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GENETICS AND PLANT BREEDING

G X E Interaction and stability analysis in chickpea (*Cicer arietinum* L.)

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Abstract

G X E interaction and stability analysis were carried out in four environments comprised of two different dates of sowing with two different locations for 10 diverse genotypes. Analysis of variance for genotype x environment interaction and stability analysis suggested that the variance for G x E interaction was significant for number of pods per plant, seed yield per plant, 100-seed weight, harvest index and protein content. The genotypes IC-269273, IC-269295 and three cultivars *i.e.,* GG-1, GJG-3 and Dahod Yellow were stable across environments. Out of these five genotypes, Dahod Yellow having the highest average seed yield per plant was found most stable over environments. Thus, any of the germplasm entry under study was not found superior with respect to seed yield per plant against the three cultivated varieties.

Highlights

- The genotypes IC-269273, IC-269295 and three cultivars *i.e.,* GG-1, GJG-3 and Dahod Yellow were stable across environments.

Keywords: *Cicer arietinum* L., G X E interaction and stability

Chickpea (*Cicer arietinum* L.) commonly known as Gram, Chana, Bengal gram and Garbanzo bean is the most important pulse crop of arid and semi-arid regions. The somatic chromosome number in chickpea are 2n = 16. It is essentially a self-pollinated crop. Two major cultivar types designated as 'desi' (=microsperma) and 'kabuli' (=macrosperma) have emerged under domestication. Desi chickpeas are small and angular with rough brown to yellow testas, while Kabuli types are relatively large, plump and with smooth cream colored testas. Kabuli types are considered relatively more advanced because of their larger seed size and reduced pigmentation achieved through conscious selection (Smartt and Simmonds, 1995).

The productivity of pulses is low in India as about 87.00 per cent area under pulses is rainfed and consequently pulses face severe moisture stress with low productivity. In recent years, wide spread deficiency of sulphur and zinc has been noticed in pulse growing regions, which constrains productivity of pulses. Transfer of improved pulse production technologies remains the most neglected component in the past and consequently the benefit of improved varieties and production technology could not be harnessed. On an average, 20 to 40 per cent crop is annually lost due to damage caused by pod borers in pigeonpea and chickpea. Pod fly also causes 10 to 15 per cent loss especially in north India. Wilt and root rots cause heavy loss

to pigeonpea and chickpea crops. Quantum jump in productivity can be achieved by applying pulse irrigation (life saving irrigation) especially in *rabi* pulses grown on residual moisture.

Stability of genotypes depends on maintaining certain morphological and physiological attributes steady and allowing others to vary, resulting in predictable G x E interaction for yield. Study of individual yield components can lead to simplification in genetic explanation of yield stability and hence are valuable to breeders in prediction and determination of the effects of the environments. Phenotype may be defined as a linear function of genotype (G), environment (E) and (G x E) interaction effect. Relative importance of main and interaction effects may vary from genotype to genotype and with environments. Thus, the study of G x E interaction serves as a guide and helps in identifying suitable genotypes for various environmental niches. Considering above facts, the present study was undertaken to study G x E interaction and stability across environment and different dated of sowing

Materials and Methods

The present research was conducted in four environments comprised two different dates of sowing and two different locations, first one at Centre of Excellence for Research on Pulses, Sardarkrushinagar, and second one at Sorghum Research Station, Deesa during *rabi* season to evaluate 10 genotypes including three cultivated varieties (Table 1).

