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Stability analysis for grain yield and its contributing characters in barley (*Hordeum vulgare* L.)

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Abstract
The present investigation carried out by the assess the phenotypic stability for grain yield and its contributing characters under three different environmental conditions using eight diverse barley parents along with their 28 F_1. The mean sum of square due to genotype and environment were found to be significant for all the characters showed differential effect of environment on genotypes. The mean sum square due to environment +(G x E) interaction was found significant for all the studies characters, G x E (linear) were also found significantly for all the character except number of spikelet's per spike and G x E (linear) showed significantly for all the character except the number of spikelet's per spike and harvest index. The genotypes RD2904 x RD2909, BH902 x DWR143 and RD2904 x DWR137 had higher grain and were suitable for variable environment conditions. These genotypes could be utilized as a donor in regular breeding programme to improve grain yield and its contributing characters in barley.

Keywords: Barley, stability, grain yield, Genotype x interaction

Introduction
Barley (*Hordeum vulgare* L. 2n =2x = 14) is the worlds' fourth most important cereal crop after wheat, maize and rice. It is a most paramount cereal crop and considered as the first cereal domesticated for use by man as food and feed (Potla *et al.*, 2013) [13]. The major use of barley grains is in the production of malt, which is used in breweries to make beer industrial alcohol, whisky, malt syrups, malted milk and vinegar. The spend malt after brewing is used as a feed. Barley is believed to have cooling effect on human system and in several regions it is preferred over wheat and other cereals particularly during summer.

Material and Methods
Crosses among the eight genotypes were made in diallel fashion excluding reciprocals, during *Rabi* season 2015-16. A number of plant were randomly selected in the parent crossed with a number of selected plants from other plants. In *Rabi 2016-07* eight genotype along with their 28 F_1's progenies were evaluated in three environments created three date of sowing 15 Nov.(normal sown), 30 Dec. (late sown) and 15 Dec. (very late sown) with three replications at Rajasthan Agricultural Research Institute, Durgapura, Jaipur row length was grown in row (4m length) plot with row to row distance of 30 cm and plant to plant distance 10cm. Stability parameters for grain yield and its contributing characters were workout as per procedure suggested by Eberhart and Russel (1966) [6].

Results and Discussion
The genotype x environment (GE) interaction is a major challenge to plant breeder. Many stability parameters for genotype grown in different environments were developed for this purpose and each has its advantages and limitations. In different method, GE interactions are used to characterize the response for genotypes to changing environment along with mean grain yield. Accordingly, genotype with a minimal variance for yield across the environments were considered stable (Kavitha, 2007, Kadi, 2010 and Mohammadi, 2012) [10, 8, 11].
To study barley genotypes with wide or specific adaptation to different environments, trials were grown at three different date of sowing. These have resulted to empirical identification of superior cultivars, some of which have been released in several countries (Basford *et al.*, 2004). The environments involve a wide range of photoperiods and temperatures which could cause large genotype (G) × environment (E) interactions (GEI), specifically in the semi-arid areas.

Large crossover-type GEI, especially among high yielding lines gives incorrect suggestions to farmers across all test environments. Quantification of GEI and comprehension its physiological bases are needed to breed effectively for superior environments (Thomason and Phillips, 2006). Most yield traits are used only to determine which cultivars give the highest average seed yield, and therefore valuable recommendation for planting by farmers. Understanding the structure and nature of GEI is important in plant breeding programs because a significant GEI can seriously impair efforts in selecting superior genotypes relative to new crop introductions and cultivar improvement programs. The detect of GEI in trials has led to the development of procedures that are generically called stability analyses. The available numerous stability statistics to breeders and to the production agronomist provide different strategies and approaches of dealing with GEI. Stability is an important concept for plant breeders interested in analysing GEI data (Ayed *et al*., 2016 and Kajla *et al.* 2020) [3, 9].

The pooled analysis of variance across the environments revealed significant differences among genotypes and environments for all the characters, indicating differential effect of environment on the genotypes. The mean sum of squares due to G x E interaction was found significant for all the characters in table 1. Similar findings were also reported by Ashraf *et al.* (2001), Sharma *et al.* (2003) [15], Arya *et al.* Kavitha (2007) [10], Bantayehu, M., (2009) [4] and Mohammadi *et al*. (2012) [11],

The mean sum of squares due to E + (G x E) was also found significantly for all the characters. Similarly, the pooled analysis of variance showed that the mean squares due to E + (G x E) interaction was partitioned into G x E (linear) and pooled deviation (nonlinear components). Mean sum of squares due to G x E (linear) component and pooled deviation (nonlinear component) were significant for all the characters which indicated that prediction across the environments was possible for all characters. Similar results were also reported by Ashraf *et al*. (2001), Swati *et al.* (2018) [16] and Kajla *et al.* (2020) [9].

