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Cicer species - Conserved Resources, Priorities for Collection and Future Prospects

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Abstract

The genus *Cicer* encompasses 34 wild perennial species, 8 annual wild species, and one annual cultivated species. Most of these species are found in the West Asia and North African region covering Turkey in the north to Ethiopia in the south, and Pakistan in the east to Morocco in the west. Chickpea (*Cicer arietinum)* is the only cultivated species, and is the second most important pulse crop in the world. The two most closely related species to the cultigen, *C. reticulatum*, and *C. echinospermum*, are endemic in southeastern Turkey and adjoining areas of northern Iraq. Good collections have been made and categorized using descriptors. As the level of tolerance to some of the biotic and abiotic stresses is not at a satisfactory level in the cultivated species, limited efforts have been made to collect and evaluate the wild *Cicer* species. For some of the wild annual species namely, *C. yamashitae*, *C. cuneatum*, and *C. chorassanicum*, there are only a few accessions in the collection and more need to be collected.

The annual *Cicer* species are not difficult to grow, and can be conserved and rejuvenated without much difficulty. But the perennial *Cicer* species are extremely difficult to grow. They probably need their original habitats and should be conserved *in situ*. The cultivated species has been extensively developed but it still lacks resistance to many biotic and abiotic stresses. The wild annual species have been evaluated for resistance to these stresses. They provide good prospects for the improvement of chickpea. Desirable genes have been introgressed from the wild species, which are crossable, but not all species are crossable with chickpea and further research is needed. It is hoped biotechnology and tissue culture in future will permit the introgression of their genes into chickpea.

INTRODUCTION

The *Cicer* genus belongs to subfamily Papillionoideae, and tribe Viceae Alef. This genus encompasses 43 species, including 34 wild perennial, 8 wild annual and the cultivated annual chickpea, *Cicer arietinum* L. (Malhotra *et al.*, 1987). All species are diploid and self-pollinating. The chromosome number of all known *Cicer* species is 2n=16 (Ladizinsky and Adler, 1976, Singh and Ocampo, 1993, Pundir *et al.*, 1993). The genus probably originated in the area of Southeast Turkey and adjoining regions of Syria where three species (*C. bijugum* K.H.Rech, *C. echinospermum* P.H.Davis and *C. reticulatum* Lad.) occur naturally. Although there are controversies on the progenitor of chickpea, the studies of Ladizinsky and Adler (1976); Singh and Ocampo (1993); Ocampo *et al.*, (1992); Labdi *et al.*, (1996); indicate that *Cicer reticulatum* is probably the wild progenitor. Remnants of *Cicer* seeds from Hacillar near Burdu (Turkey) dated to 5450 BC (Helbaek 1970) support this view. Chickpea is also known as Bengal gram or Chana in India, Chhola in Pakistan, Hommos in Mediterranean countries, Nohut in Turkey, Shimbra in Ethiopia, and Garbanzo bean in Mexico and the USA.

Chickpea ranks second in area and third in production among the pulses in the world. It is cultivated on about 10 million ha and produces about seven million tones with a yield of 700 kg/ha. Two forms are

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known, i) kabuli with white flowers, white seed coat and ram-head shaped seeds and ii) desi (indigenous) with dark colored flowers and seeds with an angular shape and various color shades. Kabuli types are grown predominantly in Mediterranean countries, and desi types in countries of South Asia, and eastern and southern Africa. Chickpea is cultivated in moderate winter or spring seasons and occupies a considerable area in over 40 countries. The plant is efficient at fixing nitrogen, the seeds are rich in protein, and the crop can be grown with a minimum of farm inputs.

CONSERVED GENETIC RESOURCES

In recent years the chickpea crop has received increased attention from research workers. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) at Hyderabad, India, and The International Center for Agricultural Research in the Dry Areas (ICARDA) at Aleppo Syria, established in

Table 1. The number of cultivated chickpea accessions, classified by country of origin, and held at ICARDA and ICRISAT in Dec 1996.

