Indian J. Plant Physiol., Vol. 9, No. 3, (N.S.) pp. 294-301 (July-Sept., 2004)

PHYSIOLOGICAL STUDIES ON TEMPERATURE TOLERANCE IN CHICKPEA (*CICER ARIETINUM* L.) GENOTYPES

TEJPAL SINGH, P.S. DESHMUKH* AND S.R. KUSHWAHA

Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi-110012

Received on 20 Nov., 2003, Revised on 24 Aug., 2004

SUMMARY

Chickpea planting is usually delayed in north-western parts of India due to popularization of rice-wheat cropping system. In the present study, efforts were made to study the impact of different planting dates on the physiological traits, viz. relative water content (RWC), percent membrane injury, chlorophyll content, dry matter production and seed yield on six chickpea (*Cicer arietinum* L.) genotypes. The results indicated that medium planting (30th Nov.) resulted in decreased membrane injury and increased chlorophyll content, relative water content, biological yield and seed yield of the genotypes as compared to early (15th Nov.) and late (15th Dec.) plantings. Further significant and clear-cut differences were noted among advance lines and released genotypes. Genotype DG36 showed superiority over other genotypes. It is emphasized that such traits may play an important role in selection of plants for temperature tolerance in breeding programme.

Key words: **Biological yield, chlorophyll content, membrane injury, planting dates, relative water content, temperature tolerance.**

INTRODUCTION

In India, chickpea occupies the first position among pulses, occupying about 35% of total cultivated area of pulses and contributing 45% towards total pulse production. In 2003, the total cropped area of chickpea in India was 10.66 million hectares and the total production was 8.25 million tonnes (ICRISAT 2003). The global demand for chickpea as per ICRISAT estimates will be around 11.1 million tonnes by 2010 as against 8.25 million tonnes in 2002, an increase of 35%. At present global productivity of chickpea stands at 0.7 to 0.8 tonnes per hectare, which is far below the potential of 5 tonnes per hectare. The major constraints for low productivity are abiotic stresses, viz. moisture, temperature, nutrients and salt stress. Among them moisture stress and temperature stress are the most important abiotic stresses for productivity. It has been reported by many researchers that rice-chickpea is more remunerative than rice-wheat cropping system in north-western parts of India. Under such situations the crop has to be sown upto the end of December due to late harvesting of high yielding rice varieties. Such late sown chickpea crop experiences low temperature at initial stage of crop growth, results in poor and slow vegetative growth, while, high temperature at the end of cropping season leads to forced maturity and the problem of poor biomass production (Chaturvedi and Dua 2003). Physiological traits like membrane injury index (Deshmukh *et al.* 1991, 2000, Gupta 1996) and relative water content (Rahangdale *et al.* 1994), have been considered for screening large number of genotypes under high temperature stress environments. In chickpea, terminal flowers abort upto 40-50% in

* Corresponding author, E-mail: psd462004@rediffmail.com

different varieties due to high temperature prevailing at the tail end of flowering period. Thus a greater part of the reproductive phase (early and late) is exposed to relatively high temperatures, affecting seed yield up to 50% (Dua 2001). Present study was an attempt to understand the underlying mechanism of temperature tolerance in chickpea genotypes in relation to the physiological traits, dry matter production and seed yield.

MATERIALS AND METHODS

A field experiment was conducted during 2002-2003 at Indian Agricultural Research Institute, New Delhi-110012 to study the effect of temperature on physiological traits and yield components in six chickpea genotypes under different planting dates. Three released varieties viz, Pusa 256, Pusa 372, BGD 72 and three advance lines viz., DG 36, DG 46 and DG 51 were grown under three planting dates i.e. 15 Nov. (early planting), 30 Nov. (medium planting) and 15 Dec. 2002 (late planting). Plant samples were collected for the study of physiological indices *i.e.*, relative water content (RWC) (Barrs and Weatherly 1962), membrane injury index (Deshmukh *et al*. 1991) and chlorophyll content (Hiscox and Israelstam 1979) at vegetative, flowering and pod formation stages. At maturity, 10 plants were selected at random from the two center rows, oven dried at 80 ^{0}C to constant weight and then weighed. The seeds were then threshed from the rest of plant, re-dried to constant weight and the seed weight determined. The data obtained were statistically analyzed by (Panse and Sukhatme 1985).

