A Review on Genotype Environment Interaction and its Stability Measures

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Abstract: Genotype × Environment Interaction (GEI) is a common phenomenon in genetics as it results in inconsistent performance between the genotype across environments. When interaction occurs, factor present in environment, as well as the genetic constitution of genotype, influences the phenotypic expression of a trait. Due to their importance in the practical world the different methods of calculating it have been studied in present paper. The stability measures of different genotypes have also been studied.

Keywords: ANOVA, Regression coefficient, Stability Measure, etc.

1. Introduction

The increase in population and the subsequent rise in the demand for agricultural produce are expected to be greater in regions where production is already insufficient, in particular in South Asia. The necessary increase in agricultural production represents a huge challenge to local forming systems and must come mainly from increased yield per unit area, given the limited scope for extension of cultivated land worldwide. To meet this requirement various crop improvement programmes all over the world have been initiated. Under any crop improvement programme a sample of promising genotypes are performance tested each year at a number of site, representing the major growing area of the crop with a view to identify genotypes which are likely to perform well in the future. But in practice, due to various reasons such as insufficient seed, poor germination, missing observation, etc, it is not possible to test every genotype at a number of site, representing the major growing area of the crop.

For carrying out stability analysis, one needs to have mean performance to all the genotypes in each of the environments. But it practice, due to various reasons such as insufficient seed, poor germination, missing observation, etc, it is usually not possible to test every genotype at environment thus the resulting genotype environment table becomes incomplete. Obviously, one should incorporate some adjustment in the genotypic effect due to unequal number of observations so as to compensate the loss. The modified regression methods suggested by different workers are considered to analysis such data. For finding the stability measure experimenters firstly go for the designing of experiment of multi-location trials and then analysis of the design. This is usually evidenced by a significant location year interaction in the ANOVA. Analysis of variance of multi-location trials is useful for estimating variance components related to different source of variation, including genotype and genotype × environmental interaction (GEI). In general, variance component methodology is important in multi-location trials, since largely from GEI. Therefore, knowledge of the size of this interaction is required to (a) obtain efficient estimates of the genotypic effects and (b) determine optimum resources allocations, that is, the number of plots and locations to be including in future trials. Different concept and definition of stability and its types have been described over the last five decades.

Plaisted and Peterson (1959) estimated the variance component of genotype environment interactions for interactions for each of the possible pairs of cultivars and considered the average of the estimate for all combinations with a common cultivar to be measure of stability. According to them the cultivars which show lower value for the \( \theta(\%) \) estimate are considered more stable. Their original measure was originally defined in term of replicated data but the formula is modified and is based on the cell mean. The modified regression method is useful for estimating variance components related to different source of variation, including genotype and genotype × environmental interaction (GEI). In general, variance component methodology is important in multi-location trials, since largely from GEI. Therefore, knowledge of the size of this interaction is required to (a) obtain efficient estimates of the genotypic effects and (b) determine optimum resources allocations, that is, the number of plots and locations to be included in future trials. Different concept and definition of stability and its types have been described over the last five decades.

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Plaisted (1960) modified his work and proposed a modified measure of stability to detect the \( i^{th} \) genotype from the subset was termed as the stability index of the \( i^{th} \) genotype, mathematically it may be written as.

\[
\theta(i) = \frac{SSGE}{(m-2)(n-1)} - \frac{m}{(m-1)(m-2)(n-1)} \sum (GE)^2
\]

Wricke (1962) proposed model use the contribution of each genotype to the sum of squares as a stability measure and define simple to calculated and is expressed as
\[ W_i^2 = \sum (y_{ij} - \bar{y}_i - \bar{y}_j + \bar{y})^2 \]

Thus, a genotype with the smallest euclidean was to be considered as the most stable.

