The Journal of Animal & Plant Sciences, 25(1): 2015, Page: 206-211
ISSN: 1018-7081

CHICKPEA GENOTYPES EVALUATION FOR MORPHO-YIELD TRAITS UNDER WATER STRESS CONDITIONS

N. Hussain, M. Aslam, A. Ghaffar, M. Irshad and Naeem-ud-Din

Arid Zone Research Institute, P.O. Box 15, Bhakkar, Punjab, Pakistan.
Corresponding Author Email: niazfm@gmail.com

ABSTRACT

A field experiment with two sets, each comprising 13 chickpea genotypes with three replications was carried out during Rabi 2012-2013 in stress and non-stress conditions. The objective of the reported research was to study the response of chickpea genotypes in drought stress and to screen the appropriate genotypes performing better in water deficit and irrigated conditions. Three genotypes TG1203, TG1221 and TG1219 exhibited best drought tolerance efficiency (92.74, 92.33 & 88.0%), good harvest index (51.6, 50.91 & 49.15%), least drought susceptibility index (0.49, 0.52 & 0.81), and minimum reduction in seed yield (7.26, 7.67 & 12.06%) in stress environment. With better yield stability, these genotypes would be recommended as drought tolerant under stress environment.

Key words: Drought tolerance, moisture stress, chickpea, yield stability.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop after peas and soybean and about 15 percent of the world's total pulse productions belong to this crop (FAO, 2010). Due to high protein content, it has become an important component of human diet in the developing countries. In Pakistan, it was cultivated on an area of 985 thousand hectares which contributed the production of 673 thousand tones (Economic survey of Pakistan, 2012-13). It is mainly grown in rainfed conditions in Thal areas of Punjab and Kyber Pakhtunkhwa provinces. In Sindh and Baluchistan, the crop is grown on residual moisture after rice harvest. The Punjab province alone contributes about 80% of chickpea production in the country where the 90% area of chickpea is grown under rainfed conditions. Drought is a major limiting factor in agricultural production (Reddy *et al.*, 2004; Yu and Setter, 2003). Therefore, its productivity is severely affected by water stress conditions.

Chickpea is usually documented as drought tolerant. The crop is more sensitive to drought during the flowering period which leads to instability and low chickpea productivity. Severe drought reduces vegetative growth, flower initiation and pod setting in mungbean (Morton *et al.*, 1982).

Chickpea yield is very inevitable due to biotic (wilt, root rot, blight diseases and weeds infestation) and abiotic (drought, high and low temperature) stresses. Drought is one of the most important abiotic stresses, which limits crop production in different parts of the country. Estimates of yield losses due to drought range from 15 to 60% depending on geographical region, duration of the crop season and dry spell (Sabaghpour *et al.,* 2006). Plants adapt to drought environment either through escape, avoidance, or tolerance mechanisms (Sabaghpour *et al.,* 2003). Drought stress affects various physiological processes and is deleterious for growth, development and economic yield of crop (Garg *et al.*, 2004; Talebi *et al.*, 2013).

Systematic breeding efforts have led to the development of large number of improved varieties in this crop. However, its maximum yield potential has not yet been achieved owing to several constraints. One of the major constraints is its susceptibility to drought stress which reduces the production of crop (Araus *et al.,* 2002). Inadequate and uneven distribution of rainfall coupled with rising frequency of chronic high temperature waves and prolong dry spells have further jeopardized the food self sufficiency and yield stability (Irshad, 2013). Drought is the most common adverse environment, which limits crop production in different parts of the country that is considered as dry and semi dry. Genetic management is the most apposite solution of this yield limiting factor. Evolution of drought tolerant varieties through genetic management would be a low economic input technology that would be readily acceptable to resource poor drought prone and small land holding farmers. Therefore, this drastic situation calls for development of drought tolerant varieties with maximum yield potential best suited to rainfed hot climate (Saxena and Toole, 2002).

It is usually acknowledged that chickpea thrives well in drought stress. However, there is a greater variability for yield performance of different chickpea genotypes in moisture stress. Attempts to measure the degree of tolerance with single parameter have limited value because of the confounding effect of the various factors to drought tolerance in field condition. Different workers used different methods to evaluate genetic differences in drought tolerance (Bidinger *et al.,* 1982).

