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Short Communication

Evaluation of grain yield and diastatic power in barley for north western plains of India

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Abstract

Information on mega environments and test sites for grain yield is scanty and even not studied for diastatic power in barley and confounding G x E invariably misleads further in yield maximization and quality improvement. Average grain yield and diastatic power over the locations were exhibited as 42.3 q/ha and 101.5^{o}L and ranged from 32.1 to 64.4 q/ha and 97.3 to 109.6^{o}L, respectively. Initial two principal components showed reasonably good amount of the interaction component and explained nearly 60% and 57 % of the variation for grain yield for diastatic power. GGE biplots revealed that no single cultivar was winning at all the locations and indicated possibilities of crossover type genotype by environment interaction. Based on AEC abscissa and ordinate scores the genotype DWRB150 and check BH902 were observed high yielding and stable, whereas the check DWRB92 showed wider adaptability for diastatic power. For grain yield the location Hisar was classified as Type 2 ideal environment with long vector and acute angle, whereas for diastatic power the environments Ludhiana and Mathura were discriminating and representative. The study initiated possibilities to review non-informative and correlated test sites based on soil, rainfall, biotic factors and previous data to eliminate in future evaluation.

Key words: Barley, mega environment, DP, G x E, GGE

Barley is an ancient coarse cereal, which is utilized for human food, livestock feed and as well as for malting and brewing purposes (Kumar et al. 2013; Kumar et al. 2014). Worldwide during 2014, Europe occupied 51.4% barley area and contributed 64.8% of grain production followed by Asia (22.3 and 13.56 %), America (9.66 and 10.86%), Africa (8.90 and 4.15%) and Australia (7.83 and 6.63%), respectively (FAOSTAT 2017; Kumar et al. 2016a). In Asia, South-Asia occupied 2.45 m ha barley acreage with 5.25 m t grain production and of which India contributed 27.46% in terms of land and 34.86% grain production. Barley is a choice either for resource poor farmer in India due to its low cultivation cost, inherent tolerance for salinity, drought or being grown over large acreage in "Contract Farming" by malting and brewing industries. Grain yield realization during multi-location evaluation is most of the time different than plant breeder's selections and field performances. This inconsistent performance is major cause of yield gap, low quality and leads breeders to devise suitable and efficient methods to judge superior and stable genotypes across the environments. Barley is highly preferred for malting and brewing and diastatic power (DP) is an important quality parameter to indicate activity of starch hydrolysing enzymes and apparent attenuation limit (AAL) in brewing. DP is measure of collective enzymatic activities of α-amylase, β-amylase, limit dextrinase and α-glucosidase required during malting and mashing. Diastatic power is an industrial trait, complex in nature and governed by polygenes, therefore influenced by the environmental effects (Arends et al. 1995; Fox et al. 2003). The unequal genotypic ranks over the environments and cross overs are inevitable and need to be studied by some stringent methodology in an easy and simplified way (Kuchanur et al. 2015).

Several models based on means, analysis of variance, linear regression, principal components etc.

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are available for stability analysis with certain merits and demerits (Flores et al. 1998; Alwala et al. 2010; Kumar et al. 2016b). The biplot graphical display concepts provided new insight and opportunity to plant breeders for graphical stability biplot models (Yan et al. 2000; Gauch et al. 2008). GGE biplot method is based on site regression linear-bilinear (multiplicative) graphical method is best suited to identify mega environments, winning cultivars and to select discriminating and representative test environments (Yan et al. 2007). GGE biplots uses singular value decomposition (SVD) of environment centred data with unique feature of mega environment biplot creation (Gauch 2006; Yan et al. 2000).The information regarding test environments and mega environments is scanty in barley and the situation further aggravates as the zones for varietal evaluation in barley are very large for coordinated testing. Therefore, GGE biplot model was applied over 19 barley genotypes grown at 8 diverse locations to ascertain the mega environments, winning cultivars and discriminating and representative test environmentsfor grain yield and diastatic power in barley.