Country	ICARDA	ICRISAT	Country	ICARDA	ICRISAT
Afghanistan	890	686	Mexico	117	396
Algeria	50	16	Moldavia	6	-
Armenia	3	-	Morocco	225	249
Australia	4	3	Myanmar	-	129
Azerbaijan	16	-	Nepal	6	80
Bangladesh	1	170	Nigeria	1	3
Bulgaria	191	9	Pakistan	265	445
Chile	346	139	Palestine	40	48
China	21	24	Peru	4	3
Columbia	1	1	Portugal	121	84
Cyprus	46	44	Romania	2	-
Czechoslovakia	10	8	Russia	22	-
Ecuador	1	-	Spain	284	121
Egypt	57	53	Sri Lanka	-	3
Ethiopia	124	932	Sudan	11	12
France	18	2	Soviet Union	104	133
Georgia	1	-	Syria	732	203
Germany	1	11	Tanzania	-	97
Greece	18	25	Tadzhikistan	8	-
Hungary	2	4	Tunisia	263	33
India	396	7180	Turkey	864	449
Iran	1737	4856	Uganda	-	1
Iraq	32	18	Ukraine	10	-
Italy	68	45	UK	8	-
Jordan	143	25	USA	121	82
Kazakhstan	1	-	Uzbekistan	11	-
Kenya	-	1	Yugoslavia	6	6
Kyrgyzstan	1	-	Unknown	235	179
Lebanon	28	19	Breeding lines	1444	-
Libya	2	-			
Malawi	3	81	Total	9775	17250

1972 and 1977 respectively, have chickpea as one of their mandate crops. ICRISAT works mainly on desi types and ICARDA on kabuli types. At both centers, efforts are being made to assemble germplasm resources, including land-races, cultivars, genetic stocks and closely related wild species. In addition to donated material, both centres have made collections. ICRISAT and ICARDA have been involved in 41 and 32 collecting missions and have secured 3113 and 2067 accessions respectively. The present holdings at ICRISAT and ICARDA are 17,250 and 9,775 respectively (Table 1)

One of ICRISAT's responsibilities is to serve as a world repository for chickpea germplasm. The collection includes desi and kabuli types and wild species. ICARDA has a regional mandate for the areas where kabulis are grown and its germplasm collection includes only kabuli types. Excepting a few occasional accessions and new acquisitions, the entire ICARDA collection is duplicated at ICRISAT.

The United States Department of Agriculture maintains a collection of 4,237 accessions of cultivated chickpea at their Regional Plant Introduction Station (RPIS) in Pullman, Washington.

CHARACTERIZATION AND EVALUATION

Spring sown and winter sown material from the ICARDA collection has been evaluated for the chickpea descriptors (IBPGR, ICARDA and ICRISAT 1985 and revised 1993) and the results published as catalogues (Singh *et al.*, 1983 and 1991). An indication of the variation observed during spring 1980, and the winter of 1987/88 is given in Table 2. In general, the mean for different traits was much higher for the evaluation of the winter-sown crop than for the spring-sown crop. At ICRISAT, chickpea evaluation work is carried out in the post-rainy season during October to February, which runs through the moderate winter, and spring seasons. Data for 25 morpho-agronomic characters were summarized and published by ICRISAT as a catalogue (Pundir *et al.*, 1988). Parts of the results are given in Table 3. Some of the important traits in chickpea can be related to their country of origin (Table 4). Accessions from Bangladesh were short in height, produced more pods and had a higher resistance to Fusarium wilt. The accessions from Sudan were of relatively short duration, had higher numbers of apical secondary branches and a higher protein content in the seed. Accessions of Indian origin produced the highest average seed yield. The accessions from Jordan were conspicuous by their spreading growth habit, whereas an erect growth habit was common in accessions from Greece and Russia.

Table 2. Variation in chickpea germplasm at ICRISAT.