Among the parents and crosses, three best stable crosses for various environments conditions were presented in Table 2. The joint consideration of mean performance of genotypes across the environments and stability parameters revealed that out of 36 genotypes, genotypes namely BH902 x DWR143, RD2904 x RD2909, RD2904 x DWR137, RD2904 x UPB1059 and RD2909 x DWR143 had higher mean than population mean, regression coefficient higher than one and S^2d_i equivalent to zero, exhibiting below average stability for the character of grain yeld. Above average stability were depicted by BH902 x RD2904, RD2909 x DWR137, HUB242 x DWR137, UPB1059 x DWR143 and DWR143 x DWR137 (mean<population mean, b_i=1 and S^2d_i=0) suggested their suitability in all type of environment. The present finding supported the results obtained by Sharma *et al.* (2003) [15] Sabhagniya (2012) [14], Singh *et al*. (2013), Baranda *et al* (2020) [5] and Kajla *et al.* (2020) [9].

Taller plants are more likely to lodge quite often. Short stature in barley is preferred. In the present study, cross combination UPB1059 x DWR143 was considered for poor environments (mean<population mean, b_i<1 and S^2d_i=0). Similar findings were also reported by Sharma *et al.* (2003) [15] Sabhagniya (2012) [14] Baranda *et al* (2020) [5], Bantayehu, M., (2009) [4] and Kajla *et al.* (2020) [9].

For flag leaf area, number of grains per spike and harvest index G x E interaction was significant. Similar findings were also reported by Sharma *et al* (2003) [15], Mohammadi *et al*. (2012 and Baranda *et al.* (2020) [11, 5].

Number of effective tillers per plant is important character from the point of view of straw and grain yield, respectively. In the current study, cross UPB1059 x DWR143 was considered for poor environments (mean>population mean, b_i<1 and S^2d_i=0). These results are also similar with the earlier findings of Jaydeep *et al*. (2006) [7] and Sabhagniya (2012) [14].

The crosses BH902 x RD2904, BH902 x RD2909, RD2904 x RD2909, RD2909 x HUB242 and UPB1059 x DWR143' RD2904, DWR143, and RD2904 x DWR137 and BH902, BH902 x DWR143, RD2904 x DWR143 and RD2909 x DWR143 were considered suitable for poor, average and rich environments repectivly for test weight. Similar finding were also reported by Sharma *et al.* (2003) [15] Sabhagniya (2012) [14] Baranda *et al* (2020) [5] and Kajla *et al.* (2020) [9].

Grain yield is a complex character and the analysis of individual yield component can lead to simplification in explaining the stability for grain yield. The joint consideration of mean performance of genotypes across the environments and stability parameters for grain yield revealed that out of 36 genotypes, cross DWR143 x DWR137 (16.05 g), was higher than population mean, regression coefficient equivalent to one and S^2d_i equivalent to zero, Hence, it was suitable for variable environment conditions; while the RD2909, DWR137, BH902 x DWR143, RD2904 x RD2909, RD2904 x DWR137, RD2904 x UPB1059 and RD2909 x DWR143 had higher than population mean (14.23 gm), regression coefficient (1.18, 1.06, 1.15, 1.24, 1.17, 1.11 and 1.1) higher than one and S^2d_i equivalent to zero, exhibiting below average stability. Above average stability were depicted by BH902 x RD2904, RD2909 x DWR137, HUB242 x DWR137& UPB1059 x DWR143, Similar results were reported by Similar results were also reported by Ayed *et al*. (2005), Kajla *et al* (2020) [9] and Baranda *et al*. (2020) [5].

Table 1: Analysis of variance for stability for grain yield and its contributing characters in Barley.

