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EMPIRICAL SELECTION OF DROUGHT TOLERANT LINES IN EARLY SEGREGATING GENERATION OF CHICKPEA DEVELOPED USING A NEW SOURCE OF DROUGHT TOLERANT GERMPLASM LINE

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ABSTRACT

Chickpea (*Cicer arietinum* L.) is an important food legume with 92 per cent of area and 89 per cent of the global production are concentrated in semi-arid tropical countries. The present study was conducted with objective of development of high yielding, drought tolerant lines. For this F_{2-3} progenies obtained from the cross ICC-13124, a drought tolerant genotype and WR-315 were evaluated separately for yield components and drought tolerance. The moisture stress was created by taking up sowing 30 days later than normal sowing and withholding irrigation 14 days after sowing on the contrary, for non-stress condition, irrigation was given at regular intervals till physiological maturity. Variability parameters were assessed for yield components and drought parameters. Among the nine quantitative characters studied, seed yield per plant was most affected by drought and exhibited 41.1% reduction followed by number of seeds per plant (33.18%) and number of pods (32.09%) under drought compared to irrigated condition. Under drought situation, most of the productivity related traits like number of pods, seeds per plant and seed yield had high heritability coupled with high GAM indicating amenability such traits for improvement of drought tolerance. About 27 F_3 families had still lower drought susceptibility index (DSI), minimum tolerance to drought stress (TDS), high drought tolerance efficiency (DTE) and mean productivity than ICC 13124. The lines 389 and 491 were observed as the best tolerant line to drought stress environment under the field condition with respect to both yield and drought parameters. Such best families can be evaluated on large scale to identify variety or as a germplasm line for breeding drought tolerance and productivity.

INTRODUCTION

Among the pulses, chickpea (*Cicer arietinum* L.) is the third leading grain legume in the world and first in the South Asia. Its range of cultivation extends from the Mediterranean basin to the Indian sub-continent and southward of Ethiopia and the East African highlands. Chickpea is extensively cultivated as winter crop throughout India, especially in northern states. Majority of chickpea crop grown area falls under semiarid tropic (SAT) region of the world where the crop is exposed to several biotic and abiotic stresses. As a result, the crop productivity is seriously challenged in SAT regions. The crop faces terminal drought, as seed filling takes place under increasing temperature and decreasing soil moisture (Leport *et al.*, 1999). Ninety per cent of the world's chickpea is produced in areas relying upon conserved, receding soil moisture; therefore, crop productivity is largely dependent on efficient utilization of available soil moisture (Kumar and Van Rheenen, 2000). Estimates of yield losses due to terminal drought range from 35 to 50% across the SAT (Sabaghpour *et al.*, 2003).

Irrigation is not the only answer to the problem. However, despite many decades of research, drought continues to be a major challenge to agricultural scientists due to unpredictability of its occurrence, severity, timing and duration. Breeding efforts for improvement of drought tolerance in crop plants is primarily based on selection for grain yield under drought stress. Because of the variability in drought pattern from year to year, further progress may not be achieved by selecting solely for grain yield. However, the progress in breeding for drought resistance is generally considered to be slow due to the quantitative and temporal variability of available moisture across years, the low genotypic variance in yield under these conditions and inherent methodological difficulties in evaluating component traits. The objective of this paper was to evaluate F_{2-3} progenies of cross between ICC 13124 and WR 315 for variability parameters, mean productivity for yield and yield components as well as determining tolerance to stress of chickpea progenies via drought susceptibility index and other drought parameters.

MATERIALS AND METHODS

Experimental material

The experimental material consisted of two parents, one check, F_2 derived F_3 progenies of the cross between ICC13124 and WR 315. Till now breeding for drought resistance in chickpea is done using either ICC 4958 or Annigeri 1. Where as in our study we have used a new source ICC 13124 which was identified as one of the best drought tolerant line by Parameshwarappa and Salimath (2010) in Dharwad after screening mini core collections obtained from ICRISAT, Hyderabad. F_2 derived F_3 progenies were evaluated during *rabi* 2010-2011 in both irrigated and drought condition at Botanical garden, University of agricultural science, Dharwad. Each F_2 derived F_3 progenies along with parents and check at regular interval were grown in augmented design with 8 blocks and 3 checks. Individual progeny row is sown in single row of 2.00meter length, spaced 30cm apart and 20cm between plants. The moisture stress was created by taking up sowing 30 days later than normal sowing and withholding irrigation after germination and seedling establishment. The last irrigation given to stress plot was on 14th day after sowing while for non-stress condition, irrigation was given at regular intervals up to physiological maturity. All other recommended package of practices was adapted for raising the good crop.

Observation and statistical analysis

From 575 $F_{2\text{-}3}$ plants observation was made on nine quantitative characters., *viz.* Days to 50 per cent flowering (DFF), plant height (PH), primary branches per plant (PB), secondary branches per plant (SB), number of pods per plant (N0P), seeds per pod (SPPO), number of seeds per plant (NOS), test weight (TW) and seed yield per plant (SY) were recorded. Analysis of variance for all characters was carried out following Steel and Torrie (1997). The genotypic and phenotypic coefficients of variation were calculated according to Burton and Devane (1953). Heritability in broad sense was estimated by following Hanson *et al.* (1956) and expressed as percentage. The extent of genetic advance that can be expected with five per cent selection intensity was calculated following Robinson *et al.* (1949).

Drought parameters

Tolerance to drought stress (TDS)

The following equality suggested by Rosielle and Hamblin (1981) was used for determination of tolerance to drought stress (TDS) of genotypes.

$$TDS = Y_2 - Y_1$$

Where, Y_1 is the seed yield in the non-stress environment (irrigation) and Y_2 is in the stress environment (drought).

Mean productivity (MP): Mean productivity was calculated by using following formula:

$$MP = (Y_1 + Y_2)/2$$

Where, Y_1 is the seed yield in the non-stress environment (irrigation) and Y_2 is in the stress environment (drought).

Drought Susceptibility Index (DSI) : The Drought Susceptibility Index (DSI) was estimated for seed yield using the formula suggested by Fisher and Maurer (1978).

$$DSI = \frac{1 - YD/YP}{D}$$

Where,

YD = Grain yield of the genotype under moisture stress condition.

YP = Grain yield of the genotype under non-stress condition

$$D = 1 - \frac{\text{Mean grain yield of all strains under moisture stress condition}}{\text{Mean grain yield of all strains under non-stress condition}}$$

Drought tolerance efficiency (DTE): Drought tolerance efficiency was calculated by the following formula given by Fischer and Mourer (1978).

$$DTE\ (\%) = \frac{\text{Yield under stress}}{\text{Yield under non-stress}} \times 100$$

RESULTS AND DISCUSSION

Mean and variability studies

The subject of breeding for drought resistance has been exhaustively dealt. However, it is more difficult to incorporate

Table 1: Mean performance and range for seed yield per plant and its components traits in parents and F_3 progenies of the cross ICC-13124 x WR-315 under irrigated (I) and drought (D) condition in Chickpea

Character	I/D*	ICC 13124	WR 315	F_3 Mean	F_3 Range Min	Max
Days to 50% flowering	I	46.00	51.00	46.57	41.00	53.00
	D	38.00	41.00	38.27	31.00	48.00
Plant height (cm)	I	41.20	46.90	42.31	26.40	58.60
	D	35.40	37.20	33.97	19.00	48.40
Primary branches	I	3.10	2.20	2.71	1.00	3.90
	D	2.80	1.90	2.26	1.00	3.60
Secondary branches	I	13.10	9.20	12.78	4.80	20.33
	D	11.80	8.10	10.99	3.60	18.67
No. of pods per plant	I	102.70	64.20	97.29	16.50	393.30
	D	85.10	48.40	66.06	12.50	190.50
Seeds per pod	I	1.00	1.80	1.26	1.00	1.90
	D	1.00	1.10	1.18	1.00	1.60
No. of seeds per plant	I	96.40	91.30	96.35	13.10	374.60
	D	77.20	62.50	64.28	9.40	184.50
Test weight (g)	I	32.40	17.80	23.92	15.40	38.10
	D	30.80	15.70	21.34	12.56	35.66
Yield per plant (g)	I	31.20	16.60	23.42	3.40	68.70
	D	23.80	7.40	13.14	2.10	35.50

*I-Irrigated condition D- Drought condition

Table 2: Estimates of genetic parameters for eight quantitative characters in F_3 progenies of the cross ICC-13124 x WR-315 under irrigated (I) and drought (D) condition in chickpea

