Indian J. Dryland Agric. Res. & Dev. 2014 29(1) : 23-26

Physiological and Yield Performance of Chickpea Genotypes under Drought Stress

Indu Swarup[1] and S. Holkar[2]

[1]*AICRP for Dryland Agriculture, RVSKVV, College of Agriculture, Indore-452 001, Madhya Pradesh*
[2]*AIC Cotton Improvement Project, RVSKVV, College of Agriculture, Indore-452 001, Madhya Pradesh*

Email: induswarup05@rediffmail.com

ABSTRACT: Ten high yielding chickpea genotypes were evaluated for yield performance under drought stress (rainfed) and non-stress (irrigated) conditions revealed the existence of considerable genetic variability in experimental materials. The magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for most of the characters. Relative water content (RWC) at pod development had high direct effect on seed yield under drought stress and non-stress conditions, while, direct effect of water saturation deficit (WSD) at pod development, showed negative impact on seed yield. Genotype IG 370 showed earliness in flowering and maturity under both drought stress and non-stress conditions and gave better yield (1674 kg/ha) with better drought tolerance efficiency as compared to late maturing genotypes (IG 226, KAK 2 and IG 592). Other genotypes namely, Vishal, IG 592, JG 412 and Ujjain 21 exhibited comparatively lower reduction in yield due to drought stress and high drought tolerance efficiency.

Key words: Chickpea genotypes, rainfed conditions, correlation and direct effects, drought tolerance

Chickpea (*Cicer arietinum* L.) is one of the important r*abi* pulse crop, mainly grown as a rainfed crop on residual soil moisture with limited irrigation. Productivity of chickpea in the world (797 kg/ha) and in India (809 kg/ha) is quite low and stagnated (Saxena *et al.,* 2010). Among the various constraints responsible for low and stagnant productivity, residual moisture status, time of monsoon termination in rainfed regions and prevailing high temperature responsible for high evapo-transpiration, are some of the important parameters adversely affecting the performance of chickpea in rainfed region. Chickpea has reputation of possessing drought tolerance and can tap moisture from deeper layer soil profile. Greater proportions photo-synthetase are allocated to pods and seeds when crop experiences moisture stress after flowering or when it was raised completely without irrigation (Deshmukh *et al.,* 2004). However, there is a need to evaluate existing genetic stock under cultivation in the region for drought stress tolerance, because most of the genotypes showed reduction in yield under drought stress situations. Therefore, it is necessary to evaluate genotypes under drought stress (rainfed) as well as non-stress (irrigated) conditions to understand drought management mechanism of genotypes and to quantify the yield losses due to these stresses in rainfed conditions.

Materials and Methods

Experimental material comprising ten chickpea genotypes *viz.* Vishal, Ujjain-21, JG 218, JG 412, IG 226, IG 370, IG 592, IGK 1, ICCV1311 and KAK 2 were evaluated under drought stress (rainfed) and non-stress (irrigated) conditions in *vertisols* at Research Farm of All India Coordinated Research Project for Dryland Agriculture and Regional Research Project on Pulses, Indore, respectively. The experiment was conducted during r*abi* 2010-11 and 2011-12 and laid out in a randomized block design with three replications in two sets (drought stress and non-stress conditions). Plot size comprised 10 rows of 6 m length with 30 cm apart and 10 cm between plants within a row. The recommended doses of NPK and S @ 20:40:20:20 kg per ha were applied at the time of sowing in both sets of experiment as basal application to raise a good crop. Experiments under stress conditions were planted in residual soil moisture after immediate harvest of soybean and no irrigation was given in both the years. During the crop growth period, 101 mm winter rainfall was received between 46th and 48th SMW (2010-11) while no winter rains were received during 2011-12. In another set of non-stress (irrigated) experiment, two irrigations were given at the time of branch initiation and at pod formation stage of the crop. Both the sets of experiment were conducted under identical conditions, except irrigation. Observations were recorded for days to flower initiation, days to 50% flowering, days to physiological maturity, number of pod/plant, 100 seed weight, biological yield and harvest index under drought stress and non-stress conditions. For screening the genotypes for drought tolerance; earliness, Relative Water Content (RWC) and Water Saturation Deficit (WSD) at flowering and pod development stages, per cent reduction in yield due to stress and Drought Tolerance Efficiency (DTE) were considered. These were estimated by following the formulae:

(i) Relative Water Content (RWC) and Water Saturation Deficit (WSD):

$$RWC = [(FW - DW) / (TW - DW)] \times 100$$

$$WSD = [(TW - DW) / (TW - FW)] \times 100$$

Where, FW: Fresh weight (g)

DW: Dry weight (g)

TW: Turgid weight (g)

