A comparison of different stability models for genotype x environment interaction in pearl millet

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Abstract:
Twenty four genotypes (hybrids) of pearl millet were tested under eight environments in Gujarat. The models of Eberhart and Russell (1966), Perkins and Jinks (1968) and Freeman and Perkins (1971) applied to study genotype x environment interaction and were compared for their efficiency empirically. The genotypes GHB-788, GHB-832 and GHB-840 were observed as most stable and widely adapted over environments in all three models. On the basis of simplicity and computational convenience, Eberhart and Russell (1966) model was recommended.

Key words: Stability models, adaptability, genotype x environment interaction, pearl millet.

Introduction
The performance of any crop variety is the resultant effect of its genotype and environment in which it grows. It is observed that the relative performance of different genotypes varies in different environments; there exists a genotype x environment interaction. This interaction is a result of changes in cultivar’s relative performance across environments, due to differential responses of the genotype to various edaphic, climatic and biotic factors (Dixon and Nukenine, 1997). Therefore, the analysis of genotype x environment interaction becomes an important tool employed by breeders for evaluating varietal adaptation. Choice of appropriate statistical models and their validation are fundamental steps which should precede any study of G x E interaction and analysis of stability. An early attempt to obtain measurement of the stability of individual lines was made by Plaisted and Peterson (1959), but their method becomes cumbersome when a large number of genotypes are tested. Recently breeders frequently employ joint regression analysis in the assessment and categorization of yield stability. It was originally

Materials and Methods
An experiment was conducted with twenty-four hybrids of pearl millet viz., GHB-715 (G1), GHB-788,
parameters deviation \( (G) \), \( (E) \) and \( G \times E \) displayed highly significant differences among genotypes \( (G) \), environments \( (E) \) and \( G \times E \) interactions (Table 1). This showed that genotypes did not differ only genetically but also some of these exhibited differential response to variable environments. The results indicated that the presence of ample genetic variability for grain yield and presence of genotype x environment interaction. The estimates of stability parameters obtained for grain yield data using three models viz., Eberhart and Russell's (ER), Perkins and Jinks' (PJ) and Freeman and Perkins' (FP) are presented in Table 2 and the correlations among them are shown in Table 3.

In the table 2, \( Y_i \) stands for mean grain yield of \( i^{th} \) genotype; \( b_i^E \), \( B_i \) and \( b_i^F \) are the regression coefficients for \( i^{th} \) genotype as per Eberhart and Russell's (ER), Perkins and Jinks' (PJ) and Freeman and Perkins' model (FP), respectively. Similarly, \( \overline{S}_d, (E) \) and \( \overline{S}_d, (F) \) represent mean square deviation from the regression under ER model and FP model, respectively.

The mean grain yield ranged from 1473 kg \( (G_24) \) to 2745 kg \( (G_1) \), the differences being significant. The \( b_i^E \) and \( B_i \) were significant for \( G_4 \) and \( G_{17} \). The genotype \( G_4 \) exhibited high grain yield and was responsive to favourable environments \( (b_i^E > 1 \text{ and } B_i > 0) \). While \( G_{17} \) gave lower yield than overall mean and was responsive to poor environments \( (b_i^E < 1 \text{ and } B_i < 0) \). Further, genotypes \( G_1, G_2, G_3, G_6, G_7, G_{10}, G_{11}, G_{13}, G_{15}, G_{18}, G_{20}, G_{22}, G_{23} \) and \( G_{24} \) deviated significantly from linearity as \( \overline{S}_d, (E) > 0 \) for these genotypes. These deviation from regression indicated that they were unstable genotypes and their performance was not stable in varied environmental conditions. On the other hand genotypes \( G_3, G_6, G_{11}, G_{20} \) and \( G_{23} \) also deviated significantly from linearity as \( \overline{S}_d, (F) \) were significant for these five genotypes and gave unstable performance over environments studied. While comparing \( \overline{S}_d, (E) \) and \( \overline{S}_d, (F) \) values, many genotypes were skipped from significant deviation from regression as calculated from Freeman and Perkins' model (1971) and was very sensitive approach as compared to Eberhart and Russell's model (1966). Similarly, while comparing regression coefficient from all the three models revealed that regression coefficient calculated from \( b_i^E \) and \( b_i^F \) were very close as compared to \( B_i \) values for most of the genotypes, but test of significance of \( b_i^E \) and \( B_i \) gave same results.

### Results and Discussion

The pooled analysis of variance for grain yield displayed highly significant differences among genotypes \( (G) \), environments \( (E) \) and \( G \times E \) interactions.
On the basis of grain yield performance (> average yield) and stability parameters \( b^{Ei} = 1, B_i = 0, b^{Fi} = 1, S_d^2 = 0 \), the hybrid \( G_6 \) (GB-788), \( G_{14} \) (GBH-832) and \( G_{16} \) (GBH-840) were considered as stable and widely adapted over all the environments. These results are in agreement with those reported by Shinde et al. (2002), Chikurte et al. (2003) and Yahaya et al. (2006).