Trait	Minimum	Maximum	Mean
Time to 50% flowering (day)	28	96	64
Time to maturity (day)	84	169	117
Plant canopy height (cm)	14	96	38
Canopy width (cm)	13	124	40
Pods per plant (no.)	3	238	39
Seeds per pod (no.)	1.0	3.2	1.2
Grain yield (g)	70	5130	1286
100-seed weight (g)	3.8	59.1	16.1
Seed protein content (%)	12.1	29.6	19.8

Table 3. Variation in kabuli germplasm at ICARDA grown at Tel Hadya, Syria during spring 1980 and winter 1987/88.

	Spring			Winter		
Trait	Min.	Max.	Mean	Min.	Max.	Mean
Time to flower (days)	58	94	81	115	156	137
Flower duration (days)	11	36	23	12	83	29
Time to maturity (days)	114	124	118	174	206	182
Plant height (cm)	15	50	30	25	85	54
Canopy width (cm)	15	60	40	20	96	57
Pods per plant (number)	5	100	25	-	-	-
Seeds per pod (number)	0.1	3.1	1.1	-	-	-
Biological yield (g/m^2)	35	533	204	28	1200	574
Grain yield (g/m^2)	7	292	99	1	567	272
Harvest index (%)	7	84	49	1	78	48
100-seed weight (g)	8.7	59.1	25.1	8.4	70.1	30.0
Protein content (%)	16.0	24.8	20.1	13.5	28.2	23.0

Table 4. Geographical distribution of major chickpea traits

Trait	Country/region
Medium duration	Bangladesh, India, Mexico, Myanmar
Long duration	India, Iran, Morocco, Nepal, Pakistan, Russia, Spain, Syria, Turkey
High branch number	Afghanistan, India, Iraq, Italy
Low branch numbers	Chile, India, Tunisia, Turkey
Erect growth habit	Greece, India, Italy, Russia
Erect (+tall) growth habit	Greece, Italy, Russia
High seed number	Afghanistan, Egypt, India, Mexico, Nepal, Pakistan
Low seed number	Mediterranean countries
High seed mass	Mediterranean countries, India, Mexico
Low seed mass	Indian sub-continent, Ethiopia, Myanmar, Tanzania
Desi (typical) seed	Indian sub-continent, Eastern Africa, Myanmar
Kabuli (typical) seed	Mediterranean countries, West Asia, Chile
Intermediate seed	Ethiopia, Iran
Fusarium wilt resistance	Bangladesh, Ethiopia, India, Iran, Pakistan
Dry root rot resistance	India, Iran
Ascochyta blight resistance	India, Iran, Mexico, Turkey
Gray mold resistance	Iran
Helicoverpa (pod borer) tolerance	India
High seed protein content	Pakistan, Sudan

An evaluation of the ICRISAT chickpea collection, conducted jointly with national programs, was initiated 15 years ago. Accessions were evaluated in India, Nepal and Ethiopia and lines with better regional adaptation were identified. The evaluation of 21,110 lines between 1986 to 1995, undertaken collaboratively with the National Bureau of plant Genetic Resources (NBPGR), India at 5 Indian locations has been very successful (Mathur *et al.*, 1993).

During 1979-80 ICARDA, together with Turkish scientists at Hymana, Turkey (Singh *et al.*, 1981) evaluated 3,158 kabuli chickpea accessions for cold tolerance. Six lines, ILC 410, ILC 2479, ILC 2491, ILC 2636, ILC 2529, and ILC 2406, were highly tolerant to cold under Hymana conditions where the crop was covered with snow for about three months after sowing. Similarly ICARDA with scientists at

Cordoba, Spain identified several sources of resistance to Fusarium wilt, from among 1904 improved lines of chickpea. The lines FLIP 84-43C, FLIP 85-20C, FLIP 85-29C, FLIP 85-30C, ILC 127, ILC 219, ILC 237, ILC 267, and ILC 513 were highly resistant to Fusarium wilt (Jimenez-Diaz *et al.*, 1991.