During *rabi*, 2015-16, multi-environment trials (MET) were conducted at 8 diverse locations namely Hisar (E1), Karnal (E2), Ludhiana (E3), Bathinda (E4), Modipuram (E5), Bawal (E6), Pantnagar (E7) and Durgapura (E8). The experimental material comprised of 14 barley genotypes *viz*., BH1011 (G1), BH1012 (G2), BH1013 (G3), DWRB147 (G4), DWRB148 (G5), DWRB149 (G6), DWRB150 (G7), KB1405 (G8), KB1426 (G9), PL890 (G10), RD2939 (G11), RD2940 (G12), RD2941 (G13), RD2943 (G14) and 05 commercial checks, namely BH902 (G15), DWRB92 (G16), DWRB101 (G17), DWRUB52 (G18) and RD2849 (G19) (Table 1). For diastatic power analysis the environment (E5) Mathura was considered in place of Modipuram and rest of the locations and genotypes were similar to grain yield. The experiments were conducted in randomized complete block design (RCBD) in four replications having 6-row plots with row to row spacing of 18 cm and row length of 5 m. All the standard package and practices were adopted to raise the good crop. Analysis of variance was performed using SAS version 9.3 and the GGE biplots were generated using R version 3.3.2 software.

Table 1. Genotypic and environmental means for diastatic power (^{0}L) for 19 barley genotypes

Genotype	Code	Hisar E1	Karnal E2	Ludhiana E3	Bathinda E4	Mathura E5	Bawal E6	Pantnagar E7	Durgapura E8	Mean
BH1011	G1	100	98	78	100	85	114	105	111	98.9
BH1012	G2	87	111	114	111	89	100	111	108	103.9
BH1013	G3	87	111	91	118	85	111	87	114	100.5
DWRB147	G4	80	118	100	91	91	111	118	105	101.8
DWRB148	G5	80	108	114	114	83	111	105	114	103.6
DWRB149	G6	87	111	95	111	91	93	100	108	99.5
DWRB150	G7	91	105	95	111	111	100	91	114	102.3
KB1405	G8	91	105	100	111	91	103	89	105	99.4
KB1426	G9	80	108	91	95	89	111	95	111	97.5
PL890	G10	80	105	100	108	92	111	98	111	100.6
RD2939	G11	80	111	108	114	111	95	100	111	103.8
RD2940	G12	83	114	100	121	114	95	100	105	104.0
RD2941	G13	85	95	100	111	105	105	111	105	102.1
RD2943	G14	96	111	100	105	87	111	95	111	102.0
BH902©	G15	82	105	83	111	82	114	98	103	97.3
DWRB92©	G16	100	105	118	114	105	111	103	121	109.6
DWRB101©	G17	89	108	108	100	91	100	108	100	100.5
DWRUB52©	G18	83	108	95	111	100	111	91	100	99.9
RD2849©	G19	83	118	91	108	87	108	103	111	101.1
Mean	86.5	108.2	99.0	108.7	94.2	106.1	100.4	108.8	101.5	

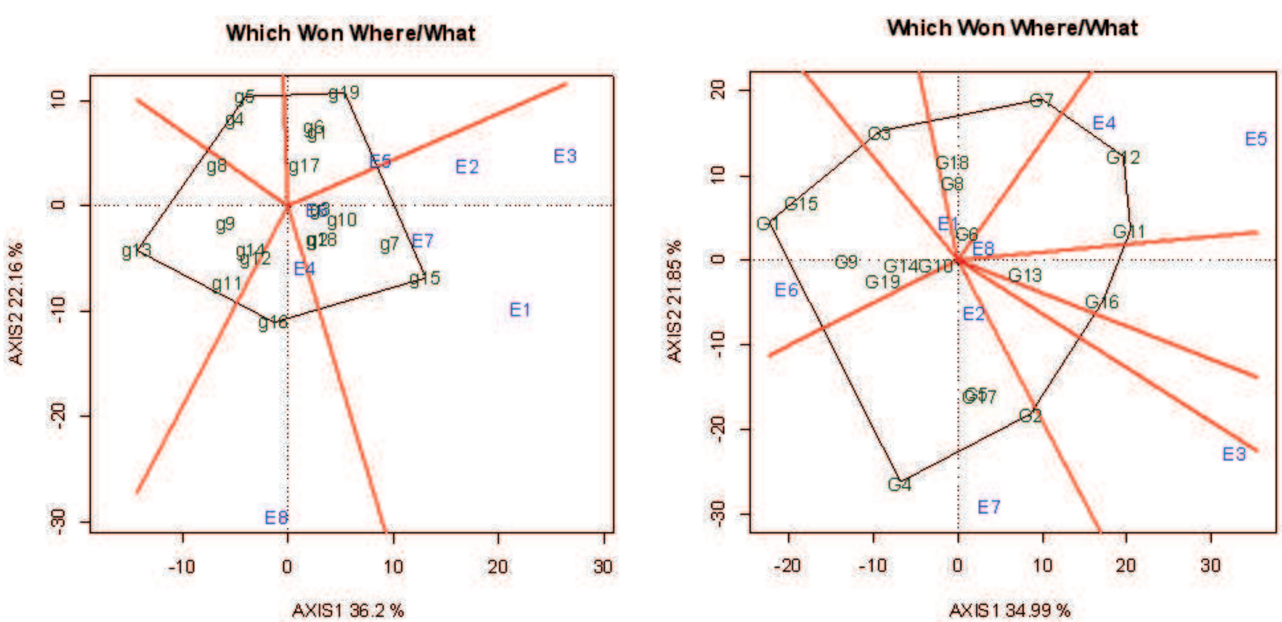
Diastatic power (^{0}L) was recorded as per European Breweries Convention (EBC) procedure (Analytica-EBC 2003).

Analysis of variance depicted significant genotypic mean squares for different locations and the combined analysis of variance also showed highly significant mean squares for genotypes and locations, indicating the presence of significant genetic and environmental interactions. Average grain yield and diastatic power over the locations were exhibited as 42.3 q/ha and 101.5 ^{o}L and ranged from 32.1 to 64.4 q/ha and 97.3 to 109.6 ^{o}L, respectively. The highest average diastatic power was observed at Durgapura (108.8 ^{o}L) followed by Bathinda (108.7 ^{o}L), Karnal (108.2 ^{o}L) and Bawal (106.1 ^{o}L) locations (Table 1).

For grain yield the first two principal components PC1 and PC2 explained 36.20% and 22.16 % variations and the vertex genotypes were viewed as G5 (DWRB148) and G13 (RD2941) with commercial check varieties G15 (BH902), G16 (DWRB92) and G19 (RD2849), respectively. The eight environments were grouped into the three different sectors. The environments E2 (Karnal), E3 (Ludhiana) and E5 (Modipuram) were grouped together, while E1 (Hisar), E6 (Bawal) and E7 (Pantnagar) represented the same sector (Fig. 1). For diastatic power the PC1 and PC2 altogether showed 56.84 % variation and the eight environments were clustered into five sectors, where the vertex genotypes were G1 (BH1011), G2 (BH1012), G3 (BH1013), G4 (DWRB147), G7 (DWRB150), G11 (RD2939), G12 (RD2940) and G16 (DWRB92).

In AEC (Average Environment Coordination) view, the commercial cultivar G15 (BH902) was observed with high AEC abscissa score followed by the genotypes G7 (DWRB150), G10 (PL890) and G18 (DWRUB52) for grain yield.In contrast, G13 (RD2941) was the low yielder with least AEC abscissa scores and very high AEC ordinate value, which indicated low stability. In mean vs. stability view of diastatic power, the check variety DWRB92 showed high value and stability followed by RD2941 (G13). The biplot also depicted that the genotypes G1, G3, G9 and G15 were poor for diastatic power. After perusal of biplot it was revealed that the location Durgapura created separate niche and was negatively correlated with the environments Karnal, Ludhiana and Modipuram for grain yield. The environments Hisar, Pantnagar, Ludhiana, Karnal and Modipuram were found positively correlated with each other. For diastatic power the location Ludhiana (E3) and Mathura (E5) were discriminating and the environments E4 (Bathinda) and E7 (Pantnagar) were also discriminating but exhibited obtuse angles from AEC absicca.