(ii) % Yield reduction due to stress:

$$[(Y_{IO} - Y_{II}) / Y_{II}] \times 100$$

Where, Y_{IO}: Yield of the genotype under stress condition

Y_{II}: Yield of the genotype under non-stress condition

(iii) Drought Tolerance Efficiency (DTE):

This was estimated as per the procedure outlined by Fisher and Maure (1978).

$$DTE\ (\%) = (Y_{IO} / Y_{II}) \times 100$$

Where, Y_{IO}: Yield of the genotype under stress condition

Y_{I1}: Yield of the genotype under non-stress condition

The statistical analysis of variance was carried out for each character under drought stress and non-stress conditions both as per the standard procedure. The association analysis was carried out as per the procedure outlined by Miller *et al.* (1958) and Dewey and Lu (1959).

Results and Discussion

Need for detection of genotypic differences for drought tolerance in chickpea

Soil moisture stress and high temperature together constitute drought stress which is the major constraint for reducing seed yield of chickpea. There were various methods to evaluate genetic differences amongst the genotypes of chickpea. It is therefore planned to find out the simple and precise field techniques to detect genotypic differences for drought tolerance and also to quantify yield losses under drought stress situations.

Analysis of variance

Analysis of variance showed significant differences among the genotypes for various physiological and yield contributing characters under drought stress as well as non-stress conditions. Relative water content (RWC) at flowering under non-stress condition and number of seeds per pod under both drought stress and non-stress showed non-significant differences. This indicates that the existence of considerable genetic variability in experiment material for the characters under study, except relative water content (RWC) at flowering and number of seeds per pod in both the stress and non stress conditions and the importance of available moisture on yield and physiological activities in stress and non stress conditions. Further, the magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variations (GCV) for most of the characters, indicating the influence of environment on the performance of genotypes in stress and non stress conditions. Higher GCV and PCV was observed for 100-seed weight, pods per plant, seed yield per plant, harvest index, water saturation deficit (WSD) at flowering, and pod formation under both drought stress and non-stress situations. The results are in agreement with those of Jeena *et al.* (2005) and Meena *et al.* (2006).

Association analysis

The association analysis between yield per plant and other yield attributing characters (Tables 1 and 2) revealed higher magnitude of genotypic correlation coefficient than that of phenotypic correlations for most of the characters, indicating that the environment do not have any impact on performance of genotypes grown in different environmental conditions either in stress or non stress conditions. Association analysis revealed that yield per plant had significant positive association with relative water content (RWC) at flowering, RWC at pod formation, plant height, 100-seed weight, biological yield and harvest index, while negative association with water saturation deficit at flowering and pod formation under drought stress conditions. Similar findings were also reported by Sidramappa *et al.* (2008) and Singh and Sandhu (2008) in chickpea.

The magnitude of direct and indirect effects (Table 1) for physiological attributes were similar for most of the characters under both drought stress and non-stress conditions except relative water content at flowering and days to physiological maturity. It revealed that RWC at pod development had significant direct effect on seed yield under both drought stress and non-stress conditions while direct effect of water saturation deficit at pod development showed negative impact on seed yield. This indicates the importance of moisture at these critical stages. Similarly direct effect of RWC on days to flowering and days to physiological maturity showed importance of moisture content under both drought stress and non-stress conditions. Higher indirect effect of relative water content on flowering (1.272) and at pod development stage (1.352) were exerted through water saturation deficit (WSD) on flowering under drought stress condition indicate the importance of relative moisture in reproductive phase. In case of yield contributing characters, the highest positive direct effect of biological yield, primary branches and harvest index was observed on seed yield. Similarly, 100-seed weight also expressed direct effect on seed yield under drought stress conditions, subject to availability of moisture at pod development stage. These findings are in conformity with the findings of Yadav *et al.* (2002) and Singh and Sandhu (2008).

Relative performance of genotypes under drought stress and non-stress conditions indicated that among the various genotypes, IG 370 showed earliness in days to flowering and maturity under both drought stress and non-stress conditions (Table 3) suggesting that earliness (5 days) in flowering and maturity under drought stress condition is helpful in facing moisture stress in rainfed condition with better yield performance (1674 kg/ha) as compared to late maturing (102-107 days) IG 226, KAK 2 & IG 592 with similar yield potential due to escaping from terminal drought situation. Kumar *et al.* (1996) reported that short duration varieties maturing before terminal drought proved as successful genotypes for enhanced productivity in drought-prone conditions. Sharma *et al.* (2007) also reported that increased moisture stress reduced the duration of reproductive phase with increased water use efficiency over crop sown in non-stress condition. Better yield performance of IG 370 under drought stress condition with minimum percent reduction due to stress (11.06%), may be due to its capability of survival with high water saturation deficit (WSD) as indicated by higher drought tolerance efficiency. Deshmukh *et al.* (2006) also reported 15-16% reduction in yield due to moisture stress in chickpea.

