlorogenic acid against *H. armigera.* When incorporated into artificial diet, maakiain and judaicin

Table 3. Survival and development of *H. armigera* larvae on *Cicer* spp. accessions under laboratory conditions

Entry	Alternate accession identifier	No. survived 10 DAR[a]	No. survived 15 DAR[a]	Days to pupation	No. pupated	Pupal wt (mg)	Days to adult emergence
C. reticulatum							
ICC 17121	ICCW 6	14	12	24	3	114.4 ± 5.3	35
ICC 17124	ICCW 9	11	10	25	1	—[b]	—
ICC 17160	ICCW 45	15	14	25	2	128.8 ± 0.0	38
ICC 17163	ICCW 48	9	9	29	3	—	—
ICC 17164	ICCW 49	12	11	26	5	101.5 ± 8.5	35
IG 69960	ILWC 21	9	8	22	3	121.5 ± 11.5	35
IG 70020	ILWC 81	7	6	—	0	—	—
IG 72933	ILWC 104	9	9	31	3	—	—
IG 72934	ILWC 105	12	12	25	1	111.4 ± 0.0	35
IG 72937	ILWC 108	11	10	—	0	—	—
IG 72938	ILWC 109	11	9	24	3	104.3 ± 16.9	35
IG 72939	ILWC 110	13	13	—	0	—	—
IG 72940	ILWC 111	11	6	—	0	—	—
IG 72944	ILWC 115	9	9	—	0	—	—
IG 72945	ILWC 116	13	13	—	0	—	—
IG 72948	ILWC 119	11	7	—	0	—	—
IG 72949	ILWC 120	6	5	—	0	—	—
IG 72951	ILWC 122	11	11	24	2	105.9 ± 8.3	33
IG 72953	ILWC 124	13	13	26	1	—	—
IG 72958	ILWC 129	13	13	24	8	92.5 ± 14.3	35
IG 72964	ILWC 135	9	9	23	1	—	—
C. arietinum							
ICC 506		14	12	17	9	246.5 ± 12.6	31
ICCC 37		11	11	16	11	230.7 ± 22.2	30
Annigeri		13	10	17	12	243.5 ± 20.4	31

[a] DAR, cays after releasing 15 larvae.
[b] None of the larvae survived hence no data were recorded.

were most potent in decreasing the weight gain by the larvae. Developing seeds of chickpea wild species also have shown a significant variation in trypsin inhibitors for the *H. armigera* gut proteinases (Patankar et al. 1999), suggesting that a large proportion of gut proteinases were insensitive to proteinase inhibitors from *Cicer* spp. Therefore, there is a possibility of using these secondary metabolites from the wild relatives as components of resistance to *H. armigera.*

C. reticulatum and *C. echinospermum* have been exploited successfully for transferring useful genes into the cultigen (Sheila et al. 1992, Badami et al. 1997, Malhotra et al. 2002). There is a need to have more extensive collections of the germplasm of these species with useful traits, particularly for resistance to insect pests such as *H. armigera* and *C. chinensis.* Use of wild relatives for introgression of useful genes into the cultivated types will result in the transfer of a number of undesirable traits; therefore, marker-assisted selection might be used to improve the efficiency for selection of the desirable traits. Because polymorphism is limited in the cultivated chickpea, lines derived through wide hybridization may be more useful for construction of genetic linkage maps (Sharma et al. 2002a).

Accessions of *C. reticulatum* seem to have a different mechanism of resistance (antibiosis based on secondary metabolites and/or poor nutritional quality of the food) to *H. armigera* than the cultivated chickpea (largely based on acid exudates). Identification and isolation of lectin and protease inhibitor genes from the wild species offers another opportunity for their deployment through transgenic plants. There is a great potential to exploit the wild relatives of chickpea for introgression of *H. armigera* resistance genes into the cultivated chickpea through conventional breeding and through the molecular marker and transgenic approaches for the management of this difficult-to-control pest.