Correlation matrix showed that the ranking patterns for \( b^{Fi} \) and \( B_i \) were similar \(( r = 1.000)\) suggesting that both the methods (ER and PJ) were identical. The ranking pattern of genotypes using \( b^{Fi} \) values was also very close to the ranking pattern done under previous two models \(( r = 0.9655, \text{Table 3})\). In ER model \( G_6 \) had the highest regression value \(( b^{Ei} = 1.323) \) followed by \( G_{10} \) \(( b^{Ei} = 1.269) \), and \( G_1 \) \(( b^{Ei} = 1.323) \) and the lowest \( b^{Ei} \) was observed for \( G_{34} \) \(( b^{Ei} = 0.652) \), whereas in FP model, \( G_4 \) had the highest regression value \(( b^{Fi} = 1.358) \), followed by \( G_7 \) \(( b^{Fi} = 1.288) \), and \( G_9 \) \(( b^{Fi} = 1.243) \) and the lowest \( b^{Fi} \) was observed for \( G_{34} \) \(( b^{Fi} = 0.662) \). This showed that ranking pattern of genotypes on the basis of responsiveness in FP model was not similar to the ranking pattern in ER and PJ models and also the \( S_d^2 \) \((F) \) showed predictable performance for all the genotypes barring \( G_3 \), \( G_6 \), \( G_{11} \), \( G_{20} \) and \( G_{23} \). It can be seen from the table 3, that \( b^{Fi} \) \((r = 0.8018) \), \( B_i \) \((r = 0.8145) \) were significantly associated with mean grain yield \(( Y_i \) ), while non-significant association of grain yield was observed with \( S_d^2 \) \((E) \) and \( S_d^2 \) \((F) \). It was also observed that \( S_d^2 \) \((E) \) was significant and positively associated with \( b^{Ei} \), \( B_i \) and \( b^{Fi} \), while \( S_d^2 \) \((F) \) was positive but non-significant with \( b^{Ei} \), \( B_i \) and \( b^{Fi} \).

The deviation observed between ranking patterns of genotypes (based on stability parameters) in FP model and other two models was primarily due to the fact that FP model used part of the experimental data (two replications in present study) and not full set of data as in ER and PJ models. FP model did not reflect actuality existing in the full set of data. Theoretically, FP model is sound but precision point of view ER and PJ are good. This study revealed the empirical association among all the three models.

The variation in sample size (replications) affected the estimates causing deviation in ranking pattern of genotypes in ER and FP models, very specifically with reference to \( S_d^2 \) estimates of both the models. Any estimate based on full set of data is more reliable and precise than that with partial data set. Therefore, it is advisable not to use FP model for stability analysis. It is concluded that ER model can be used for stability analysis. Luthra and Singh (1974) and Prajapati et al. (1998) also recommended ER model on the ground of simplicity and computational convenience.

References:


Table 1. Pooled analysis of variance of grain yield in pearl millet

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotypes (G)</td>
<td>23</td>
<td>57582749.4</td>
<td>2503597.8**</td>
</tr>
<tr>
<td>Environments (E)</td>
<td>7</td>
<td>480251169.2</td>
<td>68607309.8**</td>
</tr>
<tr>
<td>G x E</td>
<td>161</td>
<td>78427463.9</td>
<td>487127.1**</td>
</tr>
<tr>
<td>Error</td>
<td>384</td>
<td>54919138.5</td>
<td>143018.5</td>
</tr>
</tbody>
</table>

** Significant at 0.01 probability level

Table 2. Estimates of stability parameters based on eight environments using various models for grain yield in pearl millet.