Chickpea genotypes *viz.,* Vishal, IG 226 and JG 412 recorded higher number of pods per plant while genotypes IGK 1, ICCV 1311 and KAK 2 had higher 100-seed weight (37.3 - 39.2 g) under non-stress and (33.9-38.9 g) under drought stress conditions. This suggested that these genotypes had minimum variations in yield performance under both the conditions indicating their suitability for rainfed conditions.

Table 1 : Estimates of direct and indirect effects of morpho-physiological characters on seed yield of chickpea under drought stress and non-stress conditions

Characters		Days to flower initiation	Days to 50% flowering	Days to maturity	RWC at flowering	RWC at Pod formation	WSD at flowering	WSD at pod formation	Genotypic correlation with seed yield
Days to flower initiation	S	-0.685	0.785	0.123	0.024	-0.029	-0.227	0.107	0.096
	NS	-2.945	2.613	-0.130	0.302	0.905	0.260	-0.816	0.190
Days to 50% flowering	S	-0.713	0.754	0.146	0.009	-0.006	-0.101	0.044	0.134
	NS	-2.774	2.775	-0.166	0.285	-0.307	0.233	0.367	0.413
Days to maturity	S	-0.330	0.434	0.254	-0.006	0.228	0.110	-0.295	0.396
	NS	-1.714	2.061	-0.223	0.212	-1.782	0.221	1.651	0.426
RWC at flowering	S	0.152	-0.067	0.014	-0.107	0.593	1.272	-0.937	0.920
	NS	-1.999	1.773	-0.106	0.446	2.494	0.577	-2.329	0.855
RWC at pod formation	S	0.041	-0.009	0.119	-0.130	0.490	1.352	-0.928	0.934
	NS	-0.295	-0.094	0.044	0.123	9.038	0.149	-8.510	0.456
WSD at flowering	S	-0.129	0.063	-0.023	0.113	-0.550	-1.204	0.899	-0.532
	NS	1.585	-1.337	0.102	-0.531	-2.790	-0.484	2.612	-0.843
WSD at pod formation	S	-0.084	0.038	-0.086	0.116	-0.524	-1.248	0.867	-0.922
	NS	0.282	0.120	-0.043	-0.122	-9.038	-0.149	8.509	-0.441

Residual effect: Drought stress (S): 0.3031; Non-stress (NS): - 0.6495; S: Stress; NS: Non-stress;

RWC: Relative Water Content; WSD: Water Saturation Deficit

Table 2 : Estimates of direct and indirect effects of yield attributing characters on seed yield of chickpea under drought stress (rainfed) and non-stress (irrigated) conditions

Characters		Plant height (cm)	Primary branches per plant	Pods per plant	100 seed wt.	Biological yield/plant	Harvest index	Genotypic correlation with seed yield
Plant height	S	-0.599	0.488	0.000	0.207	0.224	0.068	0.997
	NS	1.107	-0.044	-0.132	-0.036	1.211	-0.307	0.799
Primary branches per plant	S	-0.464	0.631	0.000	0.026	0.263	0.395	0.851
	NS	0.070	0.068	-0.105	0.005	0.852	-0.010	0.744
Pods per plant	S	-0.214	0.366	0.000	-0.131	0.034	0.214	0.270
	NS	0.079	-0.040	-0.177	0.061	0.250	0.415	0.588
100 seed wt.	S	-0.328	0.044	0.000	0.378	0.188	0.377	0.659
	NS	0.022	0.002	0.061	-0.177	1.025	-0.549	0.383
Biological yield/ plant	S	-0.335	0.414	0.000	0.177	0.401	0.121	0.779
	NS	0.090	-0.040	-0.031	-0.127	1.432	-0.623	0.702
Harvest Index	S	-0.573	0.351	0.000	0.201	0.068	0.709	0.757
	NS	-0.032	0.001	-0.072	0.095	-0.875	1.019	0.135

Residual effect: S: (-) 0.0375 (Drought stress); NS: (-) 0.0055 (Non-stress); S: Stress; NS: Non-stress

Table 3 : Performance of chickpea genotypes under non-stress (irrigated) and drought stress (rainfed) conditions