A perfect measure of phenotypic stability was considered by Finlay and Wilkinson (1963) with regression coefficient, \( b_i = 0 \), of a genotype whose yield in each environment was almost the same. The observed values were regressed onto the environment indices, defined as the difference between the marginal mean of environments and the general mean. The stability measure is given by

\[ b_i = \frac{\sum_j (y_{ij} - \bar{y}_i) (\bar{y}_j - \bar{y})}{\sum_j (\bar{y}_j - \bar{y})^2} \]

Eberhart and Russel (1966) developed Finlay and Wilkinson (1963) regression concept of stability and suggested the use of two stability parameters. They proposed that the regression of each cultivar on an environmental index and a function of the squared deviations from regression would provide more useful estimate of yield stability parameters and may be given as

\[ \delta_i^2 = \frac{1}{(n-2)} \sum_j (y_{ij} - \bar{y}_i)^2 - \frac{b_i^2}{(n-2)} \sum_j (\bar{y}_j - \bar{y})^2 \]

They defined a stable genotype as the one which showed high mean yield, regression coefficient \( b_i \) around unity and deviation from regression near zero. Accordingly, of the mean and deviation from regression of each genotype were for testing the varietal response. Genotypes with high mean \( b_i > 1 \) with non-significant \( \delta_i^2 \) are considered as below average in stability such genotypes tend to respond favourably to better environments but give poor yield in unfavorable environment. Hence, they are suitable for favorable environments.

Perkins and Jinks (1968) discussed the linear sensitivity to change in environment, measured by the regression coefficient \( B_i \) was considered as stability adjusted for location effects and regression coefficient in modified form was calculated by

\[ B_i = \frac{\sum_j (GE)^2 (\bar{y}_j - \bar{y})}{\sum_j (\bar{y}_j - \bar{y})^2} \]

An additional measure of non-linear sensitivity to the environmental change was also considered by them. The GEI component of each genotype was considered as a linear function of the additive environmental component. The deviation from the regression line for each environment was treated as a fixed effect rather than random effect. The stability statistics was defined as

\[ \delta_i^2 = \frac{1}{(n-2)} \sum_j (GE)^2 - \frac{B_i^2}{(n-2)} \sum_j (\bar{y}_j - \bar{y})^2 \]

A genotype was considered stable when \( B_i = 0 \) and \( \delta_i^2 = 0 \). Shukla (1972) proposed a stability measure by partitioning the GE sum of square into component for each genotype separately. He defined the stability variance of \( i^{th} \) genotype as its variance across environments after the main effect of environment. Since the genotype main effect is constant, the stability variance is thus based on the residual matrix in a two way classification. The stability statistics is termed stability variance \( (\sigma^2) \) and is estimated as follows

\[ \sigma_i^2 = \frac{1}{(m-2)(m-1)} \sum_j (GE)^2 \]

A genotype is called stable if its stability variance is equal to environmental variance which means that \( \sigma_i^2 = 0 \). negative estimate of \( \sigma^2 \) maybe take be equal to zero as usual.

Laxmi (1992) proposed a stability measure by giving weightage to environmental conditions. The genotypes having the maximum yields in all the environments under trial are most stable and therefore stability factor had been considered the weighted men value of standardized yields over the environments.

\[ Z_i = \frac{(y_{ij} - \bar{y}_j)}{(V_{ij})} \]

and the stability factor for the genotype was defined as

\[ G_i = \sum_j w_j (y_{ij} - \bar{y}_j) / \sqrt{V_i} \]

where \( w_j \) is weight coefficient, \( V_i \) is environmental variance

For comparison she suggested the critical difference which is given by

\[ CS(G_i) = t_a \frac{M_e(n+1)^{1/2}}{nm} \]

Where \( M_e = \frac{\sum_j w_j M_j}{n} \), is the modified mean square error and \( t_a \) is student’s t-value for the given significance level. If \( G_i \geq C.D(G_i) \), the genotype having the values are characterized with higher stability. In case of \( G_i \leq CD(G_i) \), the genotypes having the values are characterized with lower stability. The remaining genotypes lying in between values are considered as having average stability.