Johnson *et al.,* (1980) recognized the fact that breeders have to assess plant performance at the critical development stage and field performance is the standard to assess plant response in stress. Field screening is a powerful tool for evaluation of germplasm for effective breeding to develop new crop varieties prone to drought stress. Thus, the present study was conducted to identify and evaluate the high yielding chickpea genotypes adaptable to drought-prone environment. This promising material will be helpfull for the evolution of high yielding and drought tolerant agronomically superior varieties of chickpea.

MATERIALS AND METHODS

The present investigation comprising thirteen chickpea genotypes under moisture stress (I_0) and irrigated (I_1) conditions was conducted during Rabi 2012-2013 at Arid Zone Research Institute, Bhakkar, Punjab, Pakistan. The experiment was laid out in a randomized complete block design with three replications. Plants and rows spacing was maintained at 15cm and 30cm, respectively with row length of 5m. Recommended cultural operations were done throughout the cropping season to ensure the proper growth and development of the plant. One set of experiment was sown in rainfed condition with sufficient soil moisture for good germination. Two additional irrigations were given to irrigated experiment at flowering and pod formation stage of the crop. The crop was maintained free from weeds, diseases and pests by adopting appropriate plant protection measures.

The observations were recorded on days taken to 50 per cent flowering (DFF), plant height (PLHT), primary branches per plant (PB), secondary branches per plant (SB), pods per plant (PPP), 100-seed weight (SDWT), yield per plant (YPP) and yield per hectare in moisture stress and non stress conditions.

The data were subjected to analysis of variance (Steel *et al.,* 1997) to determine the level of significance between treatments. Least significant difference (LSD) test was applied for comparison of means.

Harvest index (HI): Harvest index (HI) was worked out by the formula given by Donald and Hamblin (1976) accordingly.

$$\text{Harvest index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

The following drought related parameters were recorded and discussed to evaluate the drought tolerance efficiency of the newly evolved genotypes.

MEMBRANE INJURY INDEX (MII): The membrane injury index (MII) evaluates plant tolerance to high temperature by measuring thermostability. The test is based on the observations that when high temperatures injure leaf tissue, cellular membrane permeability is increased and electrolytes diffuse out of the cells. Two gram fresh weight of leaf sample was obtained for membrane injury index at 50% flowering stage. The certain amount of fresh leaf material was washed with distilled water, surface dried between the fold of filter paper and dipped into double deionized water for 30 minutes at 40^0C and measured the electrical conductivity (C_1) of tissue leachets. The same water was used with same leaf dipped for 10 minutes at 100^0C and electrical conductivity (C_2) measured (Parameshwarappa *et al.,* 2008 and 2012; Basu *et al.,* 2009). The relative membrane stability or membrane injury index (MII) at each temperature was calculated by the formula documented by Blum and Ebercon (1981).

$$\text{MII} = \frac{C1}{C2}$$

Where

C_1 = Electrical conductivity at 40 ^{0}C for 30 minutes

C_2 = Electrical conductivity at 100 ^{0}C for 10 minutes

DROUGHT SUSCEPTIBILITY INDEX (DSI): Drought susceptibility index (DSI) and percent in reduction due to moisture stress were estimated by the formula suggested by Fischer and Maurer (1978).

$$\text{Percent reduction} = \frac{\text{Yield in non stress} - \text{Yield in stress}}{\text{Yield in non stress}} \times 100$$

$$\text{DSI} = (1 - {}^{Yd}/_{Yp})/D$$

Where,

Yd = Grain yield of the genotype in moisture stress conditions.

Yp = Grain yield of the genotypes in irrigated conditions.

$$\text{Drought Index (D)} = 1 - \frac{\text{Mean yield of all strains in moisture stress conditions}}{\text{Mean yield of all strains in irrigated conditions}}$$

DROUGHT TOLERANCE EFFICIENCY (DTE): Drought tolerance efficiency (DTE) / Relative Performance ratio % was estimated by using formula given by Fischer and Wood (1981).

$$\text{DTE \%} = \frac{\text{Yield in stress}}{\text{Yield in non stress}} \times 100$$

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences among genotypes means for irrigated and moisture stress conditions. The genotypes TG1203, TG1219 and TG1221 bloomed earlier by taking minimum days for 50% flowering in moisture stress (88.33, 89.0 & 91.0 days) than non-stress (101, 104 & 102 days) (Table 1). Saxena *et al*., (1993), and Silim & Saxena (1993) reported that yield potential and early flowering are the two major components of drought escape in lentil and chickpea. Early maturity is an important trait to drought avoidance to the onset of severe moisture stress. The variety Bhakkar-2011 also performed better in attaining of 50% flowering in 92.67 and 100 days under stress and non-stress conditions, respectively.