Table 1: List of genotypes evaluated for G X E interaction and stability

Sr. No.	Genotypes	Source	Sr. No.	Genotypes	Source
1.	IC 269268	NBPGR, New Delhi	6.	IC 269295	NBPGR, New Delhi
2.	IC 269269	NBPGR, New Delhi	7.	IC 269310	NBPGR, New Delhi
3.	IC 269272	NBPGR, New Delhi	8.	GJG 3	Junagadh, Gujarat
4.	IC 269273	NBPGR, New Delhi	9.	GG 1	Junagadh, Gujarat
5.	IC 269277	NBPGR, New Delhi	10.	Dahod yellow	Dahod, Gujarat

The observation on five randomly selected plants were recorded for days to flowering, days to maturity, plant height, number of effective branches/ plant, number of pods/ plant, number of seeds/ pod, seed yield/ plant, 100-seed weight, harvest index (%) (Calculated as the ratio of the economical yield (total seed yield) and the total plant biomass on per cent basis), protein content (it was determined by using Near Infrared Rays (NIR) spectrophotometer) and methionine content, the methionine content was estimated by colorimetric method as per Mc. Carthy and Paille (1959). Observations were taken at 520 nm by using UV-visible Spectrophotometer. Analysis of variance was performed as per method suggested by Snedecor and Cocharan (1937) and review by Panse and Sukhatme, (1978). The statistical analysis for G x E interaction and stability parameters were carried out according to the Eberhart and Russell (1966).

Results and Discussion

The presence of G x E interactions reduces the correlation between phenotype and genotype, and makes it difficult to judge the genetic potential of a genotype. Stability of a cultivar refers to its consistency in performance across environments and is affected by the presence of G x E interactions. In presence of significant G x E interactions, stability parameters are estimated to determine the superiority of individual genotypes across the range of environments. Eberhart and Russell (1966) defined a stable genotype as one which produces high mean yield, depicts regression coefficients (b_i) around unity and non-significant deviations from regression (S^2d_i). The linear response (b_i) should be simply regarded as a measure of response of a particular genotype, whereas the deviation from regression (S^2d_i) is regarded as a measure of stability. Becker *et al.* (1982) regarded mean square for deviation from regression (S^2d_i) to be the most appropriate criterion for measuring phenotypic stability in an agronomic sense because this parameter measures the predictability of genotypic reaction to environments.

The Analysis of variance for individual environment revealed significant mean squares due to genotypes for all the characters (Table 2).

Table 2. Analysis of variance for individual environments

Sources of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Number of effective branches per plant	Number of pods per plant	Number of seeds per pod	Seed yield per plant	100-seed weight	Harvest index (%)	Protein content (%)	Methionine content (mg/g sample)
Environment – I												
Replication	2	10.03	41.70	33.14	0.20	140.83	0.03	10.45	4.12	29.14	0.17	0.00
Genotype	9	143.84**	302.77**	64.55**	5.88**	248.70*	0.19**	171.37**	86.00**	141.68**	3.84**	1.58**
Error	18	3.07	14.77	11.92	0.23	100.83	0.02	13.94	1.19	6.83	0.21	0.00
Environment – II												
Replication	2	2.53	37.30	7.06	0.01	99.70	0.00	1.15	1.30	16.54	0.22*	0.00
Genotype	9	187.54**	190.45**	51.86**	4.79**	517.34**	0.21**	52.45**	44.78**	106.70**	4.51**	1.63**
Error	18	5.72	13.67	6.15	0.05	29.40	0.01	11.69	0.52	5.96	0.06	0.00
Environment – III												
Replication	2	5.70	31.60	32.69	0.17	92.50	0.00	11.16	0.20	2.21	0.45	0.00
Genotype	9	150.99**	216.54**	28.49*	2.71**	222.43*	0.20**	132.48**	70.82**	150.55**	6.73**	1.66**
Error	18	1.96	16.53	9.59	0.10	80.69	0.01	15.38	1.01	11.18	0.15	0.00
Environment – IV												
Replication	2	5.73	34.23	12.78	0.50*	32.50	0.01	33.23	3.03	30.49	0.03	0.00
Genotype	9	130.55**	168.92**	38.87**	2.79**	288.13**	0.11**	104.13**	72.04**	72.72**	4.26**	1.72**
Error	18	2.52	12.79	6.41	0.09	71.39	0.02	17.23	1.07	9.61	0.10	0.00

*, ** Significant at P = 5 and 1 per cent levels, respectively.

