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GRAIN YIELD STABILITY OF NEWLY EVOLVED DESI CHICKPEA STRAINS UNDER RAINFED CONDITIONS

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ABSTARCT

Chickpea production in Pakistan is largely dependent upon rainfall in "Thal" region of Punjab province comprising sand dunes and marginal lands, being the major area of its cultivation, where drought affects are severe on plant growth. The current study was conducted to assess grain yield stability of new chickpea genotypes under rainfed conditions across seven environments. All the experiments were laid out in a randomized complete block (RCB) design with three replications. Pooled analysis of variance revealed significant distinctions among genotypes and environments where the experiments were conducted. Significant linear and non-linear components of G×E interactions further indicated the presence of predictable and un-predictable elements. Various stability procedures suggested that genotypes D-10008 and D-10002 possessing above average grain yield (1333 kg ha^{-1} and 1280 kg ha^{-1}) coupled with reasonable estimates of regression coefficients (1.04 and 1.02), standard deviations (0.061 and 0.063), ecovalence (88.5 and 89.3), coefficient of determination (98.3% and 98.2%), and coefficient of variation (58.0% and 59.2%) were consistent in grain yield across different environments. Other genotypes like Punjab-2008, D-10039, D-10016 and Bhakkar-2011 also yielded greater than average, however, exhibited specific adaptations to particular environments therefore could be recommended for cultivation in specific regions for improving chickpea production in Pakistan.

Key words: Chickpea, stability, grain yield, strains, rainfed.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most important grain legume of the world that is rich in crude protein (21.7-23.4%), carbohydrates (41.1-47.4%), minerals (calcium, iron, magnesium, phosphorus, potassium, zinc), vitamins (B_1, B_2, B_3, B_5, B_6, B_9, C, E, K) and various other essential nutrients (El-Adawy, 2002). Two major chickpea types i.e. *desi* have angular brown or black microsperma with rough coat while *kabuli* have round white or creamy macrosperma with smooth coat (Naghavi and Jahansouz, 2005). It is cultivated in more than 54 countries across arid and semi-arid environments with major production share from India, Australia, Turkey, Myanmar and Ethiopia. Despite ranking second in chickpea acreage, average productivity of 276 kg ha^{-1} of Pakistan is far below than world's average of 941 kg ha^{-1} (FAO STAT, 2012). This yield gap is due to cultivation of inconsistent cultivars vulnerable to various biotic and abiotic stresses (Shah *et al*. 2005). Drought is the leading stress among the abiotic factors responsible for low yield in Pakistan where 90% of the crop is being grown on rainfed and marginal lands with major portion (>80 %) on sand dunes of Thal zone of Punjab province, Pakistan. Years receiving rainfall during cropping season yield satisfactory production and *vice versa* (Khan *et al*. 1991; Shafiq *et al*. 2011). Sustainability in chickpea production in this part of the world can be achieved through the development of drought tolerant, high yielding stable genotypes possessing wider agro-ecological adaptability. The variability in environment has long been recognized as an important factor influencing the performance of genotypes (Singh and Bejiga, 1990). Variable performance of a genotype over different environments is referred as genotype × environment (G×E) interaction. It arises when two or more genotypes are compared and their relative performances are found to be variable across the diverse environments. Performance of one genotype may either be highest at one location / environment yet poor at others, leading to biasness in the estimates of gene effects due to genotype × environment interaction.

Various biometrical techniques have been proposed to estimate the magnitude of genotype × environment interaction, stability and adaptability of the cultivars across the environments. Pooled analysis of variance is the primary step in recognizing the prevalence of genotype × environment interactions (GEI) from multi-locational trials. If GEI is found to be significant then one or more statistical stability procedures can be used to assess the constancy of the genotypes. These include Wricke's ecovalence (1962), Finlay and Wilkinson (1963) regression, Eberhart and Russell (1966) stability model, Pinthus (1973) genotypic value and Crossa *et al*. (1990) multi-location statistical analysis. Stability research is an effective tool for plant breeders in forecasting response of various genotypes over changing environments. As yield stability is genetically controlled therefore selection is effective for this trait which has been demonstrated by many researchers in different crops (Farshadfar *et al*. 2012; Adebisi, 2010; Riaz *et al*. 2013). Stability analysis facilitates in understanding the adaptability of crop varieties over a wide range of environmental conditions and in the classification of adaptable genotypes. The use of adaptable genotypes for general cultivation helps in achieving stabilization in crop production over locations and years. Use of stable genotypes in hybridization schemes will lead to the development of phenotypically stable with maximum yield potential cultivars of chickpea species.

