

Assessment of Cold Tolerance of Chickpea at Rainfed Highlands of Iran

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Abstract: Work on cold tolerance in chickpea was initiated when the advantages of advancing its sowing date from traditional spring sowing to winter were established. In order to identify and select high-yielding and cold tolerance varieties in high altitude and cool regions, genetic variation of forty accessions of chickpea as well as one susceptible check (ILC 533) was studied in a RCB design with two replications at rainfed autumn sowing of Kurdistan province, west of Iran. In this nursery the susceptible check (ILC 533) repeated after every two test entries and different characteristics and variables such as seed yield, days from sowing to flowering, 100-seed weight, plant height, number of pods per plant, number of seeds per pod, number of primary branches and number of secondary branches were recorded. Annual and combined analysis of variance revealed that there were significant differences between genotypes for seed yield, number of secondary branches, 100-seed weight and cold tolerance score ($P < 0.05$). The correlation coefficient of seed yield with 100 seeds weight and cold tolerance rate were found negative and significant at 1% probability level and secondary branches number positive and significant at 1% probability level. Sixteen entries showed a desirable reaction ($3 \leq$ on 1 to 9 scale, where 1 = free, 9 = killed due to frost). The highly cold tolerant entries (FLIP 95-255C, FLIP 93-260C and Sel95TH1716) are derived from hybrids of cultivated varieties with ILWC 182 (*C. reticulatum*) a wild relation of cultigen (*C. arietinum* L.).

Key words: Chickpea (*Cicer arietinum* L.) • Abiotic stresses • Genetic variation • Cold tolerance • Autumn sowing

INTRODUCTION

Chickpea is the third important food legume crop in the world, grown in 11 m ha with 9 million-ton production [1]. It provides a high quality protein to people in developing countries [2]. Chickpea is grown as a winter crop in the subtropics and tropics and as a spring-sown crop in Mediterranean and temperate climates because the conventional cultivars tolerate only mild cold. Chickpea is the main important food legume crop in Iran, where it is grown as a rain-fed crop on an area of 700,000 ha, mostly in spring season. Spring-sown rain-fed chickpea yield ranges from 0.33 to 0.65 t ha⁻¹ whereas irrigated yield ranges from 0.70 to 1.5 [3,4].

Cold tolerance is one of the most important pre-requisites for winter or fall-sown chickpea. Even for spring-sown crop cold tolerance at early seedling stage is important [5]. Efforts have been under way since the initiation of chickpea project and breeding

for cold tolerance is the integral part of the chickpea improvement works.

Chickpea is the least cold tolerant crop among the cool-season food legumes. After the studies demonstrated a major gain in yield by advancing the sowing date from spring to early winter, the need for improving cold tolerance in chickpea has become obvious. The winter chickpea technology requires cultivars to tolerate low temperature down to -10°C for a period of 60 days [6, 7]. Three important requirements in the development of cold-tolerant lines are characterization of stress, identification of genetic variation and, availability simple screening methods. Singh and Saxena [1] have developed a field technique for screening chickpea for cold tolerance which involves: (a) Sowing the germplasm and breeding materials in early October with supplemental irrigation to allow the crop to achieve a late vegetative growth stage before the onset of severe winter conditions in late December; (b) Planting of a

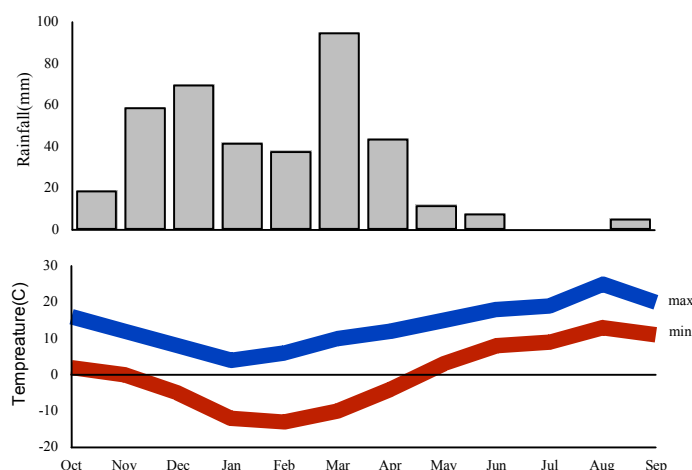


Fig. 1: Variation in rainfall and temperature by means of months during cropping seasons at the Saral experimental station, west of Iran

susceptible check after every 2-10 test lines; and (c) Evaluating the materials on a 1-9 scale after the susceptible check is killed.