Acknowledgments

We thank V. V. Rao, J. Raja Rao, N. Chandra, and Hareendernath for help in these experiments, and Grains Research and Development Corporation (GRDC), Australia, for funding support.

References Cited

Applied Biostatistics Inc. 1986–2000. Applied Biostatistics Inc. State University of New York, Stony Brook, NY.

Armes, N. J., D. R. Jadhav, and K. R. DeSouza. 1996. A survey of insecticide resistance in *Helicoverpa armigera* in the Indian subcontinent. Bull. Entomol. Res. 86: 499–514.

Badami, P. S., N. Mallikarjuna, and J. P. Moss. 1997. Interspecific hybridization between *Cicer arietinum* and *C. pinnatifidum.* Plant Breed. 116: 393–395.

Cowgill, S. E., and S. S. Lateef. 1996. Identification of antibiotic and antixenotic resistance to *Helicoverpa armigera* (Lepidoptera: Noctuidae) in chickpea. J. Econ. Entomol. 89: 224–229.

Croser, J. S., F. Ahmad, H. J. Clarke, and K.H.M. Siddique. 2003. Utilization of wild *Cicer* in chickpea improvement - progress, constraints, and prospects. Aust. J. Agric. Res. 54: 429–444.

Genstat. 2002. GENSTAT, 6th ed. Lawes Agricultural Trust, VSN International Limited, Oxford, United Kingdom.

[ICRISAT] International Crops Research Institute for the Semi-Arid Tropics. 1992. The Medium Term Plan. ICRISAT, Patancheru, A.P. 502 324, India.

Kaur, S., K. S. Chhabra, and B. S. Arora. 1999. Incidence of *Helicoverpa armigera* (Hubner) on wild and cultivated species of chickpea. Int. Chickpea Pigeonpea Newsl. 6: 18–19.

Kranthi, K. R., D. R. Jadhav, S. Kranthi, R. R. Wanjari, S. S. Ali, and D. A. Russel. 2002. Insecticide resistance in five major insect pests of cotton in India. Crop Prot. 21: 449–460.

Ladizinsky, G., and A. Adler. 1976. Genetic relationships among the annual species of *Cicer* L. Theor. Appl. Genet. 48: 197–203.

Lateef, S. S. 1985. Gram pod borer [*Heliothis armigera* (Hub.)] resistance in chickpea. Agric. Ecol. Environ. 14: 95–102.

Lateef S. S., and J. N. Sachan. 1990. Host plant resistance to *Helicoverpa armigera* (Hub.) in different agro-economical conditions, pp. 181–189. *In* Chickpea in Ninetees: Proceedings of the Second International Workshop on Chickpea, 4–8 Dec. 1989. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Malhotra, R. S., K. B. Singh, M. Di Vito, N. Grecco, and M. C. Saxena. 2002. Registration of ILC 10765 and ILC 10766 chickpea germplasm lines resistant to cyst nematode. Crop Sci. 42: 1756.

Muehlbauer F. J. 1987. Use of wild species as a source of resistance in cool-season food legume crops. *In* K. B. Singh and M. C. Saxena, [eds.], Breeding for stress tolerance in cool-season food legumes. Wiley, United Kingdom.

Patankar, A. G., A. M. Harsulkar, A. P. Giri, V. S. Gupta, M. N. Sainani, P. K. Ranjekar, and V. V. Deshpande. 1999. Diversity in inhibitors of trypsin and *Helicoverpa armigera* gut proteinases in chickpea (*Cicer arietinum*) and its wild relatives. Theor. Appl. Genet. 99: 719–726.

Pundir, R.P.S., and M. H. Mangesha. 1995. Cross compatibility between chickpea and its wild relative *Cicer echinospermum* Davis. Euphytica 83: 241–245.

Pundir R.P.S., and L.J.G. van der Maesen. 1983. Interspecific hybridization in *Cicer.* Int. Chickpea Newsl. 8: 4–5.

Sharma, H. C. 2001. Cotton bollworm/legume pod borer, *Helicoverpa armigera* (Hübner) (Noctuidae: Lepidoptera): biology and management. *In* Crop Protection Compendium. Commonwealth Agricultural Bureau International, Oxon, United Kingdom.