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>$\bar{Y}_i$</th>
<th>b^ki</th>
<th>b^fi</th>
<th>$S_{d_i}^2$ (E)</th>
<th>$S_{d_i}^2$ (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_1</td>
<td>2328</td>
<td>0.935</td>
<td>-0.065</td>
<td>0.919</td>
<td>66359.7*</td>
</tr>
<tr>
<td>G_2</td>
<td>2520</td>
<td>1.096</td>
<td>0.096</td>
<td>1.070</td>
<td>108223.5**</td>
</tr>
<tr>
<td>G_3</td>
<td>2745</td>
<td>1.068</td>
<td>0.068</td>
<td>1.135</td>
<td>241238.1**</td>
</tr>
<tr>
<td>G_4</td>
<td>2732</td>
<td>1.323*</td>
<td>0.323*</td>
<td>1.358</td>
<td>33569.0</td>
</tr>
<tr>
<td>G_5</td>
<td>1939</td>
<td>0.888</td>
<td>-0.112</td>
<td>0.913</td>
<td>-13994.1</td>
</tr>
<tr>
<td>G_6</td>
<td>2250</td>
<td>1.145</td>
<td>0.145</td>
<td>1.163</td>
<td>299571.5**</td>
</tr>
<tr>
<td>G_7</td>
<td>2679</td>
<td>1.258</td>
<td>0.258</td>
<td>1.288</td>
<td>337250.6**</td>
</tr>
<tr>
<td>G_8</td>
<td>2709</td>
<td>1.170</td>
<td>0.170</td>
<td>1.243</td>
<td>39721.8</td>
</tr>
<tr>
<td>G_9</td>
<td>2014</td>
<td>0.972</td>
<td>-0.028</td>
<td>0.956</td>
<td>39976.5</td>
</tr>
<tr>
<td>G_10</td>
<td>2490</td>
<td>1.076</td>
<td>0.076</td>
<td>1.142</td>
<td>127555.5**</td>
</tr>
<tr>
<td>G_11</td>
<td>2052</td>
<td>0.915</td>
<td>-0.085</td>
<td>0.978</td>
<td>248755.5**</td>
</tr>
<tr>
<td>G_12</td>
<td>1760</td>
<td>0.832</td>
<td>-0.168</td>
<td>0.837</td>
<td>4707.0</td>
</tr>
<tr>
<td>G_13</td>
<td>2006</td>
<td>0.821</td>
<td>-0.179</td>
<td>0.782</td>
<td>71406.3*</td>
</tr>
<tr>
<td>G_14</td>
<td>2323</td>
<td>1.006</td>
<td>0.006</td>
<td>1.054</td>
<td>798.0</td>
</tr>
<tr>
<td>G_15</td>
<td>2371</td>
<td>1.147</td>
<td>0.147</td>
<td>1.149</td>
<td>69746.8*</td>
</tr>
<tr>
<td>G_16</td>
<td>2331</td>
<td>0.839</td>
<td>-0.161</td>
<td>0.789</td>
<td>-515.0</td>
</tr>
<tr>
<td>G_17</td>
<td>1994</td>
<td>0.707*</td>
<td>-0.29*</td>
<td>0.735</td>
<td>37681.4</td>
</tr>
<tr>
<td>G_18</td>
<td>2078</td>
<td>0.928</td>
<td>-0.072</td>
<td>0.931</td>
<td>58185.7*</td>
</tr>
<tr>
<td>G_19</td>
<td>2519</td>
<td>1.269</td>
<td>0.269</td>
<td>1.182</td>
<td>156991.5**</td>
</tr>
<tr>
<td>G_20</td>
<td>2318</td>
<td>1.131</td>
<td>0.131</td>
<td>1.086</td>
<td>184477.2**</td>
</tr>
<tr>
<td>G_21</td>
<td>2205</td>
<td>0.918</td>
<td>-0.082</td>
<td>0.894</td>
<td>10625.5</td>
</tr>
<tr>
<td>G_22</td>
<td>2425</td>
<td>0.903</td>
<td>-0.097</td>
<td>0.868</td>
<td>84796.4*</td>
</tr>
<tr>
<td>G_23</td>
<td>1990</td>
<td>1.000</td>
<td>0.000</td>
<td>0.893</td>
<td>150759.9**</td>
</tr>
<tr>
<td>G_24</td>
<td>1473</td>
<td>0.652</td>
<td>-0.348</td>
<td>0.662</td>
<td>87982.3*</td>
</tr>
</tbody>
</table>

C. D. at 5% 394
Average 2260

* Significant at 0.05 probability level, ** Significant at 0.01 probability level
Table 3. Correlation matrix among various stability parameters for grain yield in pearl millet.

<table>
<thead>
<tr>
<th></th>
<th>$Y_i$</th>
<th>$b^{fi}$</th>
<th>$B_i$</th>
<th>$b^{fi}$</th>
<th>$\bar{S}_{d_i}^2$ (E)</th>
<th>$\bar{S}_{d_i}^2$ (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b^{fi}$</td>
<td>0.8018**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B_i$</td>
<td>0.8018**</td>
<td>1.000**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$b^{fi}$</td>
<td>0.8145**</td>
<td>0.9655**</td>
<td>0.9655**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{S}_{d_i}^2$ (E)</td>
<td>0.2934</td>
<td>0.4282*</td>
<td>0.4282*</td>
<td>0.4306*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{S}_{d_i}^2$ (F)</td>
<td>0.1267</td>
<td>0.3506</td>
<td>0.3506</td>
<td>0.3012</td>
<td>0.8224**</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 0.05 probability level, ** Significant at 0.01 probability level