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GRAIN YIELD STABILITY IN CHICKPEA (*CICER ARIETINUM* L.) ACROSS ENVI RONMENTS

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Abstract

Genotype × environment interaction (G x E) is a major constraint to identify single superior genotype for a number of variable environments. In order to quantify G × E interaction effect on grain yield in chickpea, 16 chickpea genotypes were studied for grain yield at 6 locations for two years using randomized complete block design. Combined analysis of variance showed significant effects of locations, genotypes, years and their interactions on grain yield. The genotypic effects contributed 45.60% and G × E interaction contributed 54.40% to the total sum of squares. The genotypes and environments, each, were divided into four groups on the basis of similarity in their response. None of the genotypic group performed consistently across the environmental groups. The parametric approach and stability parameters indicated that genotypes; G1 (BRC-1), G8 (BRC220) and G9 (BRC-224) were relatively stable in different environments. The results of bi-plot analysis, however, indicated that BRC-4, BRC-62 and BRC-231 were more stable for grain yield as they had lesser interaction with environments as compared to other genotypes.

Introduction

Chickpea (*Cicer arietinum* L.) is an important component of rain-fed agriculture system in Pakistan, though cultivated as irrigated crop as well. Annual production of this legume is low and unstable despite stability in the area under cultivation (Anon., 2009). The fluctuation in chickpea production may be attributed to environmental changes and use of varieties that are not adapted to wide range of diversified environments. Genotypes are considered to be more adapted or stable if they show low degree of fluctuation in yielding ability under different environments. Chickpea production in Pakistan can be improved and stabilized by two approaches. The first one is stratification of chickpea growing areas followed by development of suitable cultivars for target regions and the second one is development of cultivars with wide adaptability for cultivation in diversified environments. The climatic factors, such as rainfall and temperature change from year to year even in the same region. Therefore, most suitable approach to attain stability in chickpea production would be development of widely adapted varieties with high yield potential.

The measured grain yield of a cultivar in an environment is obtained due to effect of genotype (G), environment (E) and G × E interaction (Yan & Kang 2003). Environment explains dominant portion of grain yield, however, it is G × E interaction that is relevant to cultivar evaluation (Yan, 2002). The progress of a breeding program is therefore, limited due to G × E interaction specially where genotypes are selected in one environment and used in other (Kearsey & Poony, 1998; Giauffret *et al*., 2000; Farshadfar & Sutka 2003). Consequently the stability in performance of genotypes has been an important research study in all the crops for varietal development. The effect of G × E interaction on grain yield has been reported in Wheat, Chickpea, Maize, Sorghum and other crops by different workers (Arshad *et al.*, 2003; Masood *et al.*, 2006; Dehghania *et al.*, 2006; Farshadfar & Sutka 2006, Dehghania *et al*., 2010, Mohammad, 2009, Zalih *et al*., 2011; Heinrich *et al*., 1982, Ali *et al*., 2005 and Chauhan *et al*., 1998) using different approaches for the identification of stable cultivars. Bakhsh *et al.*, (1995) and Arshad *et al.*, (2003) identified relatively stable genotypes of chickpea following Eberhart and Russell's (1966) model of stability.

It is difficult to determine the pattern of genotypic response across environment by Eberhart and Russel's model. The bi-plot technique provides powerful solution to this problem. The graphical display of two way data allows visualization of inter-relationship among environments, genotypes and interaction between genotypes and environments (Gauch, 1988; Zobel *et al*., 1988; Yan *et al*., 2000; Farshadfar & Sutka, 2006 and Dehghania *et al*., 2006). Present study was undertaken for estimation of the impact of genotypes environment interaction on grain yield of chickpea and to identify relatively stable genotypes across environments by conducting multi-environment trials (MET). The relationship between genotypes on the basis of similar response to environments and between environments on the basis of similarity for effect on genotypes was another objective of this study.

Materials and Methods

The experimental material of this study consisted 16 advanced lines (Genotypes) of chickpea developed at Regional Agricultural Research Institute (RARI) Bahawalpur, Punjab, Pakistan. These genotypes were evaluated for grain yield at six locations for two years. The trials were conducted in the districts of Bahawalpur, Dera Ghazi Khan, Khaniwal, Vehari and Bhakker. These districts represent traditional and non-traditional area of chickpea in Punjab. The experiment at each location was planted in randomized Complete Block Design with three replications. Each genotype was planted in four row plot of 4 meter length. Row to row and plant to plant distance was respectively maintained at 30cm and 10cm.

