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*Short Communication*

# Using AMMI approach to delineate genotype by environment interaction and stability of barley (*Hordeum vulgare* L.) genotypes under northern Indian Shivalik hill conditions

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**Abstract**

**Genotype by environment interaction (GEI) of 18 barley varieties was assessed during two successive *rabi* crop seasons so as to identify high yielding and stable barley varieties. AMMI analysis showed that genotypes (G), environment (E) and GEI accounted for 1672.35, 78.25 and 20.51 of total variance, respectively. Partitioning of sum of squares due to GEI revealed significance of interaction principal component axis IPCA1 only On the basis of AMMI biplot analysis DWRB 137 (41.03qha$^{-1}$), RD 2715 (32.54qha$^{-1}$), BH 902 (37.53qha$^{-1}$) and RD 2907 (33.29qha$^{-1}$) exhibited grain yield superiority of 64.45, 30.42, 50.42 and 33.42 per cent, respectively over farmers' recycled variety (24.43qha$^{-1}$).**

**Key words:** AMMI Analysis, barley varieties, GEI, grain yield

Barley (*Hordeum vulgare* L.) 2n=2x=14 belonging to family *Poaceae* is grown satisfactorily under rainfed conditions in India, it is cultivated on 677 thousand hectares of land, with production and productivity of 1788 thousand tonnes and 26.41 q ha$^{-1}$, respectively. In Jammu and Kashmir region of India barley assumes greater importance especially in foot hills of shivaliks which stretch from Jammu and Kashmir in northern west India to Uttrakhand. The characteristic features of shivaliks are undulating topography, steep slopes and easily erodible soils. In this area barley is grown over an area of 6700 hectares with production of 4400 tonnes and average productivity of only 06.48 quintals ha$^{-1}$ (Singh 2018) which is very less than national average productivity. Mostly, barley is cultivated under rainfed conditions and hence the full potential of the varieties is seldom realized. It is well known that the drought stress has remained a major constrain for barley production and yield stability under rainfed ecosystems (Eshaghi et al. 2010). Genotype by environment (GEI) interaction is of major importance, because it provides information about the effects of test environments on genotype performance For the accurate assessment of GEI the additive main effects and multiplicative interaction (AMMI) model is a valuable tool (Gauch 2006; Li et al. 2006). AMMI analysis interprets the effect of the genotype (G) and environment (E) as additive effects plus the GE as a multiplicative component and submits it to principal component analysis and its bi-plot was identified as GE bi-plot by Yan et al. (2000).

Experimental material comprised of eighteen diverse barley (*Hordeum vulgare* L.) varieties obtained from different barley breeding institutes of India were evaluated during *rabi* seasons, 2017-18 and 2018-19 in four environments represented by normal and late planting in each season with gap of 25 days. The field experiments in each season were laid in Randomized Complete Block Design (RCBD) with three replications on a plot size of 4m$^2$ grain yield superiority was worked out over local check as [Test cultivar-local check/local check] x 100 for all the barley test cultivars.

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The combined analysis of variance over environments was performed as per Verma et al. (1987). The AMMI model which combines standard analysis of variance with PC (Principal component) analysis (Zobel et al.1988) was used to investigate G x E interaction.

### G x E interaction

Combined analysis of variance for grain yield exhibited significant GEI indicating that barley genotypes responded differentially to normal and late sowings over both the seasons. The AMMI analysis indicated that main effects due to genotype (G), environment (E) and GEI interaction as well as interaction principal component axis were significant. AMMI analysis of variance showed that 99.90 per cent variation was contributed by genotypes x environment interaction and this variation was partitioned among the first three interaction principal component axis which explained that IPCA 1 contributed 72.40 per cent of the total GEI variation and was highly significant while IPCA 2 and IPCA 3 were non-significant. Similar findings were observed by Aina et al. (2009) and Xu Fei-fei et al. (2014).

### AMMI analysis

The environmental variance was also significant which indicates that the environments under study were different from each other (Table 1). The relative performance of barley varieties and identification of favorable environments was done by using AMMI I and AMMI II biplot as well as interaction principal component analysis.

The interaction principal component axis 1 (IPCA 1) revealed that genotypes located in the right side of the grand mean (33.72 qtls) had high yield than those on the left side. For environment located on the right side of grand mean was considered as favorable environment. Accordingly, the varieties RD 2907, BH

