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Detection of GxE Interaction using Regression and Cross Over approach in the Germplasm of Cowpea [*Vigna unguiculata* (L.)] in the Hot -arid Climate of Rajasthan, India

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Thirty two accessions of cowpea along with checks were evaluated in six seasons *i.e. Summer* and *Kharif* of the year 2012, 2013 and 2014 for eight quantitative traits and data were subjected to regression analysis and also the analysis to detect the presence of crossover and non-crossover interactions. Four accessions IC 52110, IC 219594, IC 39897 and IC 202891 were identified to be promising using regression analysis, whereas six accessions IC 39897, IC 202891, IC 20645, IC 202707, IC 202848, and IC 39947 against standard check GC 3 were identified as potential ones by using crossover and non-crossover interactions concept. Of these accessions IC 39897 has been identified as high yielding accessions having specific adaptability and responsiveness to specific environment both by regression analysis and crossover and non-crossover interactions concept.

Introduction

Cowpea (*Vigna unguiculata* (L.)) is an important crop of *kharif* season in India. It a dual purpose crop- its pods are used as vegetable, grains are used as pulse and also it's a very important fodder crop for feeding animals. To enhance production and productivity of cowpea it is important to develop a variety that perform consistently over locations and year or a location specific or season specific (separate varieties for different seasons) varieties. It has been established fact now that genotypes interact with different environment differently. While developing a variety, genotype and environment interaction has been a major concern for the breeder. However, the ability of the genotype to demonstrate stability over a wide range of environment and its ability to yield well, relative to the productive potential of a test environment, is referred to as its consistency in performance. Any accession that demonstrated consistency of performance or slight variation across environments is said to show general adaptation. Productivity of cowpea in the hot- arid climate has always not been comparable to the normal climatic conditions. Cowpea is cultivated during *Summer* and *Kharif* seasons in India but there has not been any specific variety for the *Summer* season. However, a few varieties have been developed for the *Summer* season but they are not suitable for hot- arid climate. Thus, farmers grow the varieties of *Kharif* season in *Summer* season. To enhance productivity and production of cowpea it is advocated that breeders should look for environment specific varieties which are capable of giving high yield. This becomes more important in case of arid grain legumes to breed for their responsiveness to specific environment. Keeping in view the above, the present investigation was carried out over years during *Summer* and *Kharif* seasons in the hot- arid climate of Rajasthan to identify season specific accessions in cowpea using regression analysis (Eberhart and Russell, 1966 and Perkins and Jinks, 1968) and cross and non-crossover interactions concept (Gail and Simon, 1985). Earlier information on this aspect in cowpea germplasm is not available.

Materials and Methods

Thirty two diverse accessions collected in different years from different places in India and received from abroad also along with best performing local checks i.e. GC 3 and V-585 were evaluated in a randomized block design with three replications over three years i.e. 2012, 2013 and 2014 during *Summer* and *Kharif* seasons at Regional Station of National Bureau of Plant Genetic Resources, Jodhpur. Thus, evaluation was done broadly in six environments. In each environment plots consisted of four rows of 3 m length with row to row and plant to plant distances of 30 and 10 cm., respectively. Recommended doses of P_2O_5 @ 25 kg /ha and N_2 @ 15 kg/ha were also applied at the time of sowing. Recommended packages and practices were followed to raise good crop. The data were recorded on five randomly taken plants from middle rows of each plot in each environment on seed yield/plant (g), biological yield/plant (g), harvest index (direct values were used for statistical analysis), number of seeds/pod (average of 10 randomly taken pods from each plant), number of pods per plant, number of branches per plant, number of pod per clusters and 100-seed weight (g) and data were analyzed separately for each environment. Adjusted progeny means were used for the combined analysis and for the traits exhibiting the presence of g x e interaction. Regression analysis and analysis to detect the presence of crossover and non-crossover interactions were carried out as per Eberhart and Russell (1966), Perkins and Jinks (1968) and Gail and Simon (1985).