Seeds were sown with single row hand drill and after germination thinning was carried out to establish the required plant population. All the trials were conducted under irrigated condition where two irrigations (pre-sowing and at pod formation) were applied. The trials were kept weed free by hand weeding and one application of insecticide was given against *Heliothis armigera* at grain filling stage. At maturity, central two rows of each entry was harvested to record grain yield at each individual site. This grain yield data were converted to kilogram per hectare and statistically analyzed by analysis of variance to determine the significance of effect of environment, genotypes and all possible interactions (Steel & Torrie, 1960).

The stability parameters were computed followed by the work of Eberhart & Russel (1966), Francis & Kannenberg (1978) and Lin *et al*., (1986). Relationship between environments, between genotypes and interactions between genotypes and environments was worked out according to Sneath & Sokal (1973) and Byth *et al*., (1976).

Results

Analysis of variance presented in Table 1 revealed significant effect of locations, genotypes and genotypes × location (environment) interaction on grain yield. The interaction between locations × varieties and year x location also had significant effect on grain yield. The significant interaction of genotypes with environment warrants further computation of stability parameters. Genotypic means across locations, location means across genotypes along with coefficient of variability (CV %), coefficient of regression (bi values) and deviation from regression (S^2d) are presented in Table 2. The location's mean yield varied from 1038 to 2047 kg per hectare. Maximum mean grain yield was obtained from Khanpur and minimum from Bhakkar. Genotypic means across the locations indicated that maximum mean grain yield across all the six locations in two years were obtained from BRC-61 and minimum from genotype BRC-234.

Table 1. Genotypic means, location means and stability parameters in 16 genotypes of chickpea.

Genotypes	E1	E2	E3	E4	E5	E6	Means	ECO.	SD	CV%	Bi	S^2d	RI
G1 (BRC-1)	2118	1996	1873	1898	1571	1160	1769	61222	319	18.30	0.89	13161	0.91
G2 (BRC-4)	2170	1888	1598	2006	1482	1023	1694	114978	380	22.43	1.03	28555	0.87
G3 (BRC-61)	2938	2150	2543	2361	2423	1162	2263	628221	547	24.16	1.33	138325	0.69
G4 (BRC-62)	1922	1885	1703	2173	1582	695	1660	158094	469	28.27	1.32	20950	0.94
G5 (BRC-64)	2068	2244	1890	2136	1736	1006	1847	36378	411	22.24	1.19	2600	0.99
G6 (BRC-69)	2055	2266	1885	2020	1906	968	1850	58624	413	22.35	1.19	8580	0.97
G7 (BRC-213)	2038	2367	2271	2292	1964	1509	2074	133307	290	13.99	0.76	23486	0.81
G8 (BRC-220)	1846	2368	1996	2198	1938	1522	1978	216215	267	13.49	0.65	32407	0.70
G9 (BRC-224)	1979	2181	1786	2030	1869	1584	1903	213152	189	9.91	0.50	9255	0.83
G10 (BRC-225)	1690	2213	1909	2106	1770	1201	1815	167016	328	18.09	0.84	37256	0.77
G11 (BRC-231)	1823	2132	1598	1750	1590	765	1610	77730	419	26.02	1.19	12982	0.95
G12 (BRC-233)	2153	1957	1410	1749	1501	907	1613	151248	404	25.07	1.09	36441	0.85
G13 (BRC-234)	1459	1702	1515	1737	1576	597	1481	59566	405	27.33	1.15	10671	0.96
G14 (BRC-235)	1927	1817	1377	1850	1354	627	1492	107114	448	30.01	1.28	13218	0.96
G15 (BRC-236)	1904	1898	1456	1500	1347	604	1485	95560	372	25.05	1.02	23813	0.89
G16 (Bittle-98)	1534	1689	1594	1674	1555	1084	1522	160044	204	13.39	0.56	6367	0.90
Location. Mean	1995	2047	1775	1967	1698	1038	1753	-	-	-	-	-	-

Locations: E1=Bahawalpur, E2= Khanpur, E3 = D.G.Khan, E4=Khaniwal, E5 =Vehari, E6= Bhakkar

Table 2. Analysis of variance for grain yield across the locations.

