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Chickpea Evaluation for Cold Tolerance under Field Conditions

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ABSTRACT

Chickpea (*Cicer arietinum* L.) yields are higher when plantings are made in early winter in the Mediterranean region instead of during the traditional spring season, but winter killing is often a problem. Cold tolerant chickpea cultivars are needed to successfully utilize a winter sowing approach. A study was conducted at the International Center for Agricultural Research in the Dry Areas (ICARDA), Tel Hadya, Syria during 1982 to 1983 with the objective of developing a field screening technique for cold tolerance in chickpea, and to identify sources of tolerance. A set of previously identified tolerant, intermediate, and susceptible lines was sown from mid-fall to early spring. All susceptible lines sown during October were killed from cold injury, showing that the crop was more susceptible at the late vegetative stage than at the seedling stage. Consequently, a field screening technique was proposed, with an October sowing date to allow the crop to grow to the late vegetative stage before the onset of severe winter. Susceptible checks are grown at frequent intervals and evaluation takes place after the death of the susceptible check. This is followed by confirmation of tolerance. A 1 to 9 visual score was used to evaluate germplasm for cold tolerance. A total of 3276 germplasm accessions and breeding lines were evaluated from 1981 to 1987. Twenty-one lines were identified as tolerant. Cold tolerance was not associated with the phenotypic traits of leaflet area, seed size, time to maturity, plant height, or growth habit.

CHICKPEA is traditionally grown during the spring season in the Mediterranean region including North Africa, West Asia, and South Europe. Research at the International Center for Agricultural Research in the Dry Areas (ICARDA) in northern Syria has shown that planting in the early winter in the Mediterranean region substantially increases seed yield (4). However, winter plantings of chickpea are successful only with cold tolerant cultivars that resist Ascochyta blight (caused by *Ascochyta rabiei* [Pass.] Lab.). Plant losses during the winter are usually due to direct freezing injury. Limited work on screening for cold tolerance has been done in grain legumes (1, 2, 5).

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There are no reports of systematic work on cold tolerance in chickpea. The first attempt to screen lines for cold tolerance was made at ICARDA during the 1978 to 1979 season when more than 3000 lines were evaluated at Tel Hadya, Syria, and Terbol, Lebanon. This initial test failed to differentiate between tolerance and susceptibility to cold because freezing temperatures occurred only when the crop was at the seedling stage and was less vulnerable to cold injury (8). Harris (3) reported that in only 1 of 13 yr would freezing temperatures occur in late March and early April when winter-sown chickpea is at a late vegetative stage and susceptible to cold injury. In collaboration with the Turkish national program at Hymana near Ankara, some cold-tolerant lines were identified (7). However, these lines were weakened by cold and were less productive than the corresponding spring-sown chickpea. From these studies, it was concluded that screening for cold tolerance at high elevations was not a reliable approach, and that screening for cold tolerance would be most productive at low elevations in West Asia and North Africa regions.

In 1981 to 1982, freezing temperatures occurred 39 nights at Tel Hadya killing 4% of the lines evaluated (6). This suggested that screening could be done at Tel Hadya if a technique could be developed to evaluate chickpea lines for cold exposure at a vulnerable growth stage. The objectives of the current study were to develop a simple and reliable field screening technique for cold tolerance in chickpea, and to identify sources of tolerance.

MATERIALS AND METHODS

Ninety nine chickpea lines with varying degrees of cold tolerance as identified in the 1981 to 1982 season and a susceptible line (FLIP 81-61C), which was killed during the 1981 to 1982 season, were used in this study. These lines were sown at nine different dates (23 Oct., 3, 14, and 25 Nov., and 15 Dec. 1982; 5 and 25 Jan., 14 Feb., and 6 Mar. 1983) at Tel Hadya, Syria (36 °01′N, 36 °56′E, 284m above sea level). The field was fertilized with 22 kg ha^{-1} of P prior to planting.