Character	I/D*	V_P	GCV(%)	PCV(%)	h^2 (BS)(%)	GAM (%)
Days to 50% flowering	I	4.15	3.95	4.47	78.02	7.19
	D	2.77	3.94	4.38	81.62	7.32
Plant height (cm)	I	29.79	12.91	13.14	94.07	25.80
	D	21.16	11.75	13.54	75.32	21.01
Primary branches	I	0.32	19.48	19.98	95.00	39.15
	D	0.33	21.94	25.42	74.55	39.03
Secondary branches	I	9.10	19.79	23.61	70.30	34.18
	D	9.31	25.81	27.76	86.50	49.46
No. of pods per plant	I	1362.57	37.01	37.94	95.14	74.36
	D	874.19	44.23	44.39	99.29	90.80
Seeds per pod	I	0.29	32.15	38.48	69.78	55.32
	D	0.18	33.85	34.09	98.83	69.32
No. of seeds per plant	I	1172.54	35.75	35.91	99.00	73.30
	D	958.89	48.03	48.22	99.38	98.74
Test weight (g)	I	16.87	16.82	17.17	95.94	33.94
	D	21.34	18.66	20.62	81.90	34.79
Yield per plant (g)	I	67.20	36.46	36.56	99.45	74.91
	D	37.76	43.35	46.74	85.62	82.76

*I-Irrigated condition D- Drought condition

Table 3: Top 20 yield performers and their other characters under drought condition of the cross ICC-13124 x WR-315 in chickpea

Family	DFF	PH	PB	SB	NOP	NOS	SPPO	TW	SY
242	37.00	33.00	3.00	14.00	190.50	193.00	1.40	18.29	35.30
396	36.00	35.50	3.50	15.00	103.00	101.00	1.00	31.20	31.40
452	41.00	43.60	2.80	14.60	165.00	168.80	1.30	17.73	29.92
394	37.00	39.00	4.00	16.80	138.00	135.00	1.00	21.93	29.60
491	39.00	39.00	3.00	17.00	128.00	107.50	1.00	26.93	28.95
389	37.00	41.60	3.00	13.60	127.40	129.20	1.60	22.20	28.68
473	36.00	30.75	2.50	8.00	102.67	93.00	1.00	30.47	28.33
501	36.00	39.50	2.00	18.00	109.67	100.33	1.00	28.11	28.20
300	39.00	31.00	4.00	13.00	153.00	135.00	1.00	20.81	28.10
489	38.00	36.60	2.75	13.00	127.75	140.00	1.70	19.93	27.90
496	37.00	42.60	3.00	16.00	132.00	138.40	1.30	19.83	27.44
333	38.00	33.00	3.00	14.00	116.00	146.00	1.70	18.49	27.00
486	40.00	35.00	2.00	14.50	137.00	116.00	1.00	25.40	26.80
339	38.00	39.50	2.50	13.75	125.50	128.50	1.10	20.76	26.68
399	38.00	36.60	4.00	15.60	162.60	166.20	1.30	16.04	26.66
541	37.00	41.00	3.00	13.00	97.67	118.00	1.80	22.15	26.13
384	36.00	32.00	2.00	17.00	92.00	124.00	1.80	20.40	25.30
358	39.00	36.67	2.25	9.25	80.00	76.25	1.00	32.72	24.95
243	38.00	39.00	3.50	17.50	90.00	88.00	1.00	28.30	24.90
462	39.00	42.00	3.00	17.33	116.50	128.00	1.60	19.38	24.80

drought resistance in crop plants than to incorporate disease or pest resistance, because drought varies considerably from year to year, location to location and on different soil types within a farm. Even when the soil and plant characteristics and management factors are known or controllable, the aerial environment is difficult to predict. Therefore, the development of cultivars with high harvestable yield under drought stress through breeding is a great challenge (Ceccarelli and Grando, 1996).

The moisture stress had its effect and reduced the seed yield in drought stress plot In late sown conditions, the crop was subjected to severe stress without supplementary irrigation across the growing duration leading to drastic reduction in seed yield in drought treatment compared to irrigated conditions (Mirzaei *et al.,* 2010). The stress treatment also had effect on several yield components *viz.,* days to fifty per cent flowering, plant height, primary and secondary branches, number of pods per plant, number of seeds per plant (Table 1). However, moisture stress did not significantly reduce the test weight in both the dates of sowing. Serraj *et al.* (2004) also reported that, test weight is more stable across seasons and environments with relatively less G x E interaction. This character is mainly governed by additive gene action.