Genotype	Seed yield (kg/ha)		Days to 50% flowering		Days to maturity		Pods/plant		100 seed wt (g)		WSD at flowering		WSD at podding		% yield Reduction due to stress	DTE
	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S		
Vishal	2595	2178	61.7	52.7	107.7	99.0	56.5	27.0	26.9	26.5	17.3	26.5	24.6	33.7	15.18	84.82
Ujjain 21	2296	1854	60.3	54.7	107.3	103.0	40.0	22.7	17.3	16.9	19.3	36.1	29.9	40.8	18.67	81.33
JG 218	2574	2065	62.0	60.0	106.0	102.3	52.7	21.3	20.2	19.9	22.3	38.5	20.8	43.8	19.10	80.90
JG 412	2267	1836	61.7	50.7	106.3	101.0	47.9	27.0	31.4	27.3	20.8	30.9	27.2	36.9	18.37	81.63
IG 226	2348	1679	62.7	53.0	107.7	102.0	49.0	28.3	15.7	14.1	23.9	32.8	33.2	37.7	27.35	72.65
IG 370	1908	1674	52.0	47.7	97.7	92.3	25.7	16.7	19.3	19.2	24.7	36.7	29.1	44.4	11.06	88.94
IG 592	2161	1804	59.7	52.0	111.3	104.0	31.2	15.0	36.9	33.5	23.6	35.8	30.7	39.6	16.30	83.70
IGK 1	2022	1336	63.0	53.7	111.0	101.7	31.9	17.3	39.2	37.7	18.3	20.3	32.0	27.8	33.96	66.04
ICCV1311	2279	1504	57.3	50.3	109.0	100.7	36.2	23.0	38.5	38.9	21.3	34.2	28.4	38.1	33.86	66.14
KAK 2	2619	1642	61.3	52.7	107.3	105.3	39.3	22.3	37.3	33.9	23.2	30.4	36.7	35.2	36.93	63.07

DTE: Drought Tolerance Efficiency; WSD: Water Saturation Deficit; NS: Non-stress; S: Drought Stress

Conclusions

High RWC at flowering and pod formation stages, plant height, number of primary branches and biological yield are considered as an indication of high seed yield under both drought stress and non-stress situations. Chickpea genotypes *viz.,* IG-370, Vishal, IG-592, and JG-412 were found to be promising as they recorded high drought tolerance efficiency, less reduction in seed yield under drought stress over non-stress situations and matured 4-5 days earlier under drought stress than non-stress conditions. Thus, genotypes *viz.,* IG-370, Vishal, IG-592, and JG-412 can be recommended for cultivation under drought stress and non-stress situations to enhance chickpea production in the state.

References

Deshmukh DV, Mhase LB and Jamadagni BM. 2004. Evaluation of chickpea genotypes for drought resistance. Indian Journal Pulses Research, 17 (1): 47-49.

Deshmukh DV, Mhase LB and Jamadagni BM. 2006. Growth rate drought susceptibility index, traits for breeding genotypes tolerant to moisture stress in chickpea. Annals of Plant Physiology. 20 (2): 171-176.

Dewey DR and Lu KH. 1959. A correlation and path coefficient analysis of components of crested wheat and seed production. Agronomy Journal. 51: 515-518.

Jeena AS, Arora PP and Upreti MC. 2005. Divergence analysis in chickpea. Legume Research. 28 (2):152-154.

Kumar J, Sethi SC, Johansen C, Kelly TG, Rahman MM and Van Rheenen HA. 1996. Potential of short duration chickpea varieties. Indian Journal Dryland Agriculture Research and Development. 11: 28-32

Meena HS, Kumar J and Deshmukh PS. 2006. Genetic variability and correlation studies for traits related to drought tolerance in chickpea (*Cicer arietinum* L.). Indian Journal of Genetics. 66 (2): 140.

Miller PA, Willans LC, Robinson HF and Comstock RE. 1958. Estimates of genotypic and environmental variance and covariance in upland cotton and their implication in selection. Agronomy Journal. 50: 126-131.

Saxena DR, Gupta SC, Tikle AN, Nema KK, Yasin M, Singh RP and Saxena A. 2010. Souvenir, All India Group Meet of AICRP on Chickpea-2010, R.A.K. College of Agriculture, Sehore. 25-31.

Sharma KD, Pannu RK, Tyagi PK, Chaudhary BD and Singh DP. 2007. Effect of soil moisture stress on biomass partitioning and yield of chickpea genotypes. Journal Food Legumes. 20 (1):71-74

Sidramappa S, Patilm SA, Salimath PM and Kajjidoni ST. 2008. Direct and indirect effects of phenological traits on productivity in recombinant inbred lines population of chickpea. Karnataka Journal Agriculture Science. 21(4):491-493.

Singh A and Sandhu JS. 2008. Correlation and path analysis in chickpea under different environments. Journal Food Legume. 21(2): 145-148.

Yadav VS, Singh D, Yadav SS and Kumar J. 2002. Correlation and path analysis in chickpea. Indian Journal Agriculture Research. 15: 19-22.

Received: October 2013; Accepted: May 2014