The experiment was conducted as a split plot design with three replications. Planting dates were main plots and genotypes subplots. Subplots were single rows 2 m long with inter- and intra-row spacing of 45 and 10 cm, respectively. The susceptible check was included after every four lines. An irrigation (40 mm) was applied to the first four plantings to ensure rapid emergence. The crop was protected from ascochyta blight by periodic spraying of the fungicide chlorothalonil (tetrachloroisophthalonitrile) at the rate of 40 kg a.i. ha^{-1}. The experimental area was hand weeded. Visual cold tolerance ratings on a 1 to 9 scale were assigned after the susceptible checks were killed, and these ratings were used for statistical analysis. The date of planting study was conducted only in 1982 to 1983; subsequent screening was done by October planting.

Rating Scale

A 1 to 9 scale was developed and adopted in this study. The scale is described as follows: 1 = no visible symptoms of damage; 2 = highly tolerant, up to 10% leaflets show withering and drying, no killing; 3 = tolerant, 11 to 20% leaflets show withering and up to 20% branches show withering and drying, no killing; 4 = moderately tolerant, 21 to 40% leaflets and up to 20% branches show withering and drying, no killing; 5 = intermediate, 41 to 60% leaflets and 21 to 40% branches show withering and drying, up to 5% plant killing; 6 = moderately susceptible, 61 to 80% leaflets and from 41 to 60% branches show withering and drying, 6 to 25% plant killing; 7 = susceptible, 81 to 99% leaflets and 61 to 80% branches show withering and drying, 26 to 50% plant killing; 8 = highly susceptible, 100% leaflets and 81 to 99% branches show withering and drying, 51 to 99% plant killing; and 9 = 100% plant killing.

The rating scale was used after the susceptible check suffered 100% mortality. In seasons when the susceptible check is not killed, such screening would be ineffective.

Evaluation of Germplasm

Available chickpea germplasm accessions and breeding lines were evaluated from 1981 to 1987 for cold tolerance. Each line was planted in a preliminary screening nursery during early October in an unreplicated 2-m row with inter- and intra-row spacing of 45 and 10 cm, respectively. The same susceptible check (FLIP 81-61 C) was sown after every nine test lines. The first irrigation was given immediately after the planting and the second after 4 wk. The cultural practices described earlier were used to maintain plots. Most lines were at the late vegetative growth stage by early December when exposure to severe cold occurred.

The lines with little cold injury (rating 1–4) were rescreened in replicated tests. The highest rating (most susceptible) of any line in either season was considered the final rating of a line. If the winter in any year was mild (as occurred during the 1983–1984 and 1985–1986 seasons) and the susceptible check was not killed, the lines were reevaluated the following year. This procedure was used to evaluate 3276 kabuli chickpea lines.

Some phenotypic traits were recorded on cold tolerant

Table 1. The number of days with freezing temperatures and monthly minimum temperatures for the winters of 1981 to 1987 at Tel Hadya Syria.

	Year					
Month	1981–1982	1982–1983	1983–1984	1984–1985	1985–1986	1986–1987
November						
Days, no.	4	4	0	1	0	7
Minimum temperature, °C	−4.2	−4.4	+4.5	−1.1	+4.0	−2.3
December						
Days, no.	0	15	10	16	7	16
Minimum temperature, °C	+2.0	−6.4	−3.9	−6.0	−6.4	−6.8
January						
Days, no.	11	18	6	3	7	6
Minimum temperature, °C	−6.0	−9.8	−2.4	−0.8	−4.0	−2.1
February						
Days, no.	17	11	10	10	1	0
Minimum temperature, °C	−7.8	−3.6	−4.1	−6.8	0.0	+0.3
March						
Days, no.	7	4	1	12	2	7
Minimum temperature, °C	−4.2	−5.6	−0.5	−9.5	−1.1	−2.8
April						
Days, no.	0	0	0	0	0	0
Minimum temperature, °C	+2.2	+3.6	+2.2	+2.0	+1.6	+2.6
Total						
Days, no.	39	52	27	42	17	36
Minimum temperature, °C	−7.8	−9.8	−4.1	−9.5	−6.4	−6.8