The joint evaluation of improved sources of tolerance to Ascochyta blight undertaken by the Legume International Testing Program at ICARDA has revealed there are genotypic differences in reaction to the ascochyta blight pathogen present in different areas (Reddy *et al.*, 1992). In another joint evaluation by ICARDA and the Italian national program, 102 accessions of six wild annual *Cicer* species were evaluated for Fusarium wilt resistance under greenhouse conditions in Italy (Infantino *et al.*, 1996). All accessions of *C. bijugum* were highly resistant. Only a few accessions of *C. echinospermum, C. Judaicum, C. pinnatifidum* and *C. reticulatum* were also resistant.

Identification of New Traits

New traits, of value to crop improvement, may occur spontaneously in nature and others may be produced through induced mutation. Some traits identified in recent years include a thick stem, an open flower and short bushy mutants (Dahiya *et al.*, 1984); upright pedicel types (Pundir and van der Maesen, 1977); lobed vexillum (Rao and Pundir, 1983); polycarpy and double pods (Pundir *et al.*, 1988); and the combined occurrence of twin pods and wilt resistance (Pundir and Mengesha, 1988); glabrous stem (Pundir and Reddy, 1989); and determinate growth habit (van Rheenen *et al.*, 1994). The twin pod characteristic occurs in more than 100 accessions in the chickpea collection (mostly Indian origin). It was found this trait could lead to an increase in seed yield of about 6-11% (Sheldrake *et al.*, 1978). Pod size and pod filling percentage are economic traits, but difficult to measure and characterize. These traits were estimated by measuring the replacement of an equivalent volume of water. Accessions were identified with high pod filling percentages (Pundir *et al.*, 1992).

GENETIC RESOURCES OF WILD SPECIES

Wild *Cicer* species were scarce in germplasm collections before 1970 but currently a reasonable number are available. The gene banks of ICRISAT, ICARDA, and RPIS in Pullman hold 135, 268 and 95 accessions of wild annual *Cicer* species, respectively, which consists mostly of the eight wild annual species.

Several efforts to grow and increase seeds of perennial *Cicer* species in ambient conditions at ICRISAT- Patancheru, ICARDA-Aleppo and Izmir-Turkey failed, probably because of unsuitable weather conditions. These species need lower temperatures coupled with drier and longer days. The weather conditions in Pullman, Washington, USA meet these requirements and perennial *Cicers* have been grown successfully. Twelve species (*acanthophyllum, anatolicum, canariense, flexuosum, macracanthum, microphyllum, montbretii, multijugum, nuristanicum, oxyodon, pungens,* and *songaricum*) are maintained at Pullman. Some, such as *C. microphyllum, C. anatolicum* and *C. oxyodon,* grew profusely and produced a large numbers of pods, often with the twin pod characteristic.

Annual species can be raised relatively easily. Accessions of eight wild annual *Cicer* species have been evaluated for various morphological traits at ICARDA and a catalog prepared (Robertson *et al.*, 1995). Some of the accessions have also been evaluated for economic traits at a few locations. Some of the accessions of annual wild *Cicer* species exhibited higher level of expression of economic traits and resistance to biotic and abiotic stresses and the data is summarized in Table 5.

Table 5. Useful traits in wild *Cicer* species.

Trait	*Cicer* species	Reference[1]
Resistance to fusarium wilt	*judaicum*	2,4
	bijugum	2,3,4
	echinospermum	3,4
	canariense, chorassanicum, cuneatum, pinnatifidum	2
	reticulatum	4
Resistance to combined soilborne diseases	*bijugum, cuneatum, judaicum, pinnatifidum*	5
Resistance to gray mold	*bijugum*	3
Resistance to ascochyta blight	*bijugum*	3,7
	judaicum, pinnatifidum	1,3,7
	montbretii	1
Resistance to cyst nematode	*bijugum, pinnatifidum, reticulatum*	8
Tolerance to cold	*bijugum, echinospermum, judaicum, pinnatifidum, reticulatum,*	10
Higher seed protein	*bijugum, reticulatum*	6
Higher biomass	*cuneatum,* most perennial species	-
Resistance to leaf miner	All wild annual species	9
Twin pods	*anatolicum, bijugum, chorassanicum cuneatum, microphyllum, pinnatifidum oxyodon, songaricum*	12,11
Multiple seeds	*cuneatum, montbretii*	12,11