Results and Discussion

Analysis of variance revealed significant differences among accessions for the eight traits in all six seasons. The combined analysis revealed the presence of g x e interaction for seed yield/plant (g), biological yield/plant (g), harvest index (direct values were used for statistical analysis), number of seeds/pod (average of 10 randomly taken pods from each plant), number of pods per plant, number of branches per plant, number of pod per clusters and 100-seed weight (g). Regression analysis enables breeders to select desirable accessions with respect to the responsiveness and stability in different environments. In the studied materials the accessions IC 219594, IC 52110, IC 202891 and IC 39897 had above average performance and responsiveness with respect to seed yield/plant using regression analysis (Table 1). Among these high yielding accessions IC 219594, IC 52110 and IC 202891 can be designated as stable ones with average responsiveness. Though the accessions IC 39897 is above average yielder and also had shown above average responsiveness coupled with instability. Accession IC 39897 was highest yielder during *Kharif* 2014 followed by IC 202891 (*Kh*., 2013), IC 219594 (*Kh.*, 2013) and IC

52110 (*Kh*., 2014). Accessions IC 39897, IC 202891, IC 20645, IC 202707, IC 202848 and IC 39947 were significantly superior to the best check GC 3. The accession IC 39897 showed above average performance along with instability for seed yield per plant, number of pods per cluster, number of cluster per plant, biological yield/plant and number of branches per plant, being the best performance of this accession for these traits again during *Kharif* 2014.

The regression technique describes the response pattern of individual accession without differentiating the kind of g x e interaction involving change in magnitude of response or direction among the accessions (Baker, 1988 and Virk and Mangat (1991). Baker (1988) described a test, which was initially proposed by Gail and Simon (1985) and illustrated its application to test the kind of interaction in crop plants.

The concept of crossover and non-crossover interaction is important in decision making relating to crop improvement strategies (Baker, 1988), since the presence of crossover interaction is substantial evidence in favour of breeding for specific adaptation to certain situations. Baker (1988) further suggested that in the absence of crossover interaction there is little substance for argument in the favour of breeding for adaptation to specific environment. The accessions exhibiting crossover interaction against a standard variety can be said to have specific adaptability and can replace that standard variety in the specific environments.

The existence of prior scientific basis to explain crossover interaction is crucial (Peto, 1982). Thus, it is advantageous to define the varietal combinations among which one has to look for qualitative interaction in advance. There will be enormous multiplicity of all possible varietal pairs for detection of crossover interaction if there is no prior basis for comparison. Such a practice will greatly increase the experiment-wise error rate. In the present case the new accessions were therefore, compared with the best check GC 3 for detection of crossover interaction since the aim was to find a suitable alternative to GC 3.

The H (heterogeneity of response) and Q^+ and Q^- (for the presence of crossover interaction) against the standard variety GC 3 were estimated for all the 30 accessions for the traits exhibiting the presence of g x e interaction, *i.e.*, seed yield/plant (g), biological yield/plant (g), harvest index, number of seeds/pod, number of pods per plant, number of branches per plant, number of pod per cluster and 100-seed weight (g) and their significance was tested (Baker, 1984). The accession exhibiting either significant H or Q^+ and Q^- are given in Table 2. For seed yield/plant H was significant for the 28 accessions against GC 3. The presence of crossover interaction was observed for 24 accessions IC 20645, IC 202707, IC 206240, IC 199701, IC 20720, IC 52094, IC 202705, IC 202775, IC 219550, IC 20575, IC 39922, IC IC 202782, IC 214833, IC 39945, IC 39897, IC 202848, IC 202791, IC 39947, EC 724063, EC 202827, EC 724160, and V-585 for seed yield/plant against GC 3.

The 18 accessions *i.e.* IC 206240, IC 52094, IC 202705, IC 202791, IC 39947, IC 219550, IC 52110, IC 39922, IC 202806, IC 199701, EC 101974, IC 20720, EC 202827, IC 219594, IC 39897, IC 20645, EC 101974, and EC 724160 exhibited the presence of crossover interaction for biological yield/plant and twenty one accessions namely, IC 219550, IC 52110, IC 39922, IC 202806, EC 202827, IC 219594, EC 390277, IC 39945, IC 202707, EC 101974, IC 206240, IC 20720, IC 52094, IC 39911, IC 202775, IC 202791, IC 39947, EC 724063, EC 202827, EC 724160, exhibited the presence of crossover g x e interaction for harvest index.