The vegetative phase governs the overall phenotypic expression of the plant and plays an important role in the realization of final grain yield. The plant height, branches and all other parts constitute vegetative phase and perform specific functions. Overall, the genotypes TG1203, TG1219 and TG1221 exhibited less change for the characters like plant height, primary and secondary branches as compare to the other genotypes in stress and non-stress conditions (Table 1). The reduction in morpho-physiological traits in chickpea due to stress recorded by Kuhad *et al.*, (1988) and Jirali *et al.*, (1994). The genotypes TG1203, TG1219 and TG1221 maintained plant height in stress conditions (65.0, 60.60 & 58.07 cm) and irrigated conditions (68.40, 60.0 & 62.02cm), respectively. Gupta *et al.*, (1995) reported that there was a positive correlation between drought period and plant height. The genotype TG1227 displayed minimum plant height in moisture stress (40.23 cm) and non-stress conditions (54.23 cm).

The genotypes TG1203, TG1219 and TG1221 maintained primary branches in moisture stress (3.93, 3.13 & 3.53) and non-stress conditions (4.07, 3.13 & 3.40). Maximum primary branches (4.53) were recorded by the genotype TG1202 in non-stress while the variety Bhakkar-2011 gave maximum number of primary branches (4.13) in stress conditions. The genotypes TG1203, TG1219 and TG1221 exhibited maximum number of secondary branches in stress (11.60, 10.53 & 11.20) and non-stress conditions (12.07, 10.73 & 12.20) while the genotype TG1226 produced maximum number of secondary branches (12.73) in non-stress conditions. The genotypes TG1203, TG1219 and TG1221 revealed highest number of pods per plant in stress (74.0, 59.47 & 55.85) and non-stress conditions (83.23, 70.72 & 68.68). Similarly Ali *et al.*, (1999) and Islam *et al.*, (2008) narrated that the effect of secondary branches and pods per plant on seed yield in chickpea was significant. Rahangadale *et al.*, (1994) also reported 26.2% reduction in pod number in chickpea under water stress conditions than non-stress. The genotype TG1204 exhibited maximum number of pods per plant (86.83) in non-stress conditions. The variety Bhakkar-2011 produced maximum number of pods per plant in stress (56.38) and non-stress conditions (66.57) accordingly.

Maximum 100-seed weight was recorded by genotypes TG1203, TG1219 and TG1221 in stress (33.33, 32.37 & 30.23 g) and non-stress conditions (35.0 36.20 & 33.90 g). The genotype TG1201 and TG1226 provided maximum 100-seed weight of 36 and 31.87g, respectively in stress free environment (Table 1). The genotypes TG1203, TG1219 and TG1221 revealed maximum yield per plant in stress (31.67, 26.93 & 23.61 g) and non-stress conditions (38.22, 35.23 & 31.20 g). The check variety Bhakkar-2011 exhibited maximum yield per plant in stress (22.73 g) and non-stress conditions (27.83 g).

The genotypes TG1203, TG1221 and TG1219 exhibited maximum yield in stress (3166, 2851 & 2654 kg ha^{-1}) as well as in irrigated condition (3414, 3088 & 3018 kg ha^{-1}) (Table 2). Further, these genotypes have the highest drought tolerance efficiency (92.74, 92.33 & 88.0%), least drought susceptibility index (0.49, 0.52 & 0.81) and minimum reduction in seed yield (7.26, 7.67 & 12.06%) due to moisture stress. Rahangdale *et al*., (1994) reported that water stress decreased 15.2% seed yield in chickpea. The genotypes TG1203, TG1221 and TG1219 maintained highest values of harvest index in moisture stress (51.6, 50.91 & 49.15%) as well as irrigated (54.19, 53.24 & 51.15%) conditions. Yadav *et al.,* (1996) findings revealed that the ability of genotypes to produce more biomass in stress conditions also produced more seed yield. These genotypes also maintained very low value of membrane injury index (0.17, 0.18 & 0.19) in stress conditions and in irrigated conditions (0.19, 0.16 & 0.21), respectively. Deshmukh *et al.,* (2004) reported that drought resistant genotype had the highest drought tolerance efficiency, minimum drought susceptible index and minimum reduction in grain yield due to moisture stress. They also reported that it maintained highest harvest index and very low values of membrane injury index in rainfed as well as irrigated conditions.