1 Singh *et al.*, 1981; 2 Kaiser *et al.*, 1994; 3 Haware *et al.*, 1992; 4 Infantino *et al.*, 1996; 5 Reddy *et al.*, 1991; 6 Singh and Pundir, 1991; 7 Singh and Reddy, 1993; 8 Di Vito *et al.*, 1996; 9 Singh and Weigand, 1994; 10 Singh *et al.*, 1990; 11 Robertson *et al.*, 1995; 12 van der Maesen, 1987.

Ladizinsky and Adler (1976) classified annual *Cicer* species into three groups, based on their crossability. Crosses between members within a group were successful but not between members of different groups. Group I consisted of *C. arietinum, C. reticulatum* and *C. echinospermum* and Group II of *C. judaicum, C. pinnatifidum* and *C. bijugum.* Group III consisted of *C. cuneatum,* the only other species included in their study. The *Cicer* species were assessed for their value in breeding programs and classified into three gene pools following the scheme of Harlan and De Wet (1971). *C. reticulatum* normally crosses with chickpea and therefore, is a member of the primary gene pool. *C. echinospermum* is in the secondary gene pool because the F_1 hybrids produced from crosses with the cultivated chickpea are highly sterile. Other species, where there is no evidence or possibility of gene exchange with chickpea, were placed in the tertiary gene pool. Subsequent results reported by Singh and Ocampo (1993) and Pundir and Mengesha (1995), showed that *C. echinospermum* crosses normally with chickpea and the F_1 hybrids produced 50% of the normal pod number revealing good prospects for gene exchange. At ICARDA we have been successful in making crosses between *C. arietinum* and *C. pinnatifidum* but the F_1 hybrids survived only up to 3-5 leaf stage and then died after becoming chlorotic (Personal communication R.S. Malhotra).

A recent study of phylogenetic relations, based on isozyme polymorphism among eight wild annual *Cicer* species (Labdi *et al.*, 1996), revealed that levels of polymorphism were high and greater than in the cultivated species. The nine annual *Cicer* species formed four phylogenetic groups based on the neighbor-joining method given by Saitou and Nei (1987). The first group consisted of *C. arietinum, C. reticulatum* and *C. echinospermum*; the second group *C. bijugum, C. pinnatifidum* and *C. judaicum*; the third *C. chorassanicum* and *C. yamashitae*, and the fourth only the one species, *C. cuneatum*.

Germplasm Conservation

Chickpea has seeds that can be stored for long periods with a minimum loss of viability. In the gene banks at ICRISAT and ICARDA, seeds have been stored in medium-term storage (4°C, 20% RH) for 15 years with full seed viability. We are continuing, set by set, to transfer the entire germplasm collection to the long-term (-20°C) storage facility to increase security and minimize the possible loss of genetic diversity. Ellis (1988) has given practical advice on seed viability in storage. For example, chickpea seed having a 99% initial viability and 10% moisture content, will have a viability after 20 years of storage at 4°C, of about 80%. Having a duplicate backup collection elsewhere will further ensure security. The entire ICRISAT chickpea collection is being duplicated at ICARDA and vice versa.

***In Situ* Conservation**

The *in situ* conservation of wild Cicer species is very important especially for the species that are poorly represented in the germplasm pool and are difficult to raise at sites other than their natural habitats. To date very little has been done on this aspect of conservation. Concerted efforts should be made to save these species before these are lost.