S.O.V	df	Sum of squares	Mean squares	F-value
Locations	5	67694122.14	13538824.43	194.18
Replications (L)	12	1491470.10	124289.18	1.78
Years	1	979935.00	979935.00	14.05
Location × year	5	9140201.12	1828140.22	26.22
Genotypes	15	27995643.14	1866376.21	26.77
Location × Varieties	75	14630788.69	195077.18	2.79
Year × genotypes	15	11316916.83	754461.12	10.82
Genotype × year × location	75	15730917.05	209745.56	3.01
Error	372	25937059.23	69723.28	-
Total	575	175917553.31	-	-
CV%			**15.06**	

The relative ranking of genotypes at all the six locations was different and CV % age of varieties ranged from 9.91 to 30.01%. Similarly, regression co-efficient and deviation from regression of various genotypes were at a range of 0.50 to 1.33 and 2600 to 138325 respectively. Two way analysis of variance indicated that 45.60% sum of square was due to genotypes and 54.40% was contributed by G × E. The dandrogram presented in Figs. 1&2, clustered all genotypes into 4 groups; similarly environments were also divided into 4 groups on the basis of relatedness. The Bi-plot analysis revealed minimum angle between three environments vectors E3, E4 and E5 and relatively small angle between E2 vector and that of E6 was also observed. The largest angle was recorded between Vector of E1 and that of E6 environments. The genotype G1 was just at the origin of biplot whereas G4, G2 and G11 were not very far from the origin. Rests of the genotypes were at considerably large distance from the origin. G3 and G7 were very close to E1 and E7 vectors respectively (Table 3).

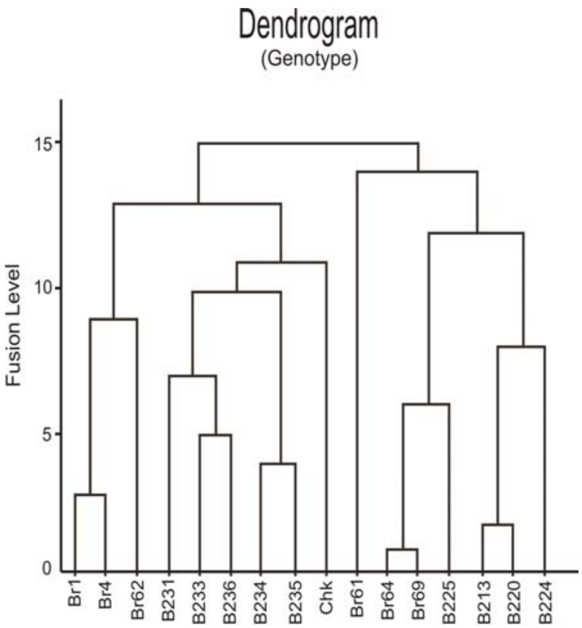


Fig. 1. Dandrogram showing clustering of genotypes based on fusion level.

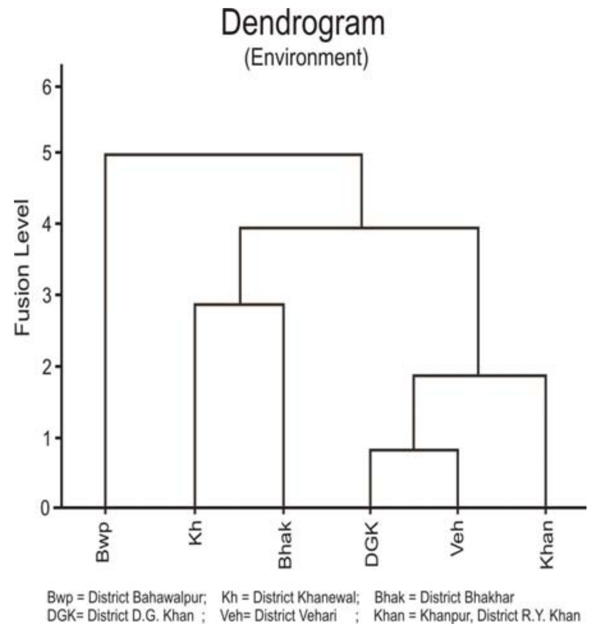


Fig. 2. Dandrogram showing clustering of different locations.