The genotypes TG1203, TG1219 and TG1221 in stress condition had the highest drought tolerance efficiency, least drought susceptibility index and minimum reduction in seed yield, and maintained highest harvest index in stress and non-stress conditions. Therefore, the genotypes TG1203, TG1219 and TG1221 were termed as drought tolerant by showing lesser change in their physiological activities and maintained their yield stability in irrigated as well as stress environments.

Table 1. Performance of promising drought tolerant chickpea genotypes evaluated in irrigated (I_1) and rainfed (I_0) condition

Genotypes	DFF		PLHT		PB		SB		PPP		SDWT		YPP	
	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1
TG1203	88.33	101.00	65.00	68.40	3.93	4.07	11.60	12.07	74.00	83.23	33.33	35.00	31.67	38.22
TG1204	95.67	105.67	47.63	71.97	2.80	2.87	10.07	10.60	39.00	86.83	25.80	28.47	13.46	33.11
TG1221	91.00	102.00	58.07	62.02	3.53	3.40	11.20	12.20	55.85	68.68	30.23	33.90	23.61	31.20
TG1219	89.00	104.00	60.60	60.00	3.13	3.13	10.53	10.73	59.47	70.72	32.37	36.20	26.93	35.23
TG1215	94.67	108.00	52.27	67.30	2.27	2.33	9.40	11.40	47.48	71.38	28.93	31.23	18.37	29.15
Bhakkar-2011	92.67	100.00	53.53	62.40	4.13	3.67	10.87	12.53	56.38	66.57	28.72	31.39	22.73	27.83
TG1201	99.33	109.00	55.50	73.80	2.87	2.60	9.67	9.40	50.73	56.93	28.47	36.00	19.89	26.82
TG1202	98.33	107.00	52.27	62.60	2.80	4.53	7.60	12.67	49.67	55.33	26.60	28.87	17.91	19.79
TG1216	96.67	108.00	55.77	61.20	2.47	3.13	8.60	10.80	43.52	51.95	26.83	31.17	15.80	21.53
TG1226	94.33	106.67	51.43	57.53	2.53	2.47	9.13	12.73	45.42	59.73	26.80	31.87	16.45	25.00
TG1220	94.67	108.67	48.83	69.40	3.40	3.13	8.53	9.80	40.72	56.13	24.27	26.47	12.61	23.50
TG1227	96.67	109.00	40.23	54.23	2.80	4.20	9.40	11.47	38.37	53.40	24.37	26.27	13.00	17.04
Punjab-2008	98.33	109.00	48.67	56.06	2.73	3.07	8.47	11.73	43.75	55.22	26.43	29.20	15.55	20.33
Punjab-2008	98.33	109.00	48.67	56.06	2.73	3.07	8.47	11.73	43.75	55.22	26.43	29.20	15.55	20.33
Grand mean	94.59	106.03	53.06	63.61	3.03	3.28	9.62	11.39	49.58	64.32	27.93	31.23	19.07	26.83
CD at 5%	1.56	1.57	1.88	5.04	0.82	0.38	2.32	0.56	3.30	3.12	0.84	1.00	1.96	2.63

Days to 50 % flowering (DFF), Plant height (PLHT), Primary branches per plant (PB), Secondary branches per plant (SB), Pods per plant (PPP), 100- Seed weight (SDWT), Yield per plant (YPP)

Table 2: Seed yield (Kg/ha) and drought tolerance related characters influenced by different genotypes