RESULTS AND DISCUSSION

Relative water content (RWC)

Relative water content of six chickpea genotypes as influenced by different sowing time are presented in Table 1. The results indicated that in general, RWC (%) was higher at initial growth stage and thereafter, declined upto pod formation stage. Under first planting significantly higher RWC was recorded throughout the growth period. However, RWC decreased in successive plantings in all the phenophases. Significant differences in RWC were recorded in all the genotypes at vegetative phase. Advance lines exhibited relatively more RWC than in released varieties at vegetative phase. During flowering phase, genotype DG 51 (74.83%) showed highest RWC content whereas it was lowest in Pusa 372 (70.38%). The average RWC values for advance lines were higher (73.03%) than the released varieties (71.18%) at flowering stage. Significantly higher RWC values were recorded in first and second plantings as compared to third planting during pod formation. Among the genotypes BGD 72 (61.90%), Pusa 372 (61.86%) and DG 36 (61.01%) showed significantly higher RWC in comparison to DG 51 (57.42%) at pod formation stage. Similar results were reported by Alluwar and Deotale (1991), Rahangdale *et al.* (1995) and Kumar *et al.* (2001).

Percent membrane injury

The percent membrane injury in leaves under different planting conditions in six chickpea genotypes are presented in Table 2. It is evident that the membrane damage was more at later stages of crop growth as compared to early stages. There were significant differences in membrane injury at all the planting dates throughout the growth duration. Membrane injury was higher in delayed planting at all the phenophases. The delay in planting of wheat resulted in increased percent membrane injury (Islam *et al.* 1998). As regards the genotypes, significantly higher membrane injury values were recorded in Pusa 372 (30.8%), BGD 72 (30.5%), Pusa 256 (25.0%) and DG 46 (24.0%) as compared to DG 36 (22.2%) at vegetative phase. At flowering phase higher MI values were recorded in Pusa 256 (42.2%), BGD 72 (47.3%) and in Pusa 372 (50.7%) as compared to DG 36 (36.7%), DG 51 (37.8%), DG 46 (40.3%). At pod formation stage all genotypes showed relatively higher membrane injury than at vegetative and flowering phases. This indicated natural senescence of leaves or more realization of stress during pod formation phase. In general the genotypes Pusa 372 showed maximum membrane injury at all the phenophases whereas it was lowest in advance breeding line DG 36. In general the released varieties recorded significantly higher membrane injury as compared to advance lines under all the planting dates and growth stages.

Ion leakage can also be used as an index for screening genotypes against heat and drought stresses in soybean (Krishnamani *et al.* 1984) and chickpea (Deshmukh *et*

Table 1. Relative water content (%) of chickpea genotypes as influenced by time of planting.

Genotype	Early	Time of planting Medium	Late	Mean
		Vegetative stage		
Pusa 256	85.25	80.27	75.44	**80.32**
Pusa 372	83.98	79.11	76.28	**79.79**
BGD72	89.89	85.17	82.00	**85.69**
DG36	90.74	84.60	77.26	**84.20**
DG46	83.01	81.70	77.22	**80.64**
DG51	89.96	82.45	80.51	**84.64**
Mean	**87.14**	**82.38**	**78.12**	**-**
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	4.37	4.34	NS	
		Flowering stage		
Pusa 256	79.86	69.32	67.63	**72.27**
Pusa 372	76.75	68.84	65.56	**70.38**
BGD72	81.07	70.95	66.06	**72.69**
DG36	80.03	69.37	67.32	**72.24**
DG46	79.30	69.55	67.21	**72.02**
DG51	87.73	69.78	66.98	**74.83**
Mean	**80.79**	**69.63**	**66.79**	**-**
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	4.23	NS	NS	
		Pod formation stage		
Pusa 256	63.88	60.42	55.12	**59.80**
Pusa 372	64.94	61.25	59.39	**61.86**
BGD72	65.07	62.23	58.42	**61.90**
DG36	64.69	61.72	56.64	**61.01**
DG46	61.38	59.11	57.56	**59.35**
DG51	59.20	58.05	55.02	**57.42**
Mean	**63.19**	**60.46**	**57.02**	**-**
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	3.00	2.90	NS	