Table 3. Two-way analysis of variance for grain yield in chickpea.

S.O.V	df	Sum of squares	Mean squares	% Age
Genotypes (G)	15	41.044	2.736	45.60
Environments (E)	5	0.000	0.000	0.00
G × E Interaction	75	48.956	0.653	54.40
Total sum of squares	95	90.00	0.947	-

Discussion

The efficiency of a breeding program aimed at yield improvement is impaired due to genotype × environment interaction which complicates the process of crop variety development especially when varieties are selected in one environment and used in other (Kearsey & Pooni, 1998; Giauffret *et al*., 2000 and Farshadfar & Sutka, 2003). When relative performance of varieties differs over a series of environments it becomes difficult to decide about the superior variety. High yielding genotypes that interact less with environments are most suitable under such situation. The identification of such genotypes requires multi-environment testing. In the present study, the multi-location testing of 16 chickpea genotypes for two years at 6 locations showed that relative ranking of genotypes and their grain yield was highly influenced by change in environment indicating the vulnerability of these genotypes to environmental changes. The location and years also had significant effect on grain yield. Three stability parameters, mean grain yield, regression coefficients (bi values) and deviation form regression as suggested by Eberhart & Russel (1966) indicated three genotypes (BRC-213, BRC-220 and BRC-224) to be relatively stable as they had minimum regression co-efficient, mean yield greater than overall mean and relatively low deviation from regression. Bakhsh *et al*., (2006), Arshad *et al*., (2003) and Bakhsh *et al*., (1995) used the same parameters to identify stable genotypes of chickpea in their studies.

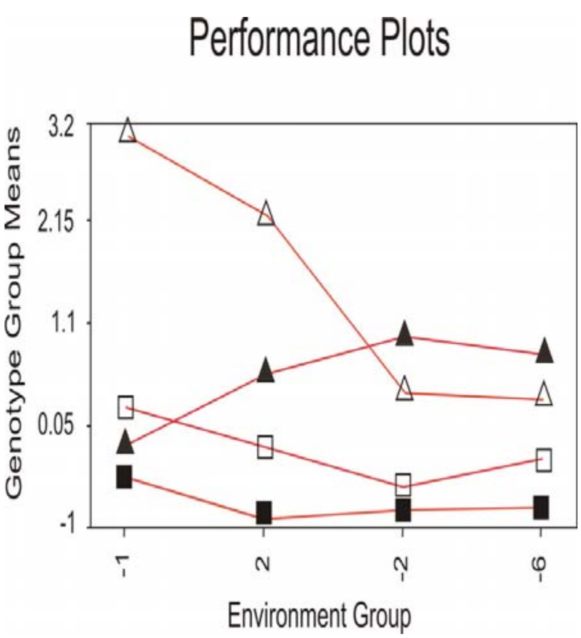
The co-efficient of variability (CV %age) revealed the same three genotypes to be stable. However, the CV determines stability by measuring variation in genotypic performance at different environments. This does not compare the other competing genotypes. The multivariate method of cluster analysis (Sneath & Sokal, 1973) grouped all the 16 genotypes in four groups with similar response pattern of yield in different environments (Fig. 1).

The grouping of environments (over all genotypes) with similar response pattern in yield (Byth *et al*., 1976) divided the environments into four groups (Fig. 2). Two major contributors accounted for overall variability in genotype-environment interaction data. Genotypes accounted for 45.60% and genotypes x environment interactions contribution was 54.40% (Table 2). The performance of genotypic groups in various environmental groups showed that none of the genotypic group performed consistently well over all environment group positions (Fig. 3). The individual genotype BRC-61 which was not placed in any group performed well only at two environment group positions. The genotype group 1 consisting of 8 genotypes showed high instability in performance across the environment groups. The individual genotype Bittle-98 (a check line) and genotypes group 2 showed stability in performance, though their performance was not outstanding. Genotypes from group-2 may be recommended for wider cultivation. When these results were compared with that obtained using parametric approach the three genotypes that were relatively stable as per criteria given by Eberhart & Russel (1966) were included in group-2 of genotypes that also appeared to be relatively more stable.