Sharma, H. C., P. C. Stevenson, M.S.J. Simmonds, and P.W.C. Green. 2001. Indentification of *Helicoverpa armigera* (Hübner) feeding stimulants and the location of their production on the pod-surface of pigeonpea [*Cajanus cajan* (L.) Millsp.]. Final Technical Report. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India.

Sharma, H. C., J. H. Crouch, K. K. Sharma, N. Seetharama, and C. T. Hash. 2002a. Applications of biotechnology for crop improvement: prospects and constraints. Plant Sci. 163: 381–395.

Sharma H. C., K. Mann, S. L. Kashyap, G. Pampapathy, and T. J. Ridsdill-Smith. 2002b. Identification of *Helicoverpa* resistance in wild species of chickpeas. *In* 12th Australian Plant Breeding Conference, 15–20 Sept. 2002, Perth, Western Australia, Australia.

Sheila, V. K., J. P. Moss, C.L.L. Gowda, and H. A. Van Rheenan. 1992. Interspecific hybridization between *Cicer arietinum* and wild *Cicer* species. Intl. Chickpea Newsl. 27: 11–12.

Simmonds, M.S.J., and P. C. Stevenson. 2001. Effects of isoflavanoids from *Cicer* on larvae of *Helicoverpa armigera.* J. Chem. Ecol. 27: 965–977.

Singh, A., N. P. Singh, and A. S. Asthana. 1999. Genetic potential of wild crosses in chickpea. Legume Res. 22: 19–25.

Singh, K. B., and B. Ocampo. 1993. Interspecific hybridization in annual *Cicer* species. J. Genet. Breed. 47: 199–204.

Singh, K. B., and B. Ocampo. 1997. Exploitation of wild *Cicer* species for yield improvement in chickpea. Theor. Appl. Genet. 95: 418–423.

Singh, K. B., R. S. Malhotra, and M. C. Saxena. 1990. Sources for tolerance to cold in *Cicer* species. Crop Sci. 30: 1136–1138.

Singh, K. B., S. Weigand, and M. C. Saxena. 1997. Registration of ILWC 39 and ILWC 181: *Cicer echinospermum* germplasm lines with resistance to *Callosobruchus chinensis* (L.). Crop Sci. 37: 634.

Singh, K. B., B. Ocampo, and L. D. Robertson. 1998. Diversity for abiotic and biotic stress resistance in the wild annual *Cicer* species. Genet. Resour. Crop Evol. 45: 9–17.

Stalker, H. T. 1980. Utilization of wild species for crop improvement. Adv. Agron. 23: 111–147.

Stevenson, P. C., and M. P. Haware. 1999. Maakiain in *Cicer bijugum* Rech. F. associated with resistance to Botrytis gray mould. Biochem. Syst. Ecol. 27: 761–777.

Stevenson, P. C., H. C. Turner, and M. P. Haware. 1997. Phytoalexin accumulation in roots of chickpea (*Cicer arietinum* L.) seedlings associated with resistance to Fusarium wilt (*Fusarium oxysporum* f. sp. *ciceri*). Physiol. Mol. Plant Pathol. 50: 167–178.

Stevenson P. C., and N. C. Veitch. 1996. *Isoflavones* from the roots of *Cicer judaicum.* Phytochemistry 43: 695–700.

Stevenson, P. C., and N. C. Veitch. 1998. A 2-arylbenzofuran from roots of *Cicer bijugum* associated with Fusarium wilt resistance. Phytochemistry 48: 947–951.

Verma M. M., J. S. Sandhu, H. S. Brar, and J. S. Brar. 1990. Crossability studies in different species of *Cicer.* Crop Imp. 17: 179–181.

Verma M. M., Ravi, and J. S. Sandhu. 1995. Characterization of interspecific cross *Cicer arietinum* L. × *C. judaicum* (Bioss). Plant Breed. 114: 549–551.

Received 7 June 2004; accepted 1 July 2005.