Sr. No.	Genotypes	Yield (Kg/ha)		% reduction in yield	DTE (%)	DSI	MII		HI (%)	
		I_0	I_1				I_0	I_1	I_0	I_1
1	TG1203	3166	3414	7.26	92.74	0.49	0.17	0.19	51.06	54.19
2	TG1204	2752	3163	13.00	87.01	0.87	0.22	0.24	46.64	49.42
3	TG1221	2851	3088	7.67	92.33	0.52	0.18	0.16	50.91	53.24
4	TG1219	2654	3018	12.06	88.00	0.81	0.19	0.21	49.15	51.15
5	Bhakkar-11	2539	2951	13.96	86.04	0.94	0.23	0.25	48.09	50.88
6	TG1215	2464	2909	15.30	84.70	1.03	0.31	0.26	44.80	48.48
7	TG1202	2327	2868	18.86	81.14	1.27	0.27	0.30	43.09	47.02
8	TG1201	2377	2798	15.05	84.95	1.01	0.23	0.27	41.70	43.05
9	TG1216	2105	2724	22.72	77.28	1.53	0.28	0.26	42.96	46.17
10	TG1226	2178	2641	17.53	82.47	1.18	0.32	0.34	40.33	47.16
11	TG1220	2146	2524	14.98	85.02	1.01	0.25	0.23	41.27	45.89
12	TG1227	2057	2518	18.31	81.69	1.23	0.29	0.31	38.81	44.96
13	Punjab-2008	1828	2332	21.61	78.39	1.45	0.25	0.27	45.70	48.58
	CV (%)	**9.90**	**11.08**							

Moisture stress conditions (I_0), Irrigated conditions (I_1), drought tolerance efficiency (DTE), drought susceptible index (DSI), membrane injury index (MII), harvest index (HI)

Conclusion: It was concluded that three genotypes TG1203, TG1219 and TG1221proved high yielding and drought tolerant and can be incorporated in stress breeding programme for the development of drought tolerant chickpea varieties.

REFERENCES

Ali, Y., M.A. Haq, G.R. Tahir, and N. Ahmad (1999). Effect of various morphological traits on chickpea yield under drought and normal field conditions. Pakistan J. Bio. Sci. 2(3):1071-1073.

Araus, J.L., G.A. Slafer, M.P. Reynolds, and C. Royo (2002). Plant breeding and drought in C-3 cereals: what should we breed for? Ann. Bot. 89:925–940.

Basu, P.S., M. Ali and S.K. Chaturvedi (2009). Terminal heat stress adversely affects chickpea productivity in Northern India— Strategies to improve thermotolerance in the crop under climate change. In "ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture". (Eds. S. Panigrahy, S.R. Shankar and J.S. Parihar) pp. 189-193. (International Society for Photogrammetry and Remote Sensing: New Dehli, India).

Bidinger, F.R., V. Mahalaxmi, B.J. Talukdar and G. Algarswamy (1982). Improvement of drought resistance in pearl millet. workshop on Principles and Methods of Crop Improvement for Drought Resistance with Emphasis on Rice, IRRI, Los Banos, Phillipines, on May. 4-8th 1981. pp: 45-49.

Blum, A. and A. Ebercon (1981). Cell membrane stability as a measure of drought and heat tolerance in wheat. Crop. Sci., 21: 43-47.

Deshmukh, D.V., L.B. Mhase and B.M. Jamadagni (2004). Evaluation of chickpea genotypes for drought tolerance. Indian J. Pulses Res., 17: 47-49.

Donald, C.M. and Hamblin (1976). The biological yield and harvest index of cereals on agronomic and plant breeding criteria. Adv. Agron., 28: 361-405.

Economic Survey of Pakistan, (2012-13). Economic Advisor's Wing, Finance Division, Government of Pakistan, Islamabad.

FAO (Food and Agriculture Organization of the United Nations)., 2010 -Agricultural production year book/ or http://faostat.fao.org.

Fischer, K.S. and G. Wood (1981). Breeding and selection for drought tolerance in tropical maize. In: Proc. Symp. on Principles and Methods in Crop Imprt. for Drought Resist. with Emphasis on Rice, IRRI, Philippines, 23-25th May, 1981.

Fisher, R.A. and R. Maurer (1978). Drought resistance in spring wheat cultivars. I. Grain yield responses in spring wheat. Australian J. Agric. Sci., 29: 892-912.

Garg, B.K., U. Burman and S. Kathju (2004). The influence of phosphorus nutrition on the physiological response of moth bean genotypes to drought. J. Plant. Nutr. Soil Sci.167: 503–508.

Gupta S.N., B.S. Dahiya, B. P. S. Malik and N.R. Bishnoi (1995). Response of chickpea to water deficits and drought stress. Haryana Agric. Uni. Res, J., 251: 11-19.

Irshad, M. (2013). Genetic mechanism of some physio-morphological traits of bread wheat under normal and heat stress conditions. Ph.D. Thesis, UAF, Faisalabad, Pakistan.