The co-efficient of variability also revealed genotypes of group-2 to be relatively stable. Therefore, simultaneous consideration of all stability parameters discussed so far indicated BRC-61 to be the best genotype for better environments and three other genotypes BRC-13, BRC-220 and BRC-224 to be relatively more stable, hence these are recommended for wider cultivation. The earlier studies reported by Mishra and Khan (2001), Masood *et al*., (2003), Ali *et al*., (2005), Dehghania *et al*., (2006), Farshadfar & Sutka (2006) and Masood *et al*., (2006) also revealed that none of the crop genotypes were ideally stable across the locations. However, chickpea genotypes with relatively better stability were identified by Arshad *et al*., (2003) and Bakhsh *et al*., (1995). They recommended genotypes for high yielding environments on the basis of high regression co-efficient and high means.

The advantage of biplot analysis is that it shows relationship of various genotypes with various environments and relationship between genotypes themselves and between various environments simultaneously. The bi-plot (Fig. 4) based on principal component-1 and principal component-2 showed G1 (BRC-1) a genotype with good average yield in all environments and no interaction with environment. The other genotypes G2 (BRC-4), G4 (BRC-62) and G11 (BRC-231) also expressed less interaction with environment as compared to rest of the genotypes. These genotypes also relatively more stable as compared to other genotypes, except G1. According to the biplot analysis G7 (BRC-312) and G5 (BRC-64) were best varieties for environment E6 and E5 respectively. However, out come of biplot analysis did not support the results obtained with the help of other stability parameters. Such differences have also been reported by Farshadfar & Sutka (2006) (Tables 4-5).

The bi plot (Fig. 4) also revealed 4 environmental groups on the basis of similarity. The three environments were very similar to each other owing to narrow angles between their vectors. Similarly, E2 and E6 were not much different from each other. On the other hand G1 appeared to be relatively suitable for all environments whereas G8, G9 and G7 were suitable for Environment 6.



Individual-1 = △, Individual-2 = □ Group-1= ▲ Group2 = ■

Fig. 3. Performance plot of genotype groups means in various environment groups.

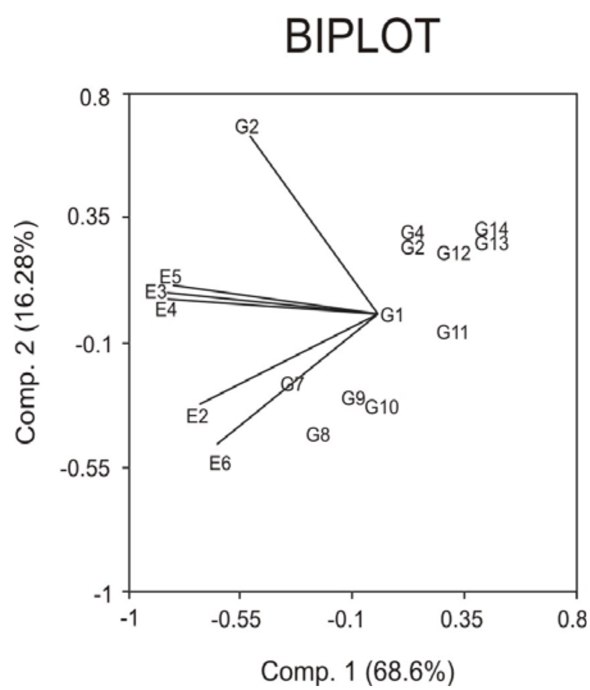


Fig. 4. Biplot analysis of Genotype × Environment interaction.

Table 4. The group members at the specified group level for genotypes.

Group	No.	Group members				
Group-1	8	BRC1	BRC4	BRC 62	BRC231	BRC233
		BRC236	BRC234		BRC235	
Group-2	6	BRC64	BRC225	BRC69	BRC224	BRC213
				BRC220		
Indiv-1	1			Check (Bittle-98)		
Indiv-2	1	BRC61				

Table 5. The group members at the specified group level for environments.

Group	No.	Group embers	
Indiv-1	1	Bahawalpur	
Indiv-2	1	Khanpur	
Group-1	2	Dera Ghazi Khan	Vehari
Group-2	2	Khanewal	Bhakkar

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