Table.1 Heterogeneity (H) test of response for the comparison of mean seed yield/plant (g) against the standard variety GC 3 along with Q^+ and Q^- values for crossover interaction and adaptability parameters for the accessions

Accession	Adaptability Parameters			Against GC 3		
	$u+d_i$	$B_i \pm SE$	$\sigma^2 d_i$	H	Q^+	Q^-
EC 107151	14.66	-0.32* ± 0.25	0.29*	75.64#	94.24	31.48$
IC 202707	21.86	0.10* ± 0.01	0.41*	47.49#	61.96$	102.39
IC 202806	15.14	-0.32* ± 0.13	0.33*	53.26#	35.11	63.55$
IC 202848	20.73	0.22* ± 0.27	0.027*	125.17#	44.84	28.65$
IC 202891	17.65	0.24* ± 0.10	0.10	86.43#	23.87	62.46
IC 20645	21.34	-0.22* ± 0.23	0.68*	34.65#	33.54	41.84$
IC 219550	15.19	0.42* ± 0.23	0.31*	88.37#	72.96	29.86$
IC 219594	17.10	0.33* ± 0.04	0.06	53.65#	63.40	28.27
IC 39897	23.45	1.25* ± 0.40	0.51*	55.14#	43.88$	53.52
IC 39922	14.86	0.63* ± 0.24	0.41*	56.67#	102.69	31.97$
IC 39947	21.65	0.75* ± 0.39	0.21*	87.97#	94.16	70.85$
IC 52094	15.07	0.07 ± 0.03	0.22*	72.86#	27.37$	42.71
IC 52110	15.75	0.11* ± 0.06	0.10	63.42#	45.38	41.66
Grand Mean	**12.85 ± 2.39**					
GC 3	**15.52 ± 2.09**					

• Significant at $P < 0.05$; # H was significant against x^2 0.05 at s-l df, where s is the number of environments. $ minimum of either Q^+ or Q^- was significant against "e" value given by Gail and Simon (1985).

Table.2 Accessions exhibiting significant *, #H (heterogeneity of response), and Q^+ and Q^- against standard variety GC 3

Characters	H	Q^+ and Q^-
Seed yield/plant (g)	All accessions except IC 202848 and IC 20720	IC 39922, IC 202782, IC 214833, IC 39945, IC 39897, IC 20645, IC 202707, IC 206240, IC 199701, IC 20720, IC 52094, IC 202705, IC 202775, IC 202848, IC 219550, IC 20575 IC 202791, IC 39947, EC 724063, EC 202827, EC 724160, and V-585 (23 accessions).
Biological yield/ plant (g)	All accessions except EC 390277, IC 202782 and IC 214833	IC 206240, IC 52094, IC 202705, IC 202791, IC 39947, IC 219550, IC 52110, IC 39922, IC 202806, IC 199701, EC 101974, IC 20720, EC 202827, IC 219594, IC 39897, IC 20645, EC 101974, and EC 724160 (18 accessions).
Harvest index	All accessions except IC 20575 IC 20645 IC 202891, IC 202848 IC 199701 EC 101974 IC 202705	IC 219550 EC 390277, IC 39945, IC 202707, EC 101974, IC 206240, IC 20720, IC 39922, IC 52094, IC 202775, IC 202791, IC 52110, IC 202806, EC 202827, IC 219594, IC 39911, IC 39947, EC 724063, EC 202827 and EC 724160 (21 accessions).

Number of seeds/pod	All accessions except IC 20575, IC 202891, EC 202827, IC 202891, IC 199701, IC 52094 IC 202848, IC 202791	IC 52110, IC 39922, IC 206240, EC 101974, IC 20720, IC 202705, IC 202775, IC 39947, EC 724063, EC 202827, EC 724160, IC 202806, IC 202782, IC 214833, IC 20645, IC 202707 (16 accessions).
No. pods /plant	All accessions except IC 219550 IC 202806 IC 202848	IC 20575, IC 39922, IC 202891, IC 202782, EC 202827, IC 214833, IC 39945, IC 20645, IC 202707, IC 206240, IC 199701, EC 101974, IC 20720, IC 52094, IC 202705, IC 202775, EC 107151, IC 202791, IC 424117, IC 39947, EC 724063 and EC 202827 (22 accessions).
No. of branches/ plant	All accessions except IC 39922, IC 219594, IC 206240, IC 202705	IC 20575, IC 52110, IC 202782, IC 39945, IC 20645, IC 202707, EC 101974, IC 199701, EC 101974, IC 20720, IC 202775, IC 202848, EC 107151, IC 202791, IC 39947, EC 724063, EC 202827, EC 72416 (18 accessions).
No. of pods/ cluster	All accessions except IC 20575, EC 202827, IC 20720, EC 101974, IC 39947.	IC 219550, EC 390277, IC 52110, IC 202806, IC 202782, IC 219594, IC 214833, IC 39945, IC 39897, IC 20645, IC 724117, IC 101974, IC 199701, IC 39922, IC 52094, IC 202705, IC 202848, IC 202791, EC 724063 and EC 724160 (21 accessions).
100-seed weight (g)	All accessions except IC 206240 IC 39945	IC 202806, IC 219594, IC 20645, IC 202891, IC 199701, IC 39922, IC 52094, IC 214833, EC 107151, IC 39911, IC 724117, IC 39947, EC 202827, IC 52110, IC 202782, EC 202827, EC 101974, IC 202705, IC 202775 and IC 20720 (20 accessions).