Flower initiation in crop plant is a quantitative trait depends upon the genetic makeup of variety and also highly influenced by variation in prevailing environments. Moisture stress usually tends the crop plant to develop early flowers which was very well noticed in the present study. Turner *et al.* (2007) indicated

Table 4: Estimates of yield and drought parameters like TDS, MP, DTE and DSI for F_3 progenies of the cross ICC-13124 x WR-315 in chickpea

Progeny No	Y I	YD	TDS	MP	DTE	DSI
P1	31.20	23.80	7.40	27.50	76.28	0.564
P2	16.30	8.80	7.50	12.55	53.92	1.092
CI	33.80	24.10	9.20	29.20	72.57	0.648
389	29.70	28.68	1.02	29.19	96.56	0.082
50	22.40	21.58	0.86	22.01	96.14	0.098
347	15.78	15.13	0.65	15.46	95.90	0.096
404	24.70	23.62	1.08	24.16	95.62	0.104
241	22.80	21.77	1.03	22.28	95.62	0.109
522	25.30	24.14	1.16	24.72	95.46	0.107
491	30.40	28.95	1.45	29.68	95.23	0.113
514	20.46	19.45	1.01	19.96	95.06	0.113.
452	31.70	29.92	1.78	30.81	94.38	0.133
381	23.10	21.75	1.35	22.43	94.15	0.139
333	28.70	27.00	1.70	27.85	94.07	0.141
31	17.20	16.16	1.04	16.68	93.95	0.143
502	26.20	24.55	1.65	25.38	93.70	0.149
394	31.70	29.60	2.10	30.65	93.37	0.157
507	21.20	19.70	1.50	20.45	92.92	0.164
541	28.27	26.13	2.14	27.20	92.24	0.179
343	25.74	23.74	2.00	24.74	92.22	0.185
496	30.17	27.44	2.73	28.81	90.95	0.215
501	31.20	28.20	3.00	29.70	90.38	0.228
486	29.70	26.80	2.90	28.25	90.23	0.232
Mean of all progeny			9.47	18.01	0.60	0.94

YI- Seed yield per plant (g) under irrigated condition YD- Seed yield per plant (g) under drought condition.

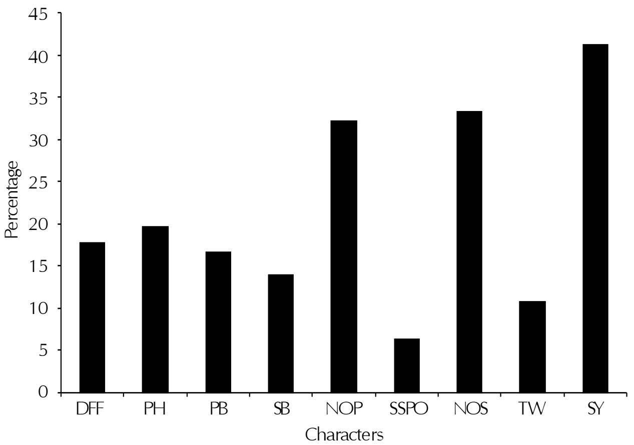

Figure 1: Percentage reduction in seed yield per plant and other components traits in $F_{2\text{-}3}$ progenies under drought condition compare to irrigated

that under terminal drought chickpea exhibits early flowering and faster maturity. This is attributed by totally reduction in vegetative phase and further affects plant height and in the present study, for this trait reduction was 18%. The results are in line with a study conducted by Deshmukh *et al.* (2004a).

Traits like primary and secondary branches also showed small reduction in mean values compared to irrigated F_3 progenies. The reduction may be due to the reduction of the growing period (Deshmukh *et al.*, 2004b). These traits further affected the important yield attributing trait like pods per plant under moisture stress compared to irrigated situation and Deshmukh *et al.* (2004a) experiment involving 45 genotypes indicated that pods per plant is the most sensitive stage for moisture stress.