Table 3: Pooled analysis of variance over environments for different characters in chickpea

Sources of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Number of effective branches per plant	Number of pods per plant	Number of seeds per pod	Seed yield per plant	100-seed weight	Harvest index (%)	Protein content (%)	Methionine content (mg/g sample)
Genotype	9	595.58**	823.60**	129.38**	13.47**	1052.24**	0.63**	367.46**	267.25**	325.54**	16.66**	6.5714**
Environment	3	519.03**	860.31**	46.72**	13.18**	6737.31**	0.46**	199.27**	225.35**	256.77**	3.04**	0.0198**
G x E	27	5.47*	18.36	18.13**	0.90**	74.79	0.02*	30.99**	2.13**	48.71**	0.89**	0.0038
Pooled error	72	3.25	14.44	8.52	0.12	70.58	0.01	14.56	0.95	8.40	0.13	0.0023

*, ** Significant at 5 and 1 per cent levels, respectively when tested against pooled error.

Table 4: Analysis of variance (mean squares) for stability for various traits in chickpea

Sources of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Number of effective branches per plant	Number of pods per plant	Number of seeds per pod	Seed yield per plant	100 – seed weight	Harvest index (%)	Protein content (%)	Methionine content (mg/g sample)
Genotypes	9	198.53**	274.52**	43.13**	4.48**	350.76**	0.21**	122.49**	89.08**	108.51**	5.55**	2.190**
Environments	3	173.01**	286.74**	15.58*	4.39**	2245.80**	0.15**	66.42**	75.12**	85.59**	1.01**	0.007**
G x E	27	1.82	6.12	6.04	0.30	24.92**	0.01	10.33*	0.71**	16.23*	0.29*	0.001
E + (G x E)	30	18.94**	34.19**	6.99	0.71**	247.01**	0.02*	15.94**	8.15**	23.17**	0.37**	0.002*
Environment (Linear)	1	519.03**	860.30**	46.72**	13.18**	6737.30**	0.46**	199.27**	225.35**	256.77**	3.04**	0.020**
Genotype x Environment (Linear)	9	2.40	11.12*	9.58*	0.26	59.44**	0.01	21.22**	1.55**	34.31**	0.62**	0.001
Pooled deviation	20	1.38	3.26	3.85	0.29**	6.91	0.01	4.39	0.26	6.48*	0.12**	0.001
Pooled error	72	3.25	14.44	8.52	0.12	70.58	0.01	14.56	0.95	8.39	0.13	0.002

*, ** Significant at 5 and 1 per cent levels, respectively when tested against pooled deviation

Table 5: Stability parameters of different genotypes for number of pods per plant, seed yield per plant (g), 100-seed weight (g), harvest index (%) and protein content (%) in chickpea

Sr. No.	Genotypes	Number of pods per plant			Seed yield per plant (g)			100-seed weight (g)			Harvest index (%)			Protein content (%)		
		Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
1.	IC-269268	107.50	0.52	-22.38	21.67	-0.89**	6.65	13.52	1.05	-0.11	26.72	-1.13**	25.68**	17.10	-0.30	-0.04
2.	IC-269269	104.08	0.73	-2.36	30.56	1.51	-4.74	14.99	0.93	-0.11	29.52	1.69	-2.78	19.04	3.70**	0.47
3.	IC-269272	100.25	1.48	-5.68	29.03	1.61	6.44	12.43	0.75*	-0.18	34.90	1.56	3.46	18.65	1.55	0.17
4.	IC-269273	100.42	0.88	-16.53	30.85	1.82	-1.80	16.20	0.98	-0.21	27.33	1.93	3.41	18.93	2.15	0.05
5.	IC-269277	111.58	1.22	-22.12	26.27	1.24	-4.51	15.70	0.85	0.32	32.60	1.57	-2.20	19.79	1.65	0.13
6.	IC-269295	103.75	1.30	-20.20	31.93	1.76	-4.84	13.45	0.75*	-0.20	30.17	1.98	-2.34	19.58	0.41	-0.04
7.	IC-269310	94.92	1.20	-15.19	25.32	-0.93**	-2.54	11.73	0.92	-0.21	29.83	-1.11**	1.46	21.05	1.89	-0.00
8.	GG-1	118.50	0.93	-17.13	35.12	1.24	4.67	26.48	1.59*	0.00	36.92	1.11	8.28	18.02	-0.61**	0.01
9.	GJG-3	120.00	0.95	-21.73	37.12	1.12	-0.07	22.48	1.30*	-0.17	40.99	1.12	3.29	19.80	-0.75**	0.02
10	Dahod Yellow	122.17	0.78	-22.88	39.67	1.52	-3.84	18.67	0.88	0.35	40.70	1.28	-1.48	17.58	0.31	0.02
	Mean	**108.32**			**30.76**			**16.56**			**32.97**			**18.96**		
	S.Em.±	**1.52**			**1.21**			**0.30**			**1.46**			**0.20**		

In pooled analysis of variance, the genotypic and environmental variances were significantly high for all the characters. The variances due to G x E interaction were observed significant for 8 out of 11 characters. This indicated very high influence of environments on the expression of various traits in the chickpea genotypes under study (Table 3).

The analysis of variance for stability (Table 4) showed that mean squares due to environments were statistically significant for all the traits indicating that variability among environments was large enough for a proper estimation of 'b' values. The G x E interaction was significant for five traits *viz.*, number of pods per plant, seed yield per plant, 100-seed weight, harvest index and protein content.

Therefore, stability parameters of the genotypes were worked out for these five characters (Table 5). Similar findings in chickpea were also reported by Rao, (2011), Gupta and Sharma (2009), Ahmad Bakhsh *et al*. (2011) for yield and yield attributing traits.

An overall study of stability parameters (Table 5) revealed that not a single genotype was ideally stable for all the five characters. The stability parameters for seed yield per plant showed that five genotypes were stable over the environments. Among these, two were germplasm accessions (IC-269273 and IC-269295), while three *i.e.*, GG-1, GJG-3 and Dahod Yellow were cultivated varieties. These genotypes registered higher mean seed yield per plant, non-significant deviation from regression and regression coefficient not deviating from one. The seed yield of the stable entries (IC-269273 and IC-269295) was not higher than highly adapted local cultivars GG-1, GJG-3 and Dahod yellow.

Among the ideally stable genotypes for seed yield, the germplasm accession IC-269273 was not stable for any of the other four traits, while the entry IC-269295 was stable for protein content (Table 6). All the three check cultivars were stable for number of pods per plant and harvest index along with seed yield per plant. The check cultivar Dahod Yellow was ideally stable for all the characters except protein content and it was the top ranking in terms of seed yield, number of pods per plant, number of effective branches per plant and days to flowering. In case of 100-seed weight, the cultivarsGG-1 and GJG-3 were found stable under favorable environments only. The cultivar GJG-3 was characterized stable for protein content under poor environments only.

Table 6: Stable genotypes identified on the basis of high mean for seed yield per plant and stability parameters

Genotypes	Seed yield per plant	Stable for other traits
IC-269273	30.85	-
IC-269295	31.93	4
GG-1	35.12	1, 2+, 3
GJG-3	37.12	1, 2+, 3, 4--
Dahod Yellow	39.67	1, 2, 3

Where,

- + = Better for favorable environment, -- = Better under poor environments, 1 = Number of pods per plant
- 2 = 100-seed weight, 3 = Harvest index, 4 = Protein content

Amongst the yield components, 100-seed weight was the most sensitive character as four out of ten genotypes were not stable for this trait. Similarly, the trait pods per plant were least sensitive as not a single entry registered regression co-efficient significantly deviating from unity. Among the four environments created based on combinations of two locations (Deesa and Sardarkrushinagar) and two dates of sowing (7th and 30th November), the environment E-I (Deesa location, 7th November) was found most favorable as it resulted into highest seed yield, number of pods per plant, 100-seed weight, number of effective branches and minimum days to maturity in the plant population.

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