Parmita (2012) modified the stability parameters obtained by Eberhart and Russel (1966) for neighbour effects by considering right and left neighbour effect of treatments. For the \( i^{th} \) genotype the modified stability measures are given by

\[ \beta_i^H = \frac{\sum_j y_{ij} E_i}{\sum_j E_i^2} \]

And

\[ \eta_i^2 = E_i y_{ij} - \left( \frac{\bar{y}_j^2}{n} - \frac{\sum_j y_{ij}}{n} \right) \frac{\sum_j y_{ij} E_i}{\sum_j E_i^2} \]

Where \( E_i \) is the effect of \( i^{th} \) environment. These stability measures are tested against given mean square errors.

2. Materials and Methods

The data in Table 1 is the pod yield of 15 varieties (G1,G2,...,G15) of ground nut crop raised at 20 locations (L1,L2,...,L20). The experimental design used is RCBD at each locations with three replication.[Rao et al. (2004)
Table 1: Grand Nut Crop Yield

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Plaisted’s Measure</th>
<th>Peterson’s Measure</th>
<th>Wricke’s Measure</th>
<th>Finlay and Wilkinson’s Measure</th>
<th>Eberhart and Russel’s Measure</th>
<th>Perkins and Jinks’s Measure</th>
<th>Shukla’s Measure</th>
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<tr>
<td></td>
<td>x10^7</td>
<td>x10^7</td>
<td>x10^8</td>
<td>x10^9</td>
<td>x10^9</td>
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<td>4.5567</td>
<td>3.0917</td>
<td>4.5567</td>
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<td>23.9701</td>
<td>-381.257</td>
<td>6.6350</td>
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<tr>
<td>G2</td>
<td>4.5567</td>
<td>3.0917</td>
<td>4.5567</td>
<td>-301.3285</td>
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<tr>
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<td>3.0917</td>
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<tr>
<td>G4</td>
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<tr>
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<tr>
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<tr>
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<td>4.5567</td>
<td>-301.3285</td>
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<tr>
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<td>4.5567</td>
<td>-301.3285</td>
<td>23.9701</td>
<td>-381.257</td>
<td>6.6350</td>
</tr>
</tbody>
</table>

For the data different stability measures discussed above are calculated and summarized in the Table 2. In general, the variance $S_i^2$ of a genotype across environment location has been largely used as a measure of stability with a simple logic that deviation from the average genotype effect is the rule to stability of genotype. Due to this reason, this measure is considered in first column of table 2 and calculated using

$$ S_i^2 = \frac{1}{n-1} \sum (y_{ij} - \bar{y}_i)^2 $$

Comparison between the investigated estimators is calculated by the concept of rank correlation coefficient after $\eta_s$ Spearman

$$ \eta_s = 1 - \frac{6 \sum d_i^2}{n(n^2-1)} $$

Where $d_i$ is the difference between two ranks of investigated stability measures.
3. Conclusion and Discussion

Analysis of stability is a biometrical method with great potential for characterization of the relative performance of a group of varieties under different environment conditions. A theoretical ideal, genotype, would be the one which possesses a relatively high yield and stable performance in the low yielding environments and the capacity to respond to favorable environment as well. In this way, several measures have been developed by different researchers for varying situations and conditions. The term stable variety has been to mean a variety that dose relatively the same over a wide range of environments. In other words, a stable variety performs well under adverse conditions but not so well in favorable environments, if increased inputs or technology are applied.

For the above data, different stability measures for all the fifteen genotypes are calculated and the genotype G8 is found most stable and G6 is found least stable when the genotypic variation is used as the stability measure. When the stability is calculated using the measures proposed by Plaisted and Peterson (1959), the genotype G15 is found most stable and reverse results are obtained when the Plaisted (1960) measure is used, which gives negatively correlation with the pervious. Using Wricke (1962) measure is used G15 is obtained most stable and G6 is least stable. Similarly results are obtained using statistics proposed by Shukla (1972)

When the concept of regression coefficient given by Ebarhart and Russell (1966) genotype G15 is found least stable while is found to least stable. But according to Perkins and Jinks (1968) all the genotypes G1 to G15 are in better yield environment.

References