Three key elements in characterization of an abiotic stress are intensity and duration of stress, rate of stress development and phenological timing of stress [8].

The objectives of this study were to characterize stress experienced by chickpea and its relation to the seed yield and assess genetic variation for cold tolerance in the field, for advancing sowing date from spring to autumn.

MATERIALS AND METHODS

This study was carried out during two successive growing seasons (2003-2005) at the Saral Agricultural Research Station, 35° 43' N, 48° 8' E and 2100 m. altitude, in the province of Kurdistan, west of Iran. Climatic conditions including rainfall and atmospheric temperature during experiment are shown in Figure 1. Plant materials consisted of 41 accessions of chickpea (Table 2), forty lines received from ICARDA and a local check "Jam".

Those were planted in two years at early October. Experiments were conducted in rain-fed plots with two replications using randomized complete block design. Each plot consisted of two rows, 1 m in length. The inter row and interplant spacing were 30 cm and 10 cm, respectively. The land was fallow in the previous year and 65kg ha⁻¹ urea fertilizer was added to the soil before planting. Plots were maintained weed free and sprayed with SEVIN® against pod borer (*Helicoverpa armigera*) prior to the pod formation.

Observations of five randomly selected plants from each plot were recorded on eight characters, namely days from sowing to flowering, 100-seeds weight, plant height, number of pods per plant, number of seeds per pod, number of primary branches, number of secondary branches and seed yield.

Simple and combined analysis of variance was performed for each character measured in the experiment. The relationship between the characters was determined by regression analysis.

RESULTS AND DISCUSSION

With respect to meteorological data (Fig.1), in these cropping seasons, cold stress was severe in January and February. The severity of stress experienced by cultivars /lines varied with their date of germination each year. Susceptible check (ILC 533) was killed due to frost both years and other genotypes experienced -17°C, slightly. Number of days with snow cover at first year was 28 days and at second year 36 days, with 7 and 6 cm in height, respectively. There were more cold days in 2003/04 than in 2004/05, but the days on which minimum temperature fell below -10°C was more in the latter.

Combined analysis of variance for recorded traits showed that, year effect is significant for cold tolerance rate, number of pods per plant and seed yield (data have not shown).

Mean, standard error, range and coefficient of variation for different traits have been showed in Table 1. Range of seed yield of genotypes revealed an interesting point. In spring-sown rainfed experiments, the best

Table 1: Mean \pm Standard error, range and coefficient of variation of recorded traits for fall- sown chickpea genotypes during cropping seasons

Trait	Mean \pm Standard Error	Range	Coefficient of variation(%)
CTR	4.4 \pm 0.76	3 - 9	17.8
YLD (g/m ²)	183.5 \pm 19.9	88 - 290	29.2
DF	193.0 \pm 1.6	182 - 195	1.7
PHT (cm)	22.4 \pm 0.62	15 - 29	15.3
P/P	16.9 \pm 1.22	12 - 25	4.2
S/P	1 \pm 0.98	1 - 3	3.3
PBN	3 \pm 0.11	2 - 5	5.6
SBN	9 \pm 0.16	4 - 12	5.5
100SW (g)	33.6 \pm 1.5	24 - 47	15.2

Abbreviations: CTR = cold tolerance rate, DF= days to flowering, PHT = plant height, P/P = pod per plant, S/P = seed per pod, PBN = primary branches number, SBN = secondary branches number, 100SW = 100 seeds weight, YLD = seed yield