There was drastic reduction in number of pods per plant in drought situation compared to irrigated situation similar results were obtained by Deshmukh *et al.* (2004a). Which might be due to abortion of pods and reduced flowering (Fang *et al.*, 2010). Another important trait that was affected due to drought was number of seeds per plant. By this we can conclude that the flowering and pod setting stages appear to be the most sensitive stages to water stress (Nayyar *et al.*, 2006; Mainassara Zaman-Allah *et al.*, 2011).

Among the nine quantitative characters studied it was noticed that seed yield per plant showed highest reduction of 41.10 per cent followed by number of seeds per plant which recorded 33.18 per cent under drought condition compared to irrigated condition. Others characters like number of pods showed 32.09 per cent reduction under drought condition. Least reduction was recorded by seeds per pod (6.34 per cent). By this we can conclude that reduction in seed yield under drought condition is due to reduction in number of seeds per plant (Fig. 1).

F_3 progenies under both irrigated and drought condition showed wide range of genetic variability, high heritability and high genetic advance for yield and its component traits (Table 2). Under drought situation the coefficient of variability was very low for days to fifty per cent flowering, moderate for traits like plant height and test weight. Similar results were obtained by Serraj *et al.* (2004), Santhosh Arya *et al.* (2013) and Garje *et al.* (2013). Heritability was high in both irrigated and drought condition for traits like secondary branches, number of pods per plant, seeds per plant and yield per plant coupled with high genetic advance over mean (Meshram *et al.*, 2013) This is in accordance with results of Parameshwarapa *et al.* (2010) who evaluated 13 germplasm lines under drought condition.

Drought tolerance parameters

Based on yield *per se* under drought situation, 20 genotypes were selected (Table 3). Progeny 242 recorded the highest yield with highest number of pods and seeds per plant. Most of them are better performers over ICC 13124 and BGD 103. These progenies are useful in further breeding program. The tolerance to drought stress, mean productivity, rate of productivity and drought susceptibility index is given in Table 4. Highest drought tolerance efficiency (DTE), least drought susceptibility index (DSI) and minimum tolerance to drought stress (TDS) was obtained for ICC 13124 compared to WR 315 and BGD 103. This result confirmed the findings of Parameshwarapa and Salimath (2008). High value for drought parameters exhibited by WR 315 confirmed the susceptibility of WR 315 to drought stress.

Khamssi *et al.* (2011) and Reza Talebi *et al.* (2011) reported that the drought resistant genotype had highest drought tolerance efficiency, minimum drought susceptible index and minimum reduction in grain yield due to moisture stress which clearly indicated that improvement in drought tolerance is possible thorough simple selection. Keeping this in mind we identified about 27 F_3 families which had still lower DSI values, minimum tolerance to drought, high DTE and mean productivity than ICC 13124. The lines 389 and 491 were observed as the best tolerant line to drought stress environment under the field condition with respect to both yield and drought parameters which is one of the important findings of the present study. This lines need to be evaluated critically for other drought tolerance characters like root length, biomass and other physiological parameters. Promising best families can be evaluated on large scale to identify variety or as a germplasm line for breeding drought tolerance and productivity.

REFERENCES

Allah, M. Z., Jenkinson, D. M. and Vadez, V. 2011. Chickpea genotypes contrasting for seed yield under terminal drought stress in the field differ for traits related to the control of water use. *Functi. Plant Bio.* **38(4):** 270-281.

Burton, G. W. and Devane, E. M. 1953. Estimating heritability in tall fescue (*Festuca circunclinaceae*) from replicated clonal material. *Agron. J.* **45:** 478-481.

Ceccarelli, S. and Grando, S. 1996. Drought as a challenge for the plant breeder. *Plant Growth Regulat.* **20:** 149-155.

Deshmukh, D. V., Mhase, L. B. and Jamadagni, B. M. 2004a. Performance of desi and Kabuli chickpea genotypes under irrigated and rainfed conditions. *Indian J. Pulses Res.* **17(2):** 181-182.

Deshmukh, D. V., Mhase, L. B. and Jamadagni, B. M. 2004b. Evaluation of chickpea genotypes for drought tolerance. *Indian J. Pulses Res.* **17(1):** 47-49.

Fang, X., Turner, N. C., Guijun, Y., Fengmin, L., Kadambot, H. and Siddique, M. 2010. Flower numbers, pod production, pollen viability, and pistil function are reduced and flower and pod abortion increased in chickpea (*Cicer arietinum* L.) under terminal drought. *J. Expt. Bot.* **61(2):** 335-345.