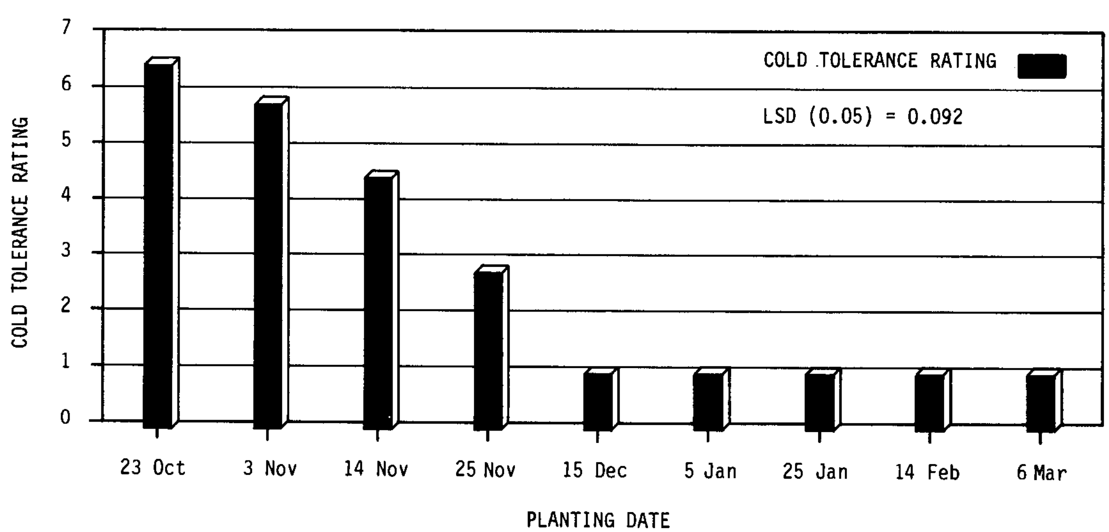

Fig. 1. Mean cold tolerance rating on chickpea genotypes sown at different dates at Tel Hadya, Syria, 1982 to 1983.

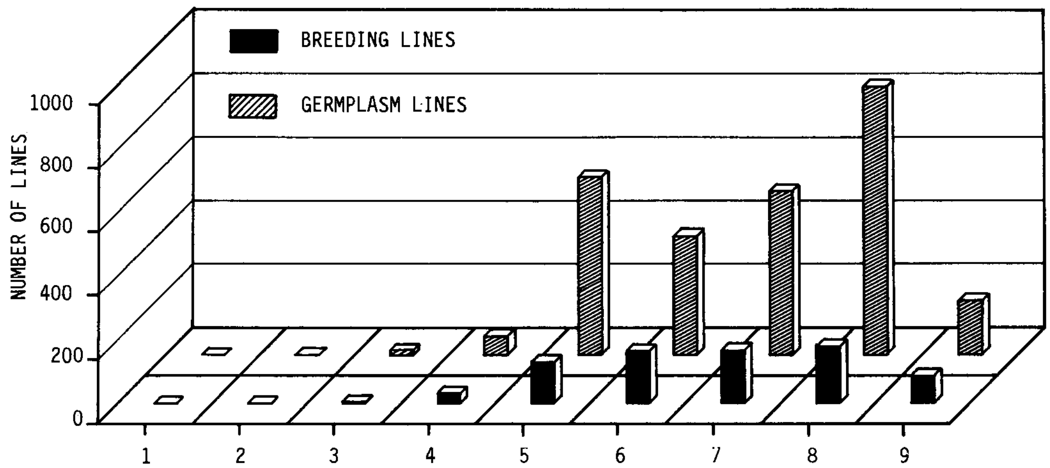

Fig. 2. Reaction of chickpea germplasm lines (1981 to 1987) and breeding lines (1984 to 1987) to cold at Tel Hadya, Syria.