The present experiments were conducted with the objective of assessing stability in grain yield of newly developed chickpea genotypes under natural field conditions without irrigation application. Information obtained from this investigation will help in evaluating the potential of newly evolved promising genotypes of desi chickpea for commercial cultivation and utilization as parents in crossing systems for the development of desirable recombinants in chickpea improvement programs.

MATERIALS AND METHODS

Experimental sites and treatments: The adaptation experiments for yield stability were conducted at seven locations (environments) of Punjab, Pakistan during rabi season of 2013-14 (Table 1). Plant material comprised twelve newly evolved chickpea desi genotypes (D-10001, D-10002, D-10004, D-10008, D-10012, D-10016, D-10018, D-10023, D-10026, D-10030, D-10036 and D-10039) and two commercially cultivated approved varieties (Punjab-2008 and Bhakkar-2011). These experimental advance lines were developed through hybridization followed by bulk and pedigree method of plant selection. Promising looking uniform genotypes possessing desirable features were selected from F_6 generation and were evaluated for three consecutive years in station yield trials like yield nursery, preliminary yield trials and advanced yield trials respectively prior to current adaptation yield trials.

Layout design and production practices: Layout at all the experimental sites was randomized complete block design (RCBD) with three replications. A plot size of 4 × 1.2 m^2 was measured for each entry by maintaining plants and rows spacing of 15 and 30 cm, respectively. Nitrogen and phosphorus fertilizers were applied pre-sowing during land preparations in the ratio of 23:9 kg ha^{-1} respectively while other cultural production practices i.e. weeding and hoeing were carried out according to the crop requirement. To avoid any economic yield loss, suitable insecticides or pesticides were sprayed at pod formation stage to protect the crop from pod borer. However, no irrigation was applied at any experimental site to assess the performance of tested genotypes under natural rainfed conditions. Crop was harvested when the plants become yellow and reached 90% physiological maturity. Grains were obtained from pods after thrashing and cleaning. Grain yield was recorded on per plot basis in grams and converted into kg ha^{-1}.

Statistical analyses: Grain yield data of the tested genotypes was subjected to analysis of variance techniques of Finlay and Wilkinson (1963), and Eberhart and Russell (1966) using Agri-Stat software package. For each entry, regression coefficient (b_i) and standard deviations (S^2d_i) were calculated as described by Eberhart and Russell (1966). Other stability measures such as ecovalence (W_i), coefficient of determination (R^2) and coefficient of variation (CV %) were computed according to Wricke's (1962), Bilbro and Ray (1976) and Francis and Kannenberg (1978), respectively. Stability and adaptability of genotypes was further assessed by using biplot analysis which was generated by plotting regression coefficients (b_i) against mean grain yield of genotypes using Microsoft Power Point.

RESULTS AND DISCUSSION

Analysis of variance: Values for mean sum of squares obtained from Finlay and Wilkinson (1963) analysis of variance technique for grain yield (Table 2) revealed statistically significant variations among genotypes, environments and their interactions. Likewise, significant differences were also obtained for genotypes, environments and G×E interaction from Eberhart and Russel (1966) pooled analysis of variance model that indicated the existence of diversity among the evaluated plant materials and in the environments where experiments were carried out (Table 3). Mean sum of squares for linear and non-linear elements of G×E interaction were highly significant suggesting the occurrence of both predictable and un-predictable elements. Linear G×E interaction revealed the existence of genetic distinctions between the entries for their regression on the environmental index. All the genotypes except D-10002, D-10004 and D-10008 contributed significantly to pooled deviation. Entries D-10012, Bhakkar-2011 and D-10018 made highest contributions to pooled deviation while D-10004, D-10008 and D-10002 were least contributor respectively suggesting their stability in the variant environments. Significant G×E interaction in the present study is in agreement to the findings reported by some earlier researchers (Arshad *et al*. 2003; Naveed *et al*. 2006a; Khan *et al*. 2008; Atta *et al*. 2009). A significant G×E interaction may either be of cross over or non-crossover nature. In crossover types, a significant change in ranks occur from one to another regime while in non-crossover types, ranks of genotypes remains constant over environments and change in magnitude of response only contributes to significance of interaction (Baker, 1988; Matus *et al*. 1997). Significant GEI in this study appeared to be of crossover type. Atta *et al*. (2009) also reported similar findings.

Yield performance and stability of genotypes: Various stability statistics measured for experimental plant materials are presented in Table 4. Mean grain yield of different genotypes ranged 1049 kg ha^{-1} to 1419 kg ha^{-1} across seven environments. Entries D-10016, Bhakkar-2011, D-10008, D-10002, D-10039 and Punjab-2008 yielded greater than average and were declared top performing genotypes with grain yields of 1419, 1373, 1333, 1280, 1274 and 1260 kg ha^{-1} respectively.

Finlay and Wilkinson (1963) suggested that regression coefficient is the only measure of stability in crop plants. Eberhart and Russel (1966), however, reported three parameters for evaluation of stability and suggested an ideal stable genotype with higher mean grain yield (m_i), regression coefficient (b_i) of one and standard deviation (S^2d_i) of zero or close to zero. Entries with regression coefficient greater than unity have below average stability and are expected to perform well under conducive environments while genotypes with regression coefficient less than unity have above average stability and are likely to perform better under adverse regimes.

In current studies, entries D-10036, D-10018, D-10023, D-10030, D-10001, D-10004, D-10012 and D-10026 performed under average and were grouped as low yielding lines. Regarding highest grain yield, genotypes D-10016, D-10039 and Punjab-2008 also have greater regression coefficients, respectively which were far from unity while moderate standard deviations suggested their cultivation suited to favorable environments. Bhakkar-2011 being the 2nd highest yielding genotype had lowest regression coefficient value and highest standard deviation indicating its fitness to unfavorable environments. Other high yielding entries D-10002 and D-10008 had regression coefficients closer to unity alongwith lowest standard deviations suggesting their adaptation to wider agro-climatic conditions. Although D-10004 had least estimate of standard deviation yet produced below average grain yield. Remaining genotypes performed poorly across environments and had varying estimates of b_i and S^2d_i therefore cannot be recommended for cultivation. Based on Eberhart and Russel's (1966) consistency model, advanced lines D-10002 and D-10008 seemed to be the most stable among the tested entries. Similar results of grain yield stability pattern in chickpea had been reported in previous studies conducted by Singh and Bejiga (1990), Bakhsk *et al*. (2006), Atta *et al*. (2009) and Shafi *et al*. (2012).

Statistical measures like ecovalence (W_i), coefficient of determination (R^2) and coefficient of variation (CV) had been extensively used in stability studies and were presented in Table 4. Wricke's (1962) proposed a procedure to determine the stable genotypes based on G×E interaction. Lowest value of W_i reveals least contribution to G×E interaction, hence, stable is the genotype. Cultivars with highest R^2 value were considered more stable as it describes the genetic contribution of an entry to grain yield (Pinthus, 1973). Further, Francis and Kannenberg (1978) proposed that low value of CV is indicative of genotypic stability. Simultaneous consideration of these three parameters indicated that two of the six top grain yielding genotypes D-10008 and D-10002 exhibited most of the stability. Both these strains occupied second and third positions regarding degree of R^2, made least contribution to G×E interaction and attained moderate estimates of CV. Remaining four high yielding genotypes D-10016, D-10039, Punjab-2008 and Bhakkar-2011 had moderate values for all these stability measures suggesting their specific agro-climatic adaptations as revealed by Eberhart and Russell stability model. Although Bhakkar-2011 had least estimates of coefficient of variation (CV) yet lowest coefficient of determination (R^2) and greater Wricke's ecovalence (W_i) values limited its scope of cultivation to particular environments.

Biplot analysis: Biplot analysis has been regarded as the powerful tool to visually discriminate the performance of the tested genotypes. Biplot association of mean grain yield with regression coefficients (Figure 1) classified the genotypes into four groups. Group III and IV represent high yielding genotypes while group I and II include low yielding genotypes. Entries D-10008 and D-10002 with above average grain yield, regression coefficients closer to unity and lower standard deviation estimates were the genotypes which responded consistently well to the changing environmental conditions. Regression coefficients for Punjab-2008, D-10039 and D-10016 are greater while that of Bhakkar-2011 is smaller than unity therefore have specific adaptations to particular environments. However D-10036, D-10023, D-10030, D-10001, D-10004, D-10018, D-10012 and D-10026 are the groups of poor grain yielding genotypes with varying estimates of regressions coefficients which represent their meager adaptation flexibility in changing environments. These results are in agreement to the findings of Naveed *et al*. (2006b), Nadagoud (2008) and Bisawas *et al*. (2014) who also categorized the genotypes into four groups. Group I and II on left side of vertical regression line consisted of low yielding genotypes with insensitive and highly sensitive to environmental responses, respectively. Group III and IV on right side of vertical regression line represent high yielding genotypes but highly sensitive and insensitive to varying environmental conditions, respectively. Genotypes in quarter I and IV interact least to the prevailing conditions and *vice versa*.

Table 1. Description of experimental sites and some meteorological data during cropping season 2013-14

Sr. No.	Experimental Sites	Altitude (meters)	Latitude / Longitude	Temperature (°C)		Total Rainfall (mm)
				Min.	Max.	
1	Pulses Research Institute (PRI), Faisalabad	184	31° 21′ 52″ N / 72° 59′ 40″ E	2.4	42.3	89.2
2	Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad	184	31° 21′ 52″ N / 72° 59′ 40″ E	2.4	42.3	89.2
3	Gram Breeding Research Sub- Station (GBRSS), Kallur Kot	187	32° 9′ 23″ N / 71° 15′ 34″ E	2.0	31.0	70.0
4	Oilseeds Research Sub-station (ORSS), Piplan	185	32° 2′ 87″ N / 71° 3′ 66″ E	3.0	33.0	119.0
5	Barani Agriculture Research Station (BARS), Fatehjang	358	33° 34′ 8″ N / 72° 38′ 16″ E	3.0	31.0	260.0
6	Barani Agricultural Research Institute (BARI), Chakwal	519	32° 33′ 0″ N / 72° 30′ 36″ E	3.0	30.0	260.0
7	Regional Agricultural Research Institute (RARI), Bahawalpur	461	29° 23′ 44″ N / 71° 41′ 1″ E	4.0	36.0	56.0

Source: Pakistan meteorological department, Islamabad

Table 2. Finlay and Wilkinson (1963) analysis of variance for grain yield of chickpea

Source of variation	Degrees of freedom	Sum of Squares $_{Mean}$
Reps. (Locations)	14	33549.2**
Genotypes	13	62286.6**
Environment	6	8162151.5**
G×E	78	79933.6**
Regression	13	3820511.0**
Reminder	65	85247.5**
Pooled Error	182	22080.5**

** = Significant at $p \leq 0.01$

Table 3. Eberhart and Russel (1966) model for chickpea grain yield across 7 environments

Source	Degrees of freedom	Sum of Squares Mean
Total	97	577499.6
Genotypes	13	62286.6**
E +(G×E)	84	657234.9**
Env. Linear	1	48972908.0**
G×E (Linear)	13	53364.3**
Pooled Deviation	70	79158.4**
D-10001	5	119841.8**
D-10002	5	13844.0^{NS}
D-10004	5	5759.0 ^{NS}
D-10008	5	12999.9 ^{NS}
D-10012	5	276682.3**
D-10016	5	33067.8**
D-10018	5	156714.5**
D-10023	5	53215.2**
D-10026	5	46524.8**
D-10030	5	50647.1**
D-10036	5	92675.3**
D-10039	5	29142.6**
Punjab-2008	5	24693.7**
Bhakkar-2011	5	192409.7**
Pooled Error	182	22080.5

NS = Non significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$

Table 4. Various stability measures and ranks for 14 chickpea genotypes across 7 environments

Entries	MGY (mi)	Rank	b_i	Rank	Sd_i^2	Rank	W_i	Rank	R^2 (%)	Rank	CV (%)	Rank
D-10001	1195	10	0.86	2	0.185	11	836.8	11	81.2	12	59.1	5
D-10002	1280	4	1.02	8	0.063	3	89.3	3	98.2	3	59.2	6
D-10004	1202	9	0.95	6	0.041	1	43.1	1	99.1	1	59.7	7
D-10008	1333	3	1.04	9	0.061	2	88.5	2	98.3	2	58.0	3
D-10012	1216	8	1.11	12	0.281	13	1779.6	14	75.6	13	77.2	14
D-10016	1419	1	1.23	14	0.097	6	441.8	9	97.0	4	64.2	10
D-10018	1163	13	1.00	7	0.212	12	980.3	12	81.8	11	69.8	12
D-10023	1168	12	0.88	3	0.123	9	397.9	8	91.0	9	57.3	2
D-10026	1235	7	1.15	13	0.115	7	393.5	7	95.2	7	70.2	13
D-10030	1188	11	0.91	4	0.12	8	351.5	6	92.0	8	58.4	4
D-10036	1049	14	0.91	5	0.163	10	617.8	10	86.1	10	68.1	11
D-10039	1274	5	1.08	11	0.091	5	208.4	5	96.5	6	62.8	9
Punjab-2008	1260	6	1.06	10	0.084	4	171.4	4	97.0	5	62.3	8
Bhakkar-2011	1373	2	0.79	1	0.235	14	1400.1	13	69.3	14	51.5	1
Average	*1240*	*8*	*1.00*	*8*	*0.134*	*8*	*557.1*	*8*	*89.9*	*8*	*62.7*	*8*

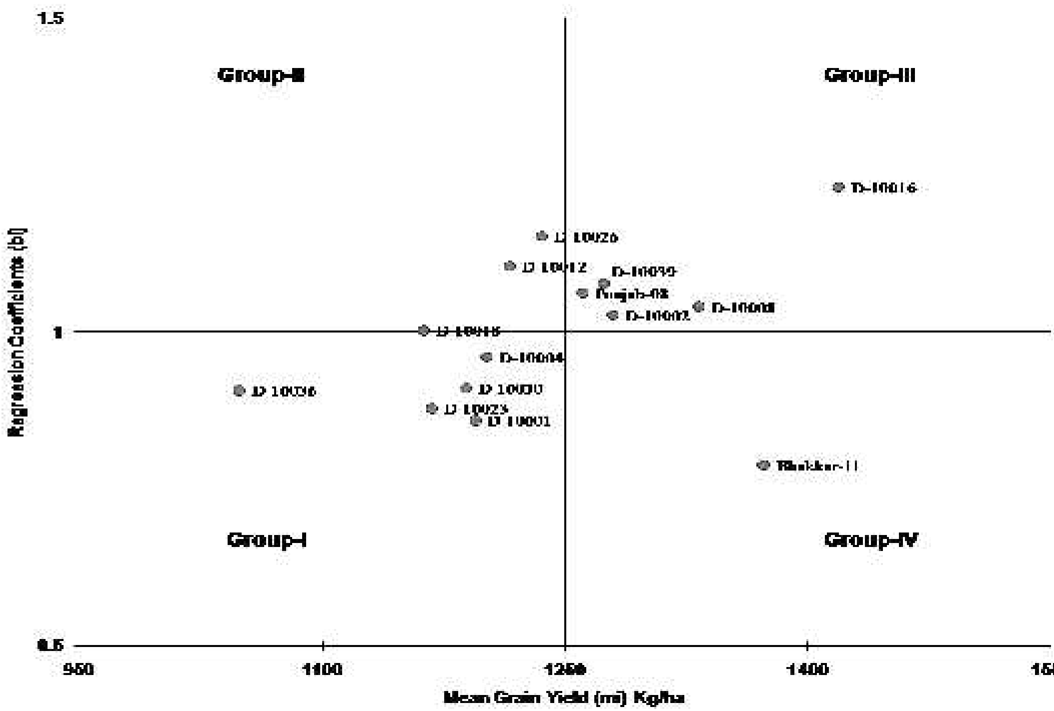

Figure 1: Biplot for chickpea mean grain yield contrived against regression coefficients

Conclusion: This study revealed that experimental plant material responded differently to varying environmental conditions implying that for achieving sustainability in chickpea production locally and globally, studies pertaining to G×E interactions should be an integral part of chickpea improvement plans. In the current study, yield stability over different agro-ecological zones suggested that new cultivars D-10008 and D-10002 might be recommended for general cultivation in chickpea growing areas of Punjab and similar environments elsewhere. Evaluation of these two strains at farmer's field under natural field conditions would further assist in realizing yield stability potential of these genotypes before approval from Punjab Seed Corporation for commercial release as varieties.

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