GGE biplot method is an effective tool to exclude confounding effect of G x E and to study mega environments, winning genotypes, wider adaptability



(a) (b)

Fig. 1. (a and b). Which won where biplot for grain yield (a) and diastatic power (b)

and representative and discriminating environments (Villegas et al. 2016). In GGE methodology initial two principal components showed reasonably good amount of the interaction component and explained nearly 60% of the variation for grain yield and 57 % for diastatic power, respectively. In which won where biplot, the eight locations were grouped into three and five mega environments and indicated that no single cultivar was winning and stable in the all environments for yield and enzymatic activity. Yan and Tinker (2006) and Yan et al. (2007) also reported that GGE biplot method is extremely useful in the similar situation to identify similar set of the environments, when there are different winning genotypes for different mega environments. The vertex cultivars for grain yield were observed namely DWRB148, RD2941, BH902, DWRB92 and RD2849 and indicated either superior or inferior performance of these varieties under varying environments. The genotypes BH902 and DWRB150 were found winning at Hisar and Pantnagar locations, while the check RD2849 was high yielder at Karnal, Ludhiana and Modipuram locations. The AEC abscissa depicts the main effects of the genotypes as of intrinsic property of biplot and genotypic scores are proportional to genotypic main effects due to the rank-two approximation. The genotypic scores on biplot were found correlated with main genotypic *per se* performances and indicated the meaningful ranking of the genotypes (Yan and Tinker 2006). The biplot constructed for grain yield mean and stability view exhibited that the genotypes BH902, DWRB150, PL890 and DWRUB52 were higher yielders with wider adaptability. The check variety DWRB92 showed the highest mean and stability for diastatic power. The high activity of β-amylase enzyme, which synthesizes during grain filling (Arends et al. 1995) and starch protein interplay may be the reason associated with bold grains and high diastatic power in DWRB92 and needs to be confirmed in future studies.

GGE biplot method provides opportunity to compare environments for discriminating power and representativeness based on vector length and cosine angles from AEC abscissa, respectively (Silva et al. 2016; Villegas et al. 2016). As reported by Rakshit et al. 2012; Sousa et al. 2015the environments with long vectors and acute angles from AEC abscissa are ideal environments for future consideration. The location Hisar (E1) was the ideal environment followed by Pantnagar for grain yield and the locations Ludhiana and Mathura were best suited for diastatic power. Yan et al. 2007 reported that the Type 2 environments are desirable and informative with long vectors and acute angles from the AEC abscissa and Type 1 environment are less useful with short vectors (Bathinda and Bawal). The genotypic pattern on biplots again confirmed the negative correlation of yield and quality as the genotypes G7 and G15 were better for yield but found poor for enzymatic activity and G16 was instable for grain yield performances. The environmental behaviour indicated that location effect was different for yield and quality but the environments Ludhiana and Pantnagar were found discriminating for grain yield and as well as for diastatic power. In conclusion, the genotype DWRB150 and commercial six-rowed check BH902 were found with high *per se* and wider adaptability for grain yield, whereas,the check DWRB92 and genotype RD2941 were ideal for diastatic power.

Author's contribution

Conceptualization of research (VK, ASK, GPS); Designing of experiments (VK, DK); Contribution of materials (VK); Execution and coordination (VK, DK, ASK), analysis of data, quality analysis, compilation and interpretation (VK, ASK); Preparation of manuscript (VK).

Declaration

The authors declare no conflict of interest.

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