Grain Yield Stability Analysis of Some Durum Wheat (*Triticum durum* Desf.) Genotypes Growing under Sub-humid Conditions

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**ABSTRACT**

**Background:** Assessment of yield stability of durum wheat growing under different environments has been an important issue for wheat breeder. More information about phenotypic stability is useful for the selection of adapted and stable genotypes which are suitable for wider range of planting.

**Methods:** To calculate the parametric and non-parametric index, we use the program STABILITYSOFT. The aim of this study is the selection of adapted and stable genotypes based on the use of parametric and non-parametric index.

**Result:** The graphic distribution of the genotypes tested based on the relationship between the mean grain yield and regression coefficient (bi), proved that the suitable genotypes for the tested conditions are Bidi17, Wahbi and Gta dur. The values of deviation from regression (S²reg) classified the genotype Waha, as the most desirable genotypes. The Association between Wricke's ecovarance (Wi²) indice and the grain yield proved that the best genotype for growing under these conditions are Bidi17, Wahbi and Gta dur. In addition, the non-parametric index confirmed the results which are registered by the selection based on the parametric index. Thus, the genotypes Bidi17 and Wahbi are the most stable genotypes. The classification based on the use of the principal component analysis classified the genotypes Wahbi and Bidi17 in dynamic stability group with highest grain yield. Therefore, genotypes with b values close to 1 (Wahbi, b = 0.95 and Bidi17, b = 0.98) are preferred since it is indicative of wide adaptation (dynamic stability), provided their mean yield is over the general mean. Overall, the uses of the parametric and non-parametric index are very suitable tools to select adapted and stable genotypes under sub-humid conditions.

**Key words:** Algeria, Durum wheat, Non-parametric, Parametric, Stability.

**INTRODUCTION**

Durum wheat is one of the most important cultivated plants in the world. Environmental stresses; including water stress are one of the factors in limiting wheat growth and crop productivity. It affects strongly the arid and semi arid zones, characterized by low and irregular rainfall and high temperatures. Genotype-by-environment interactions (GEI) refer to changes in genotypic performance across different environments. The presence of GEI in multi-environment trials is expressed either as inconsistent responses of different genotypes (relative to others) due to changes in genotypic rank, or as the absolute difference between genotypes without rank change (Crossa, 2012). The identification and subsequent selection of superior crop varieties in target environments are important goals of agronomic and plant breeding studies (Vaezi et al., 2018).

To identify superior varieties across multiple environments, plant breeders undertake trials across several years and locations, usually during the final developmental stages of a crop variety. Many statistical approaches have been proposed for using stability analyses to interpret GEI, all of which have been based on univariate and multivariate models (Flores et al., 1998). There are two major statistical groups for interpreting GEI by numerical analysis. The first group contains many parametric indices such as the regression coefficient (bi) (Finlay and Wilkinson, 1963); the variance of deviations from the regression (S²reg) (Eberhart and Russell, 1966), Wricke’s ecovariance stability index (Wi²) (Wricke, 1962), Shukla’s stability variance (σ²i) (Shukla, 1972), environmental coefficient of variance (CVi) (Francis and Kannenberg, 1978) and the yield stability index (YSi) (Kang, 1991). These parametric statistics are primarily used to assess genotype stability by relating observed genotypic responses (*e.g.*, yield, plant height, seed oil content) to a sample of environmental conditions (*e.g.*, rainfall, temperature, osmotic stress, soil type). The second group of analytical methods includes non-parametric methods such as Nassar and Huhn’s statistics (S¹i and S²i) (Nassar and Huhn, 1987), Huhn’s equation (S¹i and S²i) (Huhn, 1990), Thennarasu’s statistics (NP¹i) (Thennarasu, 1995). The aims of this study were to identify high yielding and stable durum wheat genotypes over different cropping seasons under sub-
humid (Eastern Algeria) based on some parametric and non-parametric index.

**MATERIALS AND METHODS**

**Plant material and field conditions**

This study was carried out with 8 durum wheat genotypes (Table 1). Field experiment was conducted during three cropping seasons at the experimental field of Technical Institute of Field Crops Constantine (ITGC), Algeