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Stability analysis for yield and its contributing characters in kabuli chickpea (*Cicer arietinum* L.)

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Abstract
The present investigation was carried out to study stability performance over three environments for seed yield and contributing characters in 38 genetically diverse genotypes of kabuli chickpea. Pooled analysis of variance revealed significant mean square estimates due to genotypes for all the characters included for stability analysis. The significance of genotype x environment interaction for all the traits except seeds per pod and protein content revealed differential response of the genotype to varying dates of sowing. This suggested the importance of testing the material over different environmental conditions. Mean squares due to linear and non-linear components of genotype x environment interaction were significant for all the characters. This showed that genotypes possessed differences for linear response to varying environments as well as for deviation from regression for all the traits. Thus, prediction for these traits was difficult. Eight genotypes viz., KAK 2, BG 2084, NDGK 902, HK 04-178, JSC 51, BG 2082, ICCV 6301 and ICCV 7310 possessed higher mean than population mean coupled with non-significant regression coefficient and deviation from regression, hence, above said genotypes may be considered as ideal. The yield stability of different genotypes has been discussed in relation to their stability for yield contributing characters.
For further improvement, it was suggested to adopt appropriate selection procedure for yield and yield components like days to flowering, number of branches per plant, number of pods per plant, biological yield per plant and 100-seed weight.

Keywords: Kabuli chickpea, stability, genotype × environment (GxE) interaction

Introduction
Among the food crops, pulses are an important group which occupies a unique position in the world of agriculture by virtue of their high protein content. In pulses, chickpea (*Cicer arietinum* L.) is one of the important crops with high acceptability and wider use, besides being rich in protein, its ability to use atmospheric nitrogen through biological nitrogen fixation is economically sounder and environmentally acceptable grown in *Rabi* season. It is self-pollinated crop belongs to the sub-family Papilionaceae of family Leguminaceae (Bentham and Hooker 1970) [1].
Kabuli chickpea accounts for about 20 per cent of the world's chickpea production. Kabuli types are characterized by large seeds (more than 26 g per 100 seeds) that are pale cream and shaped like a ram's head or brain. Kabuli chickpea seed is sought for whole seed consumption in confectionery products, salads, savoury meals or ground into paste (hommos); hence its appearance (size and colour) is an important characteristic that can affect marketability and price.
The development of improved and stable genotype is one of the main objectives of the plant breeders. So, multilocational trials are conducted over several years to find out stability of various genotypes. In this context, the testing of kabuli genotypes under different dates of sowing is useful to isolate stable genotypes. These genotypes will be used in crop improvement programme.

Matrials and Methods
The experiment was conducted with 38 genotypes of kabuli chickpea in randomized block design with three replications during *rabi* season at Instructional Farm, JAU, Junagadh. Each genotype was planted as a single row of 4.0 m length, keeping plant to plant distance of 15 cm and row to row spacing of 45 cm. The recommended package and practices were followed to raise the healthy crop. The observations were recorded on the basis of 5 randomly selected plants for different characters namely, days to 50% flowering, days to maturity, reproductive phase

duration, plant height (cm), branches per plant, number of pods per plant, number of seeds per pod, biological yield per plant (g), 100 seed weight (g), seed yield/ plant (g) and harvest index (%). Three different environments were used to obtain information stability of yield and its contributing characters in 38 genotypes of kabuli chickpea. Environments were created by sowing crop on three dates viz., early, timely and late. The data were statistically analyzed and the genotypes were assessed for their stability of performance across environments following the method described by Eberhart and Russell (1966) [2].

Results and Discussion

The pooled analysis of variance showed that mean sum of squares due to genotypes and environments were highly significant for all the characters included for stability analysis, indicating presence of variability among the genotypes and environments (Vijay Prakash, 2006) (Table 1). Prediction of performance of Reproductive phase was possible due to the preponderance of linear component of G x E interaction (Singh and Kumar, 1994) [3]. Higher yielding and stable genotype JSC 51 and ICCV 6310 showed longer and stable performance for this trait. It may be the reason of its stability over environments. In the present investigation for seed yield per plant, eight genotypes namely KAK 2, BG 2084, NDGK 902, HK 04-178, JSC 51, BG 2082, ICCV 6301 and ICCV 7310 possessed higher mean than population mean coupled with non-significant unit regression and least deviation from regression (Table 2). Hence, they were well adapted to all the three sowing conditions i.e. early, timely and late sown conditions. One genotype namely GNG 1808 had high mean seed yield per plant with bi values above unity and non-significant deviation from regression. Therefore, it was specifically adapted to high yielding environments. On the other hand one genotypes viz., BGD 128 had lower mean performance, non-significant S^2d_i values and bi values below unity. It showed its adoptability to low yielding environment only. Twenty genotypes exhibited low mean yield (i.e. poor than population mean). Nineteen genotypes exhibited significant S^2d_i values suggesting non-predictability of performance for these genotypes across environments.

Eight genotypes namely, KAK 2, BG 2084, NDGK 902, HK 04-178, JSC 51, BG 2082, ICCV 6301 and ICCV 7310 had high mean, regression coefficient around unity and non-significant deviations from regression for seed yield per plant. Hence, all these eight genotypes could be considered as most suitable ones.

Role of the predictable and non-predictable components of G x E interaction was equal for number of pods per plant. Therefore, perfect prediction is not possible. The highest yielding genotype GNG 1809 had below unity regression coefficient and significant S^2d_i values suggesting their unpredictable nature under varying sowing dates. Two genotypes viz., JSC 51 and BG 2082 which recorded higher and stable seed yield.

Table 1: Regression analysis showing mean sum of squares for 12 different characters over three environments in kabuli chickpea

Source	d.f.	Days to flowering	Days to maturity	Reproductive phase	Plant height (cm)	Number of branches per plant
Genotypes	37	96.473**++##	15.187**	57.246**++##	31.027**++##	1.112**++##
Environments	2	197.188**++##	1881.850**++##	1859.390**++##	256.491**++##	2.518**++##
Genotype X Environment	74	28.087**	12.946**	18.969**	7.664**	0.244**
Environment+ (Genotype X Environment)	76	32.537**	62.128**##	67.402**##	14.212**	0.304**
Environment (Linear)	1	394.375**##	3763.700**##	3718.780**##	512.983**##	5.036**##
Genotype X Environment Linear	37	24.646**	14.697**	18.644**	4.988**	0.285**
Pooled Deviation	38	30.697**	10.901**	18.787**	10.067**	0.198**
Pooled error	222	4.442	5.572	57.246	2.163	0.053
Genotypes	37	40.352**#	89.302**++##	75.061**++##	5.164**	132.825**
Environments	2	104.411**#	1946.034**++##	212.274**++##	139.690**++##	250.452**
Genotype X Environment	74	39.160**#	45.745**	4.989**	5.746**	95.173**
Environment+ (Genotype X Environment)	76	40.877**##	95.752**##	10.443**##	9.271**##	99.259**
Environment (Linear)	1	208.821**##	3892.068**##	424.547**##	279.379**##	500.905**#
Genotype X Environment Linear	37	54.953**##	49.572**	5.061**	7.462**#	90.539**
Pooled Deviation	38	22.752**	40.815**	4.787**	3.923**	97.181**
Pooled error	222	2.975	2.997	0.926	0.559	9.095

+, ++ Significant at 5 and 1 per cent levels, respectively when tested against G x E

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

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

Table 2: Mean over the environments ($\bar{x}$), regression coefficient (b_i) and deviation from regression (S^2d_i) for seed yield per plant (g) in chickpea

S. N.	Genotypes	$\bar{x}$	b_i	S^2d_i
1	KAK 2	12.47	0.27	-0.03
2	JGK1	13.72	1.13	8.82**
3	BGD 128	11.99	0.01	-0.56
4	GNG 1808	13.44	0.10	-0.48
5	CSJK 1	10.28	0.52	1.46
6	BG 2084	12.84	0.49	1.18
7	NDGK 902	12.94	0.40	0.64
8	HK 4161	11.12	0.59	1.98*
9	IPCK 25	11.12	0.12	-0.44
10	PG 9926	11.55	1.04	7.44**

11	BGM 564	9.66	0.13	-0.43
12	HK 04-178	12.19	0.41	0.69
13	IPCK 26	10.56	0.22	-0.20
14	GNG 1809	12.54	1.09	8.19**
15	CSJK 24	8.33	0.90	5.44**
16	JSC 51	13.69	0.16	-0.37
17	WCGK 2000-16	12.69	1.42	14.30**
18	BG 2082	12.49	0.15	-0.39
19	GLK 25184	10.01	0.31	0.16
20	BG 2083	10.30	0.86	4.94**
21	ICCV 3407	12.24	0.75	3.52**
22	ICCV 4305	13.69	0.70	3.03*
23	ICCV 6301	11.82	0.11	-0.46
24	ICCV 6302	11.35	0.24	-0.12
25	ICCV 6306	9.53	0.04	-0.55
26	ICCV 7301	10.28	0.58	1.93*
27	ICCV 7302	11.28	0.59	2.02*
28	ICCV 7303	9.90	0.58	1.86*
29	ICCV 7304	11.09	0.65	2.55*
30	ICCV 7305	10.85	0.56	1.79*
31	ICCV 7306	11.50	0.43	0.78
32	ICCV 7307	11.31	0.34	0.32
33	ICCV 7308	11.61	1.51	16.20**
34	ICCV 7309	12.11	1.64	19.28**
35	ICCV 7310	12.62	0.18	-0.33
36	ICCV 7311	13.34	0.68	2.84*
37	ICCV 7312	11.27	0.61	2.14*
38	ICCV 2	9.95	1.62	18.77**
Mean		11.57	-	
S.Em. ±		1.40		

*, ** Significant at 5 and 1 per cent levels, respectively

Conclusion

It seems that the stability of different characters varies in a compensating manner in imparting yield stability in the diverse genotypes, which constituted the material of this study. Therefore, it can be inferred that different yield contributing characters of the genotypes vary in compensating manner to impart them yield stability. Genotypes KAK 2, BG 2084, NDGK 902, HK 04-178, JSC 51, BG 2082, ICCV 6301 and ICCV 7310 are considered to be more desirable ones, as they showed wider adaptation over three dates of sowing.

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