Table 2: Average of seed yield and other characteristics of chickpea entries

No	entry name	CTR	DF	PHT	P/P (cm)	S/P	PBN	SBN	100 SW (g)	YLD (g/m ²)
1	ILC 8262	1	197	22	20	2	3	11	28	233
2	FLIP93-255C	1	193	21	12	2	2	9	29	250
3	FLIP93-260C	3	197	26	22	1	5	12	32	223
4	FLIP93-262-C	5	195	18	12	1	3	8	32	142
5	FLIP96-90C	3	195	19	18	2	3	10	37	165
6	FLIP97-28C	1	197	25	13	1	3	7	24	180
7	FLIP97-81C	3	195	22	13	1	3	12	34	205
8	FLIP97-83C	5	195	23	14	1	5	8	46	142
9	FLIP97-95C	3	193	29	15	3	4	11	36	218
10	FLIP97-112C	3	195	21	12	1	2	9	43	180
11	FLIP97-115C	7	195	25	20	1	2	4	47	97
12	FLIP97-116C	3	193	21	18	1	2	7	36	126
13	FLIP97-121C	7	194	23	15	1	3	8	44	155
14	FLIP97-126C	5	195	25	17	1	4	7	45	183
15	FLIP97-135C	7	193	23	15	2	4	9	45	180
16	FLIP97-136C	3	193	19	14	1	4	5	44	88
17	FLIP97-149C	3	190	29	13	1	3	8	40	178
18	FLIP97-150C	5	192	22	17	2	3	4	36	165
19	FLIP97-198C	3	195	21	16	2	2	10	28	112
20	FLIP97-173C	3	195	25	17	3	3	8	43	182
21	FLIP97-179C	1	190	23	17	1	5	12	29	233
22	FLIP97-182C	3	192	19	18	1	3	7	40	185
23	FLIP97-189C	1	193	21	18	1	3	10	38	173
24	FLIP97-192C	3	188	18	20	1	4	8	38	185
25	FLIP97-221C	7	192	24	22	1	2	8	42	188
26	FLIP97-230C	3	195	22	20	1	3	6	42	163
27	FLIP97-231C	5	195	28	14	2	3	4	38	142
28	FLIP97-232C	1	193	23	17	1	3	11	30	258
29	FLIP97-239C	3	192	29	17	2	4	12	34	218
30	FLIP98-16C	7	193	24	15	2	3	5	35	110
31	FLIP98-50C	3	195	19	20	1	2	8	33	211
32	FLIP98-108C	1	193	29	16	1	2	8	39	290
33	Sel96TH11403	5	193	17	17	3	5	9	44	108
34	Sel93TH24460	1	195	23	15	1	3	12	34	265
35	Sel93TH24464	3	192	23	16	1	2	10	31	252
36	Sel93TH24469	3	195	19	22	1	4	11	28	202
37	Sel93TH24483	3	195	22	25	1	4	12	31	228
38	Sel95TH1716	3	189	22	18	1	4	10	30	203
39	Sel95TH1744	5	192	15	19	1	3	5	34	123
40	Sel95TH1745	3	188	15	17	1	3	12	31	200
41	ILC533	9	-	-	-	-	-	-	-	0
Mean		4.4	193.4	22.4	16.9	1.4	3.2	8.7	36.3	183.5
LSD (5%)		1.5	11.8	8.6	13.1	1.9	2.8	4.4	8.3	65.9

For abbreviations see table 1

Table 3: Correlation coefficients (phenotypic) for agronomic attributes (n=40)

Traits	YLD	100SW	SBN	PBN	S/P	P/P	PHT	DF
100SW	-0.438**	-	-	-	-	-	-	-
SBN	0.643**	-0.473**	-	-	-	-	-	-
PBN	-0.033	0.070	0.281	-	-	-	-	-
S/P	-0.136	0.082	-0.002	0.134	-	-	-	-
P/P	0.112	-0.091	0.149	0.145	-0.153	-	-	-
PHT	0.295	0.126	0.005	0.009	0.180	-0.165	-	-
DF	-0.067	-0.006	-0.035	-0.094	0.104	0.006	0.188	-
CTR	-0.611**	0.569**	-0.510**	0.037	0.117	0.036	-0.017	-0.010

**: Significant at 1% level For abbreviations see table 1

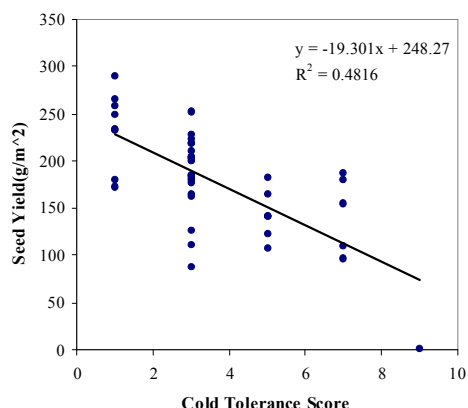


Fig. 2: Correlation between seed yield and cold tolerance scores of chickpea genotypes

chickpea genotypes yield ranges from 0.8 to 1.0 t ha⁻¹, whereas in this trial cold tolerant lines yielded more than 2.0 t ha⁻¹.

Mean yield for all genotypes over two years has been 1.8 t ha⁻¹ and this shows that accessions using adequate moisture during growth stages and due to long period from germination to maturity have produced considerable seed yield. Mean and least significant differences for characteristics of chickpea entries are shown in Table 2. FLIP 98-108C is produced the highest seed yield and, apart from ILC 533(susceptible check), which killed by cold both years, the lowest yield is produced by FLIP 97-136C.