Fischer, R. A. and Maurer, R. 1978. Drought resistance in spring wheat cultivars, I. grain yield response. *Austral. J. Agric. Res.* **29:** 897-912.

Garje, U. A., Bhailume, M. S. and Nagawade, D. R. 2013. Genetic diversity analysis of green gram (Vigna radiate (L.) Wilczek.). *The Bioscan.* **8(4):** 1477-1480.

Hanson, G. H., Robinson, H. F. and Comstock, R. E. 1956. Biometrical studies of yield in segregating populations of Korean Lespedeza. *Agron. J.* **48:** 267-282.

Khamssi, N. N., Golezani, K. G , Najaphy, A. and Zehtab, S. 2011. Evaluation of grain filling rate, effective grain filling period and resistance indices under acclimation to gradual water deficit stress in chickpea cultivars. *Austral. J.Cro.Sci.* **5(6):** 1044-1049.

Kumar, J. and Van Rheenen, H. A. 2000. A major gene for time of flowering in chickpea. *J. Heredity.* **91:** 67-68.

Leport, L., Turner, N. C., French, R. J., Barr, M. D., Duda Davies R., Tennant, D. and Siddique, K. H. M. 1999. Physiological responses of chickpea genotypes to terminal drought in a Mediterranean-type environment. *European J. Agron.* **11:** 279-291.

Meshram, M. P., Ali, R. I., Patil, A. N. and Sunita, M. 2013. Variability studies in M_3 generation in blackgram (*Vigna mungo* (l.) Hepper). *The Bioscan.* **8(4):** 1357-1361.

Mirzaei, N., Abdolghayoum, G., Ahmad, T., Ali, A., Mostafaei, H. and Shahzad, J. S. 2010. Yield and yield components of chickpea affected by sowing date and plant density under dry condition. *World Appl. Sci. J.* **10(1):** 64-69.

Nayyar, H. S., Singh, S., Kaur, S., Kumar, J. and Upadhyaya, H. D. 2006. Differential sensitivity of macrocarpa and microcarpa types of chickpea (*Cicer arietinum* L.) to water stress: association of contrasting stress response with oxidative injury. *J. Integrative Plant Biol.* **48:** 1318-1329.

Parameshearappa, S. G., Salimath, P. M., Upadhaya, H. D., Patil, S. S., Kajjidoni, S. T. and Patil B. C. 2010. Characterization of drought tolerant accessions identified from the minicore of chickpea (*Cicer arietinum* L.). *Indian J. Genet.* **70(2):** 125-131.

Parameshwarappa, S. G. and Salimath, P. M. 2008. Field screening of chickpea genotypes for drought resistance. *Karnataka J. Agric. Sci.* **21(1):** 113-114.

Robinson, H. F., Comstock, R. E. and Harvey, P. H. 1949. Estimates of heritability and degree of dominance in corn. *Agron. J.* **41:** 353-359.

Rosielle, A. A. and Hamblin, J. 1981. Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Sci.* **21:** 943-946.

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

Santosh, A., Mishra, D. K. and Bornare, S. S. 2013. Screening genetic variability in advance lines for Drought tolerance of bread wheat (*Triticum aestivum*). *The Bioscan.* **8(4):** 1193-1196.

Serraj, R., Krishnamurthy, L., Kashiwagi, J., Kumar, J., Chandra, S. and Crouch, J. H. 2004. Variation in root traits of chickpea (*Cicer arietinum* L.) grown under terminal drought. *Field Crop Res.* **88(2):** 115-127.

Steel, R. G. D. and Torrie, J. H. 1997. Principles and procedures of statistics. *McGraw Hill Book Co., NY. USA.*

Talebi, R., Baghebani, N., Karami, E. and Ensafi, M. H. 2011. Defining Selection Indices for Drought Tolerance in Chickpea under Terminal Drought Stresses. *J. Appl. Biol. Sci.* **5(3):** 33-38.

Turner, N. C., Abbo, S., Berger, J. D., Chaturvedi, S. K., French, R. J., Ludwig, C., Mannur, D. M., Singh, S. J. and Yadava, H. S. 2007. Osmotic adjustment in chickpea (Cicer arietinum L.) results in no yield benefit under terminal drought. *J. Exp. Bot.* **58(2):** 187-94.