Source	df	Days to 50% flowering	Days to maturity	P Height	tillers	Flag leaf area	Peduncle length	Spike length (cm)	Number of spikelets per spike	Number of grain per spike	1000-Grains weight (g)	Harvest index (%)	Grain yield per plant
Genotypes	35	58.37**	74.68**	238.16**	7.44**	14.26**	28.7**	0.82**	1.13**	37.65**	31.61**	18.71**	4.14**
Environment	2	1563.14**	7356.83**	3827.32**	100.56**	409.48**	140.98**	11.3**	21.18**	742.91**	712.84**	935.69**	194.77**
Env. + (G x E)	72	45.73**	209.74**	125.76**	3.58**	12.4**	5.39**	0.37**	0.61**	21.93**	21.49**	27.33**	5.91**
Env. (linear)	1	3126.29**	14713.65**	7654.64**	201.12**	818.96**	281.97**	22.61**	42.35**	1485.82**	1425.69**	1871.38**	389.54**
G x E (linear)	35	3.55**	7.21*	29.79**	1.16**	1.62**	2.37**	0.08*	0.02	2.13**	2.7**	1.44	0.69*
Pooled deviations	36	1.16	3.76	9.93	0.45	0.46	0.64	0.042135	0.03	0.52	0.76	1.27	0.33
Pooled error	216	0.22	0.46	0.63	0.15	0.3	0.76	0.023	0.01	0.27	0.35	0.33	0.15

*and ** significant at 5 and 1 per cent level of significance, respectively

Table 2: Best stable crosses for different environments (Ranked on the basis of means)

Characters	Better environment	Average environment	Poor environment
Days to 50% flowering	1. RD2904 x BH959 2.DWR143 x BH959	1. BH902 x RD2909 2.RD2904 x UPB1059	1.BH902 x DWR137 2.RD2904 x RD2909 3.RD2904 x DWR143
Days to maturity	1.UPB1059 xDWR143	1. RD2904 x DWR143	1.BH902 x DWR137 2. RD2904 x RD2909 3. RD2904 x DWR137
Plant height	-	--	1.BH902 x DWR137 2.RD2904 x DWR143 3.RD2904 x DWR137
No. Of effective tillers per plant	1.BH902 x RD2904 2. BH902 x DWR143 3. BH902 x BH959	,--	1. UPB1059 x DWR143
Flag leaf area	1. BH902 x HUB242 2.BH902 x BH959 3.RD2904 x DWR143	. --	1. RD2909 x DWR137 2.HUB242 x DWR137 3. HUB242 x BH959
Peduncle Length	1.BH902 x DWR143, 2.RD2904 x HUB242 3.RD2909 x DWR143	1.RD2909 xHUB242 2.HUB242xDWR137 3.UPB1059 x BH959	1. BH902 x HUB242 2.BH902 x BH959, 3. RD2904 x DWR143
Spike Length No. of grains per spike	1.BH902 xRD2909 2.RD2904xDWR143 3.RD2909 x DWR143	1. BH902 x RD2904 2.RD2904 x DWR137 3.HUB242 x BH959	1. BH902 x UPB1059 2.BH902 DWR137 3.BH902 x BH959
Spikelet's per spike	1. RD2904 x BH959	1. RD2904 x RD2909 2. RD2904 x DWR137 3.RD2909 x DWR143	1. BH902 x DWR137
Number of Grain per Spike	1.BH902 x RD2904, 2.BH902 x DWR143, 3.BH902 x BH959	1. BH902 x UPB1059, BH902 x DWR137, RD2904 x HUB242,	1. BH902 x RD2904, BH902 x HUB242, RD2904 x RD2909
1000-seed weight	1. BH902 x DWR143 2. RD2904 x DWR143 3. RD2909 x DWR143	1.BH902 x RD2904, 2.BH902 x RD2909, 3.RD2904 x RD2909	1. RD2904 x DWR137
Harvest index	1. BH902 x HUB242 2.RD2904 x DWR137 3.RD2909 x DWR143	1. BH902 x RD2904 2.RD2904 x HUB242 3.RD2904 x HUB242	1. RD2904 x RD2909 2.RD2909 x DWR137 3.HUB242 x DWR137
Grain yield per plant	1. DWR143 xDWR137	1.BH902 x DWR143 2. RD2904 x RD2909 3. RD2904 x DWR137	1. BH902 x RD2904 2. RD2909 x DWR137 3. HUB242 x DWR137

- Better environment (Below average stability): mean >μ, bi >1 and $S_2di = 0$
- Poor environment (Above average stability): mean >μ, bi <1 and $S_2di = 0$
- Average environment (Average stability): mean > μ, bi = 1 and $S_2di = 0$

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