Results obtained from association among traits (Table 3) indicated that seed yield has positive and significant correlation with number of secondary branches and have negative and significant correlation with 100-seeds weight and cold tolerance rate (Fig. 2). Correlation between 100seeds weight and cold tolerance rate was positive and significant (P<0.01). Malhotra and Saxena [9] and Hadjichristodoulou [10], also have grouped cold tolerant varieties in small / medium seed size category of chickpeas. In other hand, most of genotypes with high

cold tolerance score had more secondary branch number and correlation between these two attributes has been significant. Investigators believe that, cold tolerant chickpea varieties after effects of cold damage on their primary branches will compensate cold damage via more secondary branches production [11, 12].

According to the results sixteen entries showed a desirable reaction (3 ≤ on 1 to 9 scale, where 1= free and... 9= killed). The most cold tolerance entries were FLIP 95-255C, FLIP 93-260C and Sel 95TH1 716 with an average reaction of equal or less than 3. All the aforementioned lines are derived from hybrids with ILWC 182 (*C. reticulatum*), a wild relative of cultivated genotype. Useful genes for cold tolerance could be transferred from alien chromosomes of wild relatives to cultigene [13].

The implication of the results for development of chickpeas for cold prone climates is clear. It is emphasized that breeding strategies must seek to develop lines with a greater degree of adaptability to cold conditions. Towards this end, the physiological and biochemical basis for cold tolerance must be clarified further.

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REFERENCES

1. Singh, K.B. and M.C. Saxena, 1999. Chickpeas, the Tropical Agriculturalist. Mac Millan Education. London and Basington.
2. Acikgoz, N., M. Karaca, C. Er and K. Meyveci, 1994. Chickpea and Lentil Production in Turkey. In Expanding the production and use of cool season food legumes, Eds., F.J. Muehlbauer F. J. and W.J. Kaiser. Kluwer Academic Publ., Dordrecht, the Netherlands, pp: 388–398.

3. Kanouni, H., M. Kh. Ahmadi, S.H. Sabaghpour, R.S. Malhotra and H. Ketat, 2003. Evaluation of Spring Sown Chickpea (*Cicer arietinum* L.) Varieties for Drought Tolerance. In the Proceedings of the International Chickpea Conference, Chickpea Research for the Millennium, Raipour, Chhattisgarh, India. January 20-22, 2003, pp: 294-300.
4. Saxena, M.C., 1984. Agronomic Studies on Winter Chickpea. In Ascochyta blight and winter sowing of chickpeas, Eds., M.C. Saxena and K.B. Singh. Martinus Nijhoff, The Hague, the Netherlands, pp: 98-123.
5. Saxena, N.P. and C. Johnson, 1990. Chickpea Ideotypes for Genetic Enhancement of Yield and Yield Stability in South Asia. In the Proceedings of second International Workshop on Chickpea Improvement: Chickpea in nineties. 4-8 Dec. 1989. ICRISAT, pp: 80-88.
6. Baker, R.J., 1994. Breeding Methods and Selection Indices for Improved Tolerance to Biotic and Abiotic Stresses in Cool Season Food Legumes. *Euphytica*, 73: 67-72.
7. Malhotra, R.S. and K.B. Singh, 1991. Gene action for cold tolerance in chickpea. *Theoretical and Applied Genetics*, 82: 598-601.
8. ICARDA, 2006. Food Legume Improvement Program: Annual Report 2005. Aleppo. Syria: ICARDA.
9. Malhotra, R.S. and M.C. Saxena, 1993. Screening for cold and heat tolerance in cool-season food legumes. In *Breeding for stress tolerance in cool-season food legumes*, Eds., K.B. Singh and M.C. Saxena. John Wiley and Sons, Chichester, UK, pp: 429-438.
10. Hadjichristodoulou, A., 1984. New chickpea varieties for winter sowing and mechanical harvesting. Technical Bulletin, Agricultural Research Institute, Ministry of Agriculture and Natural Resources, Cyprus No.58.
11. Kumar, L. and P.P. Arora, 1991. Basis of selection in chickpea. *International Chickpea Newsletter*, 24: 14-15.
12. Singh, K.B., 1993. Problems and Prospects of Stress Resistance Breeding in Chickpea In *Breeding for stress tolerance in cool- season food legumes*, Eds., K.B. Singh and M.C. Saxena. John Wiley and Sons, Chichester, U.K, pp: 17-36.
13. Rosielle, A.A. and J. Hamblin, 1981. Theoretical Aspects of Selection for Yield in Stress and non-Stress Environments. *Crop Sci.*, 21:943-46.