*H was significant against x^2 0.05 at s-l df, where s is the number of environments. # minimum of either Q^+ or Q^- was significant against "C" value given by Gail and Simmons (1985).

The 15 accessions exhibited the presence of crossover interaction for number of seeds/pod for the accessions namely; IC 52110, IC 39922, IC 202806, IC 202782, IC 214833, IC 20645, IC 202707, IC 206240, EC 101974, IC 20720, IC 202705, IC 202775, IC 39947, EC 724063, EC 202827, EC 724160. The presence of cross over interaction showed by the accessions IC 20575, IC 39922, IC 202891, IC 202782, EC 202827, IC 214833, IC 39945, IC 20645, IC 202707, IC 206240, IC 199701, EC 101974, IC 20720, IC 52094, IC 424117, IC 202705, IC 202775, EC 107151, IC 202791, IC 39947, EC 724063 and EC 202827 for number of pods per plant. The 18 accessions had the presence of cross over interaction for number of branches per plant were IC 20575, IC 52110, IC 202782, IC 39945, IC 20645, IC 202707, EC 101974, IC 199701, EC 101974, IC 20720, IC 202775, IC 202848, EC 107151, IC 202791, IC 39947, EC 724063, EC 202827, EC 72416.

The 21 accessions namely; IC 219550, EC 390277, IC 52110, IC 202891, IC 202806, IC 202782, IC 219594, IC 214833, IC 39945, IC 724117, IC 39897, IC 20645, IC 101974, IC 199701, IC 39922, IC 52094, IC 202705, IC 202848, IC 202791, EC 724063 and EC 724160, expressed the presence of cross over interaction for number of pods per cluster. The 20 accessions i. e. IC 202806, IC 219594, IC 20645, IC 202891, IC 199701, IC 39922, IC 52094, IC 214833, EC 107151, IC 39911, IC 724117, IC 39947, EC 202827, IC

52110, IC 202782, EC 202827, EC 101974, IC 202705, IC 202775 and IC 20720 showed the presence of cross over interaction for test weight. However, most of the accessions expressed the presence of crossover interaction but all accessions failed to exhibit crossover interaction for all traits against GC 3 thus, presence or absence of crossover interaction was accession specific and trait specific (Rathore and Gupta 1995). The accession IC 219550 and IC 39897, in *Kharif* 2014; IC 202891, IC 20645 and IC 202848, had significantly higher seed yield/plant than check GC 3 during *kharif* 2014. The conclusion drawn from regression analysis and crossover and non-crossover interactions concept about identifying accessions having specific adaptability differs considerably. The accessions IC 219594, IC 52110, IC 202891, and IC 39897 identified as potential yielder having specific adaptability on the basis of regression analysis failed to exhibit significant min (Q^+ or Q^-) against standard variety GC 3 except and IC 39897 which had significant min (Q^+, Q^-) against GC 3. On the other hand the accessions IC 39897, IC 202891, IC 20645, IC 202707, IC 202848, and IC 39947 were identified as potential yielders having specific adaptability on the basis of crossover and non-crossover interaction concept, failed to exhibit stable above average performance and responsiveness for seed yield/plant except IC 39897.

A mention may be made of the accession IC 39897 that had been identified as a high yielding one having specific adaptability both by using regression analysis and crossover and non-crossover interaction concepts. This accession gave significantly more mean seed yield/plant than the standard variety GC 3. Thus, accession and IC 39897 had specific adaptation rather than possessing general adaptation (Sharma, 1995).

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