Some phenotypic traits were recorded on cold tolerant lines. The growth habit was recorded at the time of final rating for cold tolerance as prostrate, semi-prostrate and semi-erect. The leaf area of 10 randomly selected leaves was measured with a leaf area meter. The days to flower was recorded in days from planting to the day on which at least 50% of the plants in the row had started to flower. The plant height was recorded in centimeters as the average height of three plants in the plot at the late podding stage. The 100-seed weight was recorded in grams from 100 randomly selected seeds from each line.

RESULTS AND DISCUSSION

Development of Screening Technique

In the winter of 1982 to 1983, 52 nights had freezing temperatures (Table 1). The lowest temperature in the 1982 to 1983 winter was −9.8 °C. Sufficient cold stress occurred for screening for cold tolerance under field conditions. Analysis of variance of phenotypic damage data showed that dates, genotypes, and their interactions were significant ($P < 0.05$). These data indicated that cold tolerance in different genotypes of chickpea varied by planting date.

The mean cold tolerance rating at different planting dates revealed that the susceptibility of germplasm to cold increased with early planting (Fig. 1). The effect of cold was gradually reduced with later planting dates and disappeared in the material planted after mid-December. The susceptible check was killed only at the two earliest planting dates. (23 October and 3 November). Planting in October at Tel Hadya would allow germplasm to be screened for cold tolerance. Lines found tolerant in any one screening have to undergo one more season of evaluation to confirm their rating.

It has been observed that the advancement of the sowing date to mid-fall with irrigation for rapid emergence the crop reaches an advanced stage of growth

Table 2. Origin, growth habit, leaf area, days to flower, plant height, and 100-seed weight of the cold tolerant chickpea germplasm and breeding lines.

Line	Origin	Growth habit	Leaflet area	Days to flower	Plant height	100-seed weight
		score†	cm²	d	cm	g
ILC 794	Iran	P	0.70	185	58	29
ILC 1071	Iran	SP	1.10	185	59	41
ILC 1251	Iran	SE	0.85	184	60	20
ILC 1256	AFG‡	SE	0.87	184	56	18
ILC 1444	AFG	SP	0.62	188	45	16
ILC 1455	AFG	P	0.77	180	50	26
ILC 1464	AFG	P	0.78	180	56	20
ILC 1875	India	SE	0.76	180	45	26
ILC 3465	Spain	SP	0.73	186	50	31
ILC 3598	India	SE	0.81	183	57	23
ILC 3746	Nepal	SP	0.59	180	50	10
ILC 3747	Nepal	P	0.67	180	45	9
ILC 3791	India	SE	0.73	180	60	28
ILC 3857	Morocco	SE	1.25	182	60	23
ILC 3861	Morocco	SP	1.05	185	60	27
FLIP 82- 85C	ICARDA	SP	1.24	182	65	29
FLIP 82-131C	ICARDA	SE	0.98	185	65	30
FLIP 84-112C	ICARDA	SE	0.63	180	45	26
FLIP 85- 4C	ICARDA	SE	1.36	189	75	49
FLIP 85- 49C	ICARDA	SE	1.49	189	80	34
FLIP 85- 81C	ICARDA	P	1.39	182	70	35

† P = Prostrate; SP = Semi-prostrate; SE = Semi-erect.
‡ AFG = Afganistan.

Table 3. Country of origin of cold tolerant and moderately tolerant germplasm lines in chickpea.

Origin	Lines		Origin	Lines	
	Evaluated	Tolerant or mod. tol.†		Evaluated	Tolerant or mod. tol.†
	no.			no.	
Afganistan	452	7	Lebanon	24	0
Algeria	17	0	Malawi	1	0
Bulgaria	3	0	Mexico	46	0
Chile	131	12	Morocco	84	9
Cyprus	1	0	Nepal	2	2
Czechoslovakia	6	0	Pakistan	23	3
Ecuador	1	0	Peru	3	0
Egypt	47	0	Portugal	3	0
Ethiopia	47	0	Spain	138	5
France	3	0	Sudan	6	0
Greece	9	0	Syria	38	0
India	132	14	Tunisia	45	0
Iran	872	15	Turkey	182	4
Iraq	29	0	USA	19	0
Italy	7	0	USSR	34	0
Jordan	39	0	Others	118	2
			Total	2526	73

† Moderately tolerant.

when it is susceptible to cold injury. Field observations with chickpea confirm the observations with other crops that seedlings are not as sensitive to cold injury as the plants at the late vegetative stage of growth (9).

Significant ($P < 0.05$) correlations ($r = 0.76$–0.91) between cold tolerance reaction of plants from 23 October, 3 November, 14 November, and 25 November sowings were found. The trend for increased cold susceptibility of susceptible lines at earlier planting dates was similar. The effects of cold were reduced and almost negligible at later planting dates, resulting in nonsignificant ($P > 0.05$) correlations.

Previously, Singh et al. (8), classified the germplasm for cold tolerance on a 1 to 5 scale mainly on the basis of plant survival. Auld et al. (1) have screened pea (*Pisum sativum* L.) under field conditions at Idaho, and used percent survival as an indicator of winterhardiness. Their scale was developed for environmental conditions where the cold effect on plants was not easily measured due to extended snow cover. A 1 to 9 scale described in the Materials and Methods section, was developed for use in the Mediterranean region, where winters are mild and snow coverage is rare.

Based on these results, the following field screening technique for evaluation of chickpea for cold tolerance is proposed: (i) plant in October and irrigate to ensure the plants enter the winter season in the late vegetative growth stage, (ii) plant a susceptible check at frequent intervals, and (iii) evaluate test lines only if environmental conditions are severe enough to kill the susceptible check.

Evaluation of Germplasm

This procedure was used to evaluate 2526 germplasm lines. Since the 1981 to 1982 season was cold and provided a good opportunity for screening, we evaluated the germplasm accessions and have included the result with this study. Lines found tolerant during the 1981 to 1982 season were confirmed in later screenings. No line was found free from cold injury, but 0.6% of the lines were rated 3, 2.3% were rated 4, 22.1% were rated 5, and 68.4% were rated 6 to 8. About 6.7% were killed (Fig. 2).

Seven hundred and fifty breeding lines developed through hybridization at ICARDA and possessing resistance to ascochyta blight were evaluated for cold tolerance. None of these lines had a rating of 1 or 2, but 0.8% and 4% lines were rated 3 and 4, respectively (Fig. 2), 17.1% lines were tolerant, 67.8% were susceptible, and about 11.3% lines were killed, respectively. The 15 germplasm lines and six breeding lines with cold tolerance ratings of 3 are listed in Table 2.

Of the 2526 germplasm lines evaluated for cold tolerance, 2408 came from 31 countries (Table 3). Twenty-two of these 31 countries did not contribute sources of cold tolerance. Four countries (Chile, India, Iran, and Morocco) had 68% of the cold tolerant lines. Further exploration in these countries for additional cold tolerance sources might prove useful. Additional collection from Nepal could be beneficial because both Nepalese lines were cold tolerant. With the exception of Morocco, Spain, and Turkey, germplasm from the countries in the Mediterranean region did not contribute tolerance to cold. All the cold-tolerant lines were highly susceptible to ascochyta blight, explaining why the chickpea crop is sown during spring and why previous attempts to introduce this crop for winter sowing would have failed.

The growth habit, leaflet size, time to flower, plant height, and 100-seed weight of 21 cold tolerant germplasm and breeding lines were measured (Table 2). No significant ($P > 0.05$) correlation was established between these parameters and cold tolerance. This lack of correlation with cold tolerance will allow the plant breeder to develop cold-tolerant chickpea cultivars with any desired maturity, plant height, and seed weight.

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