**Table 1.** Average grain yield ($qha^{-1}$), environmental index and interaction component scores of barley varieties

| Genotypes | *Rabi* 2017-18 | | *Rabi* 2018-19 | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $E_1$ (Normal sowing) | $E_2$ (Late sowing) | $E_3$ (Normal sowing) | $E_4$ (Late sowing) | Genotype mean | Index | IPCA1 | IPCA 2 |
| RD 2035 | 33.50 | 19.58 | 48.71 | 28.50 | 32.57 | -0.05 | -0.37 | 0.13 |
| RD 2052 | 40.31 | 19.31 | 49.90 | 29.99 | 34.88 | 0.05 | 0.31 | 0.08 |
| RD 2552 | 41.94 | 28.94 | 42.79 | 24.91 | 34.64 | 0.04 | 0.11 | -0.08 |
| RD 2592 | 44.79 | 28.55 | 48.80 | 34.19 | 39.08 | 0.22 | -0.20 | 0.03 |
| RD 2715 | 36.91 | 26.98 | 46.43 | 19.83 | 32.54 | -0.05 | 0.05 | 0.26 |
| RD 2794 | 41.12 | 29.87 | 47.88 | 20.23 | 34.78 | 0.05 | 0.15 | 0.27 |
| RD 2849 | 47.82 | 35.63 | 47.63 | 19.24 | 37.58 | 0.15 | 0.55 | 0.16 |
| RD 2899 | 42.94 | 24.76 | 50.92 | 30.52 | 37.29 | 0.14 | -0.19 | 0.07 |
| RD 2907 | 40.90 | 26.44 | 39.36 | 26.46 | 33.29 | -0.02 | 0.09 | -0.36 |
| BH 902 | 46.02 | 29.30 | 47.00 | 27.80 | 37.53 | 0.15 | 0.02 | 0.08 |
| BH 946 | 43.35 | 28.63 | 34.92 | 19.34 | 31.56 | -0.08 | 0.35 | -0.24 |
| BHS 352 | 41.48 | 24.02 | 48.51 | 34.59 | 37.15 | 0.14 | -0.34 | 0.01 |
| BHS 400 | 41.31 | 30.36 | 35.74 | 19.31 | 31.68 | -0.08 | 0.42 | -0.11 |
| VLB 118 | 38.90 | 15.92 | 38.99 | 22.55 | 29.09 | -0.18 | -0.09 | -0.12 |
| BHS 380 | 30.03 | 13.34 | 34.96 | 20.30 | 24.66 | -0.35 | -0.22 | -0.31 |
| DWRB 123 | 35.91 | 26.35 | 43.48 | 25.08 | 32.71 | -0.05 | -0.02 | 0.12 |
| DWRB 137 | 47.10 | 38.04 | 49.96 | 28.98 | 41.03 | 0.29 | 0.15 | 0.11 |
| Local check | 27.90 | 14.90 | 32.56 | 24.43 | 24.95 | -0.36 | -0.18 | -0.14 |
| Grand mean | 40.12 | 25.61 | 43.81 | 25.35 | GM= 33.72 | | | |
| Environment index | 6.40 | -8.15 | 10.08 | -8.37 | | | | |

*Significant at $P \leq 0.05$, **significant at $P \leq 0.01$

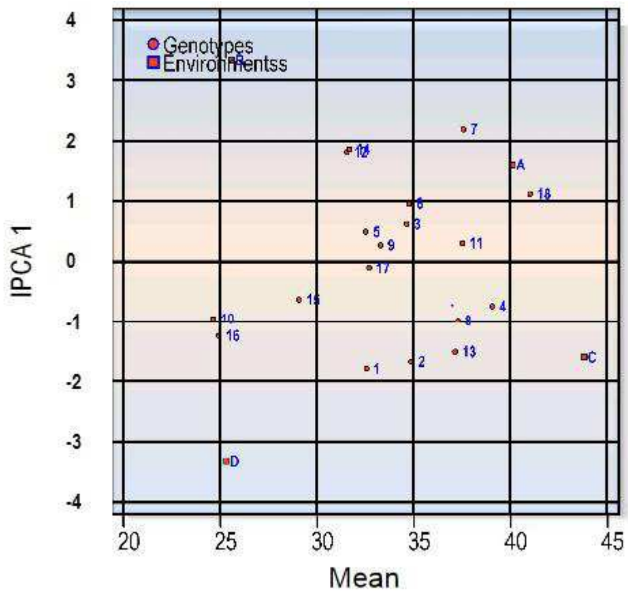


**Fig. 1. AMMI I biplot for grain yield of 18 barley genotypes and four environments using genotypes and environments IPCA scores. Grand mean yield = 33.72 q ha$^{-1}$**

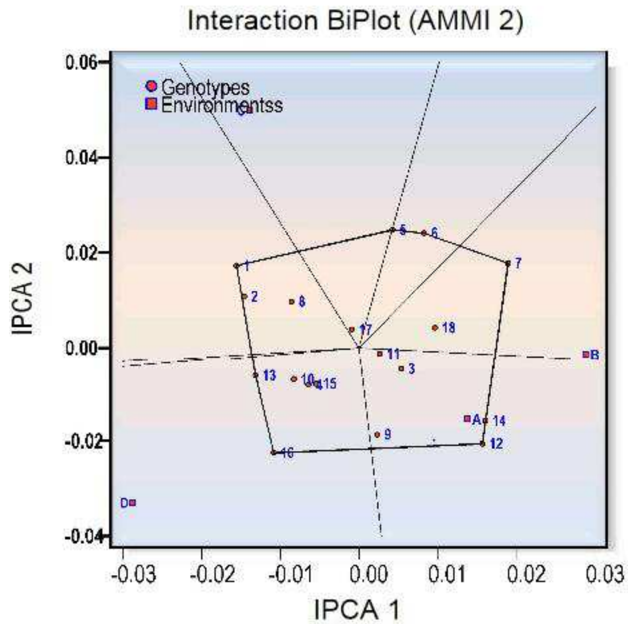


**Fig. 2. AMMI II biplot for grain yield showing the interaction of IPCA 2 against IPCA 1 scores Grand mean yield = 33.72 q ha$^{-1}$**

**Table 2.** Combined per cent grain yield superiority over local check and their relative ranking across environments

| S.No. | Genotypes | Grain yield superiority (%) | Rank | S. No. | Genotypes | Grain yield superiority (%) | Rank |
|---|---|---|---|---|---|---|---|
| 1 | RD 2035 | 30.54** | 8 | 10 | BH 902 | 50.42** | 3 |
| 2 | RD 2052 | 39.80** | 6 | 11 | BH 946 | 26.49** | 9 |
| 3 | RD 2552 | 38.84** | 7 | 12 | BHS 352 | 48.90** | 4 |
| 4 | RD 2592 | 56.63 | 2 | 13 | BHS 400 | 26.97** | 10 |
| 5 | RD 2715 | 30.42** | 8 | 14 | VLB 118 | 16.59** | 11 |
| 6 | RD 2794 | 39.40** | 6 | 15 | BHS 380 | -1.16 | 13 |
| 7 | RD 2849 | 50.62** | 2 | 16 | DWRB 123 | 31.10** | 10 |
| 8 | RD 2899 | 49.46** | 5 | 17 | DWRB 137 | 64.45** | 1 |
| 9 | RD 2907 | 33.43** | 8 | | S.E. (±) 0.069 | | |

* Significant at $P \leq 0.05$, **significant at $P \leq 0.01$

902, VLB 118 and DWRB 123 have differences only in main (additive) effects (Fig. 1). Conversely the two groups of varieties RD 2794, RD 2552, BH 902, RD 2899 and BHS 352 separately have differences only in interaction effects. The varieties RD 2907, BH 902, VLB 118 and DWRB 137 had lower interaction and hence they exhibited stable behaviour.

In AMMI II biplot (Fig. 2) the environmental scores were connected to the origin by side lines. $E_1$ (Normal sowing) and $E_3$ (Normal sowing) had short spokes and they did not exert strong interaction force while environment $E_2$ (Late sowing) and $E_4$ (Late sowing) having long spokes exerted strong interaction. Lal et al. (2019) emphasized that AMMI ANOVA contributed to G, E and GEI to the tune of 53.1%, 27.7% and 15.6%, respectively for peanut yield and identified three significant IPCA1 to IPCA3 which explained 48.4, 32.8 and 18.8% of GE sum of squares, respectively. AMMI biplot analysis had identified more stable genotypes. Similarly, AMMI analysis revealed that the first two significant IPCA scored together explained 77.18% of the total interaction variance in basmati rice. Biplot graphical analysis also showed that particular location to be the less interacting and stable location (Dwivedi et al. 2020). Varieties RD 2552, BH 902, BHS 400, VLB 118, DWRB 123 and DWRB 137 were near the origin, hence, they were non sensitive to environmental interaction forces while genotypes RD 2035, RD 2052, RD 2849, BH946, BHS 400 and BHS 380 were away from zero line, therefore found most responsive to environmental interaction.

The varieties BH 902, DWRB 137, RD 2794, RD 2592 and RD 2899 had higher average grain yields with positive index values, indicating that these varieties were adopted to favorable environment Varieties RD 2715, RD 2907, BH 902, DWRB 137 were non sensitive to environmental interaction forces, hence more stable. Similar conclusion was reported by Sara et al. (2019) and Novosad et al. (2017). The variety DWRB 137 (41.03 $qha^{-1}$) ranked first among all followed by RD 2592 (39.08 $qha^{-1}$), RD 2849 (37.58 $qha^{-1}$), BH 902 (37.53 $qha^{-1}$) and BH 946 (37.15 $qha^{-1}$). DWRB 137 exhibited 64.45 per cent grain yield superiority (Table 2) over local check followed by RD 2849 (50.62 per cent) and BH 902 (50.42 per cent) and have also demonstrated stable behavoiur over environments.

### Authors' contribution

Conceptualization of research (PS); Designing of the experiments (PS, OPY); Contribution of experimental materials (PS); Execution of field/lab experiments and data collection (OPY, AKR, BK); Analysis of data and interpretation (OPY, PS, AKS); Preparation of manuscript (PS, OPY, AKS).

### Declaration

The authors declare no conflict of interest.

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