Germplasm Distribution and Use

Chickpea research gained momentum with the availability of germplasm from the ICRISAT and ICARDA gene banks. The centers have distributed a large number of samples (Table 6). This includes repatriation of germplasm to countries that have lost their own collections. For example, 4800 chickpea accessions of Iranian origin were sent to Iran and 82 accessions to Nepal. Besides their use in research, many accessions (land races) were found promising and worth cultivating in specific areas of adaptation. Ten accessions supplied from the germplasm collections at ICRISAT and ICARDA were found to be superior and released for cultivation in Algeria, China, Cyprus, Egypt, India, Iran, Iraq, Italy, Jordan, Lebanon, Morocco, Myanmar, Nepal, Oman, Sudan, Syria, Turkey, Tunisia and the USA.

Table 6. Distribution of seed samples from chickpea germplasm collections at ICRISAT and ICARDA, from 1974 to 1996.[1]

Year	ICRISAT	ICARDA	Year	ICRISAT	ICARDA
1974[2]	3070	-	1986	3104	-
1975	7020	-	1987	6268	-
1976	2687	-	1988	5095	-
1977	800	-	1989	8825	-
1978	2318	-	1990	2860	462
1979	1454	-	1991	4745	83
1980	8336	-	1992	1945	714
1981	10202	-	1993	2624	165
1982	5861	-	1994	1166	4481
1983	10548	-	1995	1300	9809
1984	6596	-	1996	5879	4899
1985	4808	-	Total	107511	20613

1 Germplasm samples from ICRISAT, were supplied to various institutes in 80 countries and from ICARDA, to 24 countries.
2 Germplasm samples from ICARDA were supplied from 1977 to 1989, but proper records were not maintained.

A large number of lines identified as sources of resistance to biotic (Ascochyta blight, Fusarium wilt, and leaf miner) and abiotic (cold and drought) stresses have been shared with the national programs through the Legume International Testing Program at ICARDA and ICRISAT.

Priorities for Germplasm Collection

The chickpea collections at ICRISAT and ICARDA are fairly well represented from most chickpea growing countries, except northern Ethiopia, Eritrea, Colombia, Peru, Russia and the Central Asian Independent States. Chickpea germplasm needs to be collected from these countries. A large number of germplasm lines we have received as donations are known only by country of origin and precise passport data are not available. In such cases we need to have germplasm representing diverse agroclimatic-regions of those countries. Our wild *Cicer* collections are far from optimum. Of the wild annuals, *C. yamashitae*, and *C. chorassanicum* are represented by only three and 2 accessions respectively. *C. cuneatum* is represented by only one accession. Representation of perennial *Cicer* species is still very poor. Of the 34 perennial species, live seeds of 42 accessions of only 12 *Cicer* species are available in the collection. We need to secure germplasm of these species as early as possible. Additional collections should also be made from south east Turkey and adjacent areas of Iraq, of the useful wild species namely, *C. reticulatum* and *C. echinospermum* that are crossable with the cultigen.

Future Prospects

Future research and conservation activities relating to the genetic resources of the genus *Cicer* should consider the following:

i) The status of the germplasm needs to be reviewed periodically and new material collected from priority areas. This would include the annual wild species, namely *C. cuneatum* from Ethiopia, *C. chorassanicum* and *C. yamashitae* from Afghanistan, and *C. reticulatum* and *C. echinospermum* from Southeast Turkey and adjacent areas of Iraq and the germplasm of all the perennial *Cicer* species.
ii) Efforts should continue to identify new traits and to collect genetic information and evaluate the germplasm for these traits
iii) Where possible, germplasm sets should be jointly evaluated with National Agricultural Research Systems (NARSs).
iv) the long-term storage of the germplasm should be undertaken at more than one place to increase its security and minimize the possible loss of genetic diversity.
v) A core subset (core collection) of the base collection should be developed to enhance work efficiency and economy in operation.
vi) Passport as well as evaluation details need to be made available to users through (SINGER) the System-wide Information Network for Genetic Resources.
vii) Seeds of *Cicer* germplasm should be rejuvenated at frequent intervals and made available to researchers on demand.
viii) Pre-breeding work on interspecific hybridization needs to be strengthened to facilitate introgression of desirable traits from the wild species to the cultigen. Biotechnological techniques should be used to introgress desirable wild genes into the cultigen.

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