al. 2000). The delay in planting resulted in higher percent membrane injury at all the stages of growth and development, the increase being more in released varieties than advanced lines. Gupta *et al.* (2000) observed that the genotypes, which were more tolerant to moisture stress, had lower membrane injury (less ion leakage), higher seedling growth, osmotic regulation, water use efficiency and low drought susceptibility index.

Total chlorophyll content

Total chlorophyll content was significantly higher in medium planting throughout the growth period as compared to late planting (Table 3). Significant differences in total chlorophyll content were recorded in chickpea genotypes at all the phenophases, with advance lines showing significantly higher values of total chlorophyll content

Table 2. Percent membrane injury of chickpea genotypes as influenced by time of planting.

Genotype	Early	Time of planting Medium	Late	Mean
		Vegetative stage		
Pusa 256	22.5	25.1	27.2	**25.0**
Pusa 372	27.2	31.7	33.4	**30.8**
BGD 72	29.3	30.2	32.0	**30.5**
DG 36	20.0	22.4	24.3	**22.2**
DG 46	21.7	24.1	26.2	**24.0**
DG 51	19.5	23.0	25.3	**22.6**
Mean	**23.4**	**26.1**	**28.1**	
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	1.06	0.98	NS	
		Flowering stage		
Pusa 256	37.3	40.3	48.9	**42.2**
Pusa 372	42.4	53.5	56.1	**50.7**
BGD 72	39.0	50.2	52.8	**47.3**
DG 36	31.3	37.4	41.3	**36.7**
DG 46	35.4	41.3	44.2	**40.3**
DG 51	29.7	40.1	43.5	**37.8**
Mean	**35.8**	**43.8**	**47.8**	
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	1.68	1.70	NS	
		Pod formation stage		
Pusa 256	58.1	65.7	69.2	**64.3**
Pusa 372	66.5	69.8	74.6	**70.3**
BGD 72	57.2	63.6	69.8	**63.5**
DG 36	48.8	53.4	59.1	**53.8**
DG 46	55.3	60.0	65.3	**60.2**
DG 51	52.9	57.2	63.5	**57.9**
Mean	**56.5**	**61.6**	**66.9**	
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	2.20	2.16	NS	

Table 3. Total chlorophyll content (mg g fr.wt.) of chickpea genotypes as influenced by time of planting.

Genotype	Early	Time of planting Medium	Late	Mean
		Vegetative phase		
Pusa 256	2.558	2.651	2.195	**2.468**
Pusa 372	2.514	2.665	2.252	**2.477**
BGD72	2.576	2.899	2.305	**2.593**
DG36	2.817	3.112	2.576	**2.835**
DG46	2.701	2.955	2.493	**2.716**
DG51	2.715	2.868	2.504	**2.696**
Mean	**2.647**	**2.858**	**2.387**	-
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	0.136	0.127	0.220	
		Flowering phase		
Pusa 256	2.735	2.963	2.596	**2.765**
Pusa 372	2.732	3.041	2.685	**2.819**
BGD72	2.895	3.191	2.776	**2.954**
DG36	3.220	3.783	2.945	**3.316**
DG46	3.053	3.362	2.927	**3.114**
DG51	2.965	3.214	2.881	**3.020**
Mean	**2.933**	**3.259**	**2.802**	-
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	0.190	0.179	0.311	
		Pod formation		
Pusa 256	2.271	2.613	2.138	**2.341**
Pusa 372	2.361	2.732	2.271	**2.455**
BGD72	2.379	2.777	2.354	**2.503**
DG36	2.748	3.189	2.807	**2.915**
DG46	2.654	3.029	2.767	**2.817**
DG51	2.702	2.859	2.729	**2.763**
Mean	**2.519**	**2.867**	**2.511**	-
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	0.160	0.152	0.264	

throughout crop growth period. At flowering stage released variety BGD 72 showed higher amount of total chlorophyll in comparison to Pusa 256. Total chlorophyll was found to be the maximum in DG 36 at all the planting dates. Genotypic differences for chlorophyll content have been observed in chickpea subjected to water deficits by Rahangdale *et al*. (1995).