Islam, M. M., M. R. Ismail, M. Ashrafuzzaman, K. M. Shamsuzzaman and M. M. Islam (2008). Evaluation of chickpea lines/mutants for growth and yield attributes. Int. J. Agri. Biol. 10:493-498.

Jirali, D.I., Y.C. Panchal, B.S. Janagoudar and B.C. Patil (1994). Studies on the growth pattern and yield in chickpea (*Cicer arietinum* L.) genotypes under receding soil moisture conditions. Indian J. Pl. Physiol., 37(4): 275-276.

Johnson, D.A. (1980). Improvement of perennial herbaceous plants for drought stressed western rangelands. In: N.C. Turner and P.J. Kramer, (eds.) Adaptation of plants to water and high temperature stress. John Willey and Sons. Inc. Pp.419-433.

Kuhad, M.S., B.S. Kundu, R.S. Hooda and Sheoran (1988). Physiological studies in chickpea under qualified moisture level. J. Plant Physiol., 31(4): 423-427.

Mallikarjun, H. B. (2001). Genetic variability for early vigour, root and nodulation traits in chickpea (*Cicer arietinum* L.), M.Sc. (Agri) Thesis, Univ. Agric. Sci., Dharwad (India).

Morton F., R.E. Smith and J.M. Poehlman (1982). The Mungbean. University of Puerto Rico, Mayaguez. 136 p.

Parameshwarappa, S.G., P.M. Salimath, H.D. Upadhyaya, S. S. Patil, S.T. Kajjidoni, B.C. Patil and Y.D. Narayana (2012). Variation in root characters of selected drought tolerant accessions of chickpea (*Cicer arietinum* L.) grown under terminal drought. Karnataka J. Agric. Sci., 25 (3): 389-391.

Parameshwarappa, S.G and P.M. Salimath (2008). Field screening of chickpea genotypes for drought resistance. Karnataka J. Agric. Sci., 21 (1): 113-1 14.

Rahangdale S.L., A.M. Dhopte and K.B. Wanjar (1994). Evaluation of chickpea genotypes for yield stability under moisture deficit. Annals of plant physiology, 8:179-184.

Reddy A.R., K.V. Chaitanya and M. Vivekanandan (2004). Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants. J. Plant. Physiol.161: 1189–1202.

Sabaghpour S.H., E. Sadeghi and R.S. Malhotra (2003). Present status and future prospects of chickpea cultivation in Iran. International chickpea Conference. 20-22 Jan, 2003, Raipur, India.

Sabaghpour, S. H., A. K. Mahmodi, A. Saeed, M. Kamel and R. S. Malhotra (2006). Study on chickpea drought tolerance lines under dryland condition of Iran. Indian J. Crop Sci., 1 (1-2): 70-73.

Saxena, N.P. and J.C.O. Toole (eds.) (2002). Field screening for drought tolerance in crop plants with emphasis on rice: proceedings of an international workshop on field screening for drought tolerance in rice, 11–14 Dec 2000, ICRISAT, Patancheru, India. Patancheru 502 324, Andhra Pradesh, India, and the Rockefeller Foundation, New York, New York 10018-2702, USA. 208 pp.

Saxena, N.P., L. Krishnamurthy and C. Johansen (1993). Registration to a drought resistant chickpea germplasm (En.) Crop Sci., 33(6): 14-24.

Silim, S.N. and M.C. Saxena (1993). Adaptation of spring sown chickpea to Mediterranean basin. II. Factors influencing drought. Field Crop Res., 34(2): 137-146.

Steel, R.G.D., J.H. Torrie and D.A. Dickey (1997). Principles and Procedures of Statistics: A Biometrical Approach. 3rd Edi. McGraw Hill Book Co., New York, USA.

Talebi, R., M.H. Ensafi, N. Baghebani, E. Karami and K. Mohammadi (2013). Physiological responses of chickpea (*Cicer arietinum* L.) genotypes to drought stress. Environ. Exp. Bio. 11: 9–15.

Yadav, V. K., N. Yadav and R.D. Singh (1996). Metabolic changes and their impact on yield in chickpea under water stress. Pl. Physiol. Biochem., 23: 49-52.

Yu, L. X. and T. L. Setter (2003). Comparative transcriptional profiling of placenta and endosperm in developing maize kernels in response to water deficit. Plant Physiol. 131: 568-582.