Biological yield

The biological yield decreased significantly in all genotypes when sown on 15th December compared with the two earlier plantings (Table 4). The highest mean biological yield was observed at early planting (24.5 g/plant) and lowest at late planting (18.2 g/plant). Among the genotypes, Pusa 256 (22.8 g/plant), BGD 72 (24.0 g/plant) and DG 36 (24.6 g/plant) had significantly higher yields. It is worthwhile to mention that the biological yield of the advance lines was not significantly different from the released cultivars. However, the advance breeding line DG 36 had the highest biological yield per plant at the early and medium planting, whereas BGD 72 had a significantly higher biological yield at late planting.

Table 4. Biological yield, seed yield and harvest index of chickpea genotypes as influenced by time of planting.

Genotype	Time of planting Early	Medium	Late	Mean
		Biological yield (g/plant)		
Pusa 256	25.81	24.19	18.44	**22.81**
Pusa 372	25.08	24.20	13.98	**21.09**
BGD72	25.49	25.34	21.27	**24.03**
DG36	28.58	25.76	19.54	**24.63**
DG46	20.87	22.69	17.18	**20.24**
DG51	21.26	22.06	19.05	**20.79**
Mean	**24.51**	**24.04**	**18.24**	**-**
	Planting time (P)	Genotype (G)	PxG	
CD at 5%	0.841	0.868	1.504	
		Seed yield (g/plant)		
Pusa 256	5.04	5.47	4.27	**4.93**
Pusa 372	5.62	6.15	3.75	**5.17**
BGD72	5.31	6.03	5.16	**5.50**
DG36	7.91	8.27	6.46	**7.55**
DG46	5.24	6.28	4.88	**5.47**
DG51	5.12	5.84	5.02	**5.33**
Mean	**5.70**	**6.34**	**4.92**	**-**
	Planting time (P)	Genotypes (G)	PxG	
CD at 5%	0.220	0.211	0.365	
		Harvest index (%)		
Pusa 256	19.53	22.61	23.16	**21.77**
Pusa 372	22.41	25.41	26.81	**24.87**
BGD72	20.83	23.80	24.26	**22.96**
DG36	27.67	32.11	33.06	**30.95**
DG46	25.11	27.67	28.41	**27.06**
DG51	24.08	26.47	26.36	**25.64**
Mean	**23.27**	**26.35**	**27.01**	**-**
	Planting time (P)	Genotype (G)	PxG	
CD at 5%	0.698	0.616	1.067	

Seed yield

Seed yield is the final outcome of all the biological processes from germination to maturity. The highest seed yield per plant occurred when the plants were sown on 30th November with yields 10% higher than yields of chickpeas sown 15 days earlier and 22% higher than chickpeas sown 15 days later (Table 4). Regarding the performance of the individual genotypes, significantly higher seed yields were obtained in DG 36 (7.55 g/plant) followed by BGD 72 (5.50 g/plant), DG 46 (5.47 g/plant), DG 51 (5.53 g/plant), Pusa 372 (5.17 g/plant) and Pusa 256 (4.93 g/plant). The advance breeding lines had significantly higher yields than the released varieties. Pusa 256 recorded the lowest seed yield among all the genotypes. This clearly indicated that there has been significant genetic improvements in seed yield of the advanced breeding lines.

Harvest index

The values for harvest index were higher at the late planting (27.0%) followed by the medium and early planting (26.4% and 23.3%), respectively (Table 4). Among the genotypes, the highest harvest index was recorded in DG 36 and lowest in Pusa 256. The average harvest index of the advance breeding lines was significantly higher (27.9%) compared with the released varieties (23.2%). High harvest index values were also observed in DG 36 at the medium (32.1%) and late (33.1%) plantings. The released variety Pusa 256 showed the lowest harvest index at all three planting times.

The yield performance of the advance breeding line DG 36 was found to be superior as compared to the other advance breeding lines and released genotypes. The results also indicated that medium planting was better than early and late plantings because the crop experienced relatively mild temperatures in which flower retention and pod per seed growth was better (Fig. 1). Previous work has shown that higher pod production is required for higher yields in chickpea (Singh *et al.* 1997, Dua 2001, Chaichi and Farahani 2003, Hegde *et al.* 2003). Planting on 30 November at this location in northern India had the advantage that the chickpeas escaped the low temperatures at early podding as well as the high temperatures during seed filling compared to the earlier planting on 15

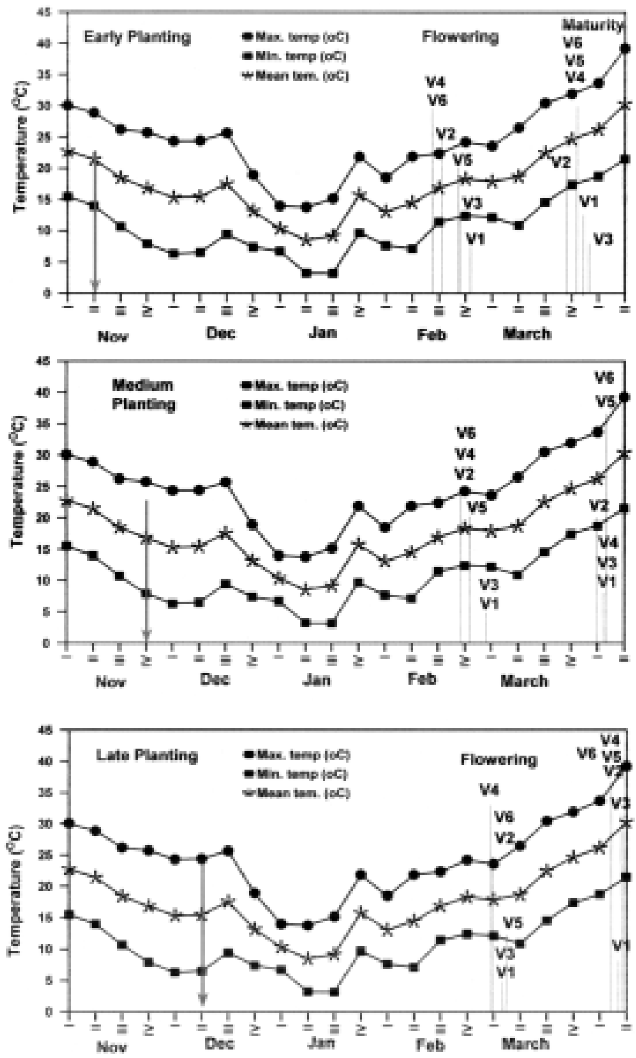

Fig. 1. Maximum, minimum and mean temperature during the experimental period at flowering and maturity time
(V1=Pusa 256; V2=Pusa 372; V3=BGD 72; V4=DG 36; V5=DG 46; V6=DG 51)

November and the later planting on 15 December. Shrestha *et al.* (2002) reported that soil moisture stress in the post-flowering period showed significant variation in phenology, above-ground biomass, pod number, seeds per pod and seed yield of lentil genotypes. Delayed planting reduced the biological yield, but increased the harvest index. However, in early planting, the low temperatures at flowering probably resulted in flower drop and pod abortion causing low seed yield. On the other hand, at late planting the high harvest index of the genotypes was insufficient to compensate for the low biological yield thus resulting in a lower seed yield as compared to medium planting.

On the basis of results it is emphasized that these physiological traits may be used in breeding for increasing productivity of chickpea under the delayed planting conditions.

ACKNOWLEDGEMENTS

The senior author is thankful to the Director, Indian Agricultural Research Institute, New Delhi for providing the necessary facilities and sanction of three years study leave. The research facilities extended by Dr. G.C. Srivastava, Head, Division of Plant Physiology are duly acknowledged.

REFERENCES

Allurwar, M.W. and Deotale, R.D. (1991). Correlation of chlorophyll content with net assimilation rate and yield in chickpea. *J. Soils Crops* **1**: 33-39.

Barrs, H.D. and Weatherley (1962). A re-examination of the relative turgidity technique for estimating water deficit in leaves. *Aust. J. Biol. Sci.* **15**: 413-428.

Chaichi, M.R. and Farahani, S. (2003). Effects of cold stress at different growth stages on vegetative and generative growth characteristics in chickpea cultivars. International Chickpea Conference, 20-22 January 2003, p. 73, Raipur, India.

Chaturvedi, S.K. and Dua, R.P. (2003). Breeding chickpea for late sown conditions in northern India. International Chickpea Conference, January 20-22, 2003. p. 11, Raipur, India,

Deshmukh, P.S., Sairam, R.K. and Shukla, D.S. (1991). Measurement of ion-leakage as a screening techniques for drought resistance in wheat genotypes. *Indian J. Plant Physiol.* **34**: 89-91.

Deshmukh, P.S., Sairam, R.K., Sunita Kumari, Kushwaha, S.R. and Pankaj Kumar (2000). Physiological traits for yield improvement of chickpea in drought prone environments. National Seminar on Plant Physiology at Interface of Agri-horticulture and Industry, 20 Dec., 1999 to Ist Jan., 2000, p. 104, RAU, Udaipur, India.

Dua, R.P. (2001). Genotypic variation for low and high temperature tolerance in gram (*Cicer arietinum* L.). *Indian J. Agric. Sci.* **71**: 561-566.

Gupta, N.K. (1996). Investigations on grain growth in contrasting wheat genotypes under normal and late sown conditions. Ph.D. Thesis submitted to IARI, New Delhi, India.

Gupta, S.C., Rathore, A.K., Sharma, S.N. and Saini, R.S. (2000). Response of chickpea cultivars to water stress. *Indian J. Plant Physiol.* **5**: 274-276.

Hedge V.S., Kumar, J. and Yadav, S.S. (2003). Designing new plant type to increase yield potential in chickpea (*Cicer arietinum* L.) for drought prone rainfed environments. International Chickpea Conference, 20-22 January 2003, p. 3, Raipur, India.

Hiscox, J.D. and Israelstam, G.F. (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. *Can. J. Bot.* **57**: 1332-1334.

ICRISAT (2003). ICRISAT monthly news letter, January.

Islam, M.S., Srivastava, P.S.L. and Deshmukh, P.S. (1998). Genetic studies on drought tolerance in wheat. I. Relative leaf water content membrane stability and stomatal frequency. *Ann. Agric. Res.*, **19**: 458-462.

Krishnamani, M.R.S., Yopp, J.H. and Myers, O. Jr. (1984). Leaf solute leakage as a drought tolerance indicator in soybean. *Phyton.* **44**: 43-49.

Kumar, P., Deshmukh, P.S., Kushwaha, S.R. and Sunita Kumari (2001). Effect of terminal drought on biomass production, its partitioning and yield of chickpea genotypes. *Ann. Agric. Res.* **22**: 408-411.

Panse, V.G. and Sukhatme, P.V. (1985). Statistical Methods for Agricultural Workers. ICAR Publication, New Delhi.

Rahangdale, S.L., Dhopte, A.M. and Wanjari, K.B. (1994). Evaluation of chickpea genotypes for yield stability under soil moisture deficit. *Ann. Plant Physiol.* **8**: 179-184.

Rahangdale, S.L., Dhopte, A.M. and Wanjari, K.B. (1995). Alteration in osmoregulation, DW formation and salt deposits in leaves of chickpea genotypes under soil moisture stress. *Ann. Plant Physiol.* **9**: 17-23.

Shrestha, R., Siddique, K., Turner, D. and Turner, N.C. (2002). Adaptation of lentil to dryland environments: response to water deficit. Biennial Report, pp. 48-49, CLIMA Australia.

Singh, S.P., Ram, R.S., Lal, K.B. and Singh, G.S. (1997). Physiological variability and inter-relationship in chickpea. *Agric. Sci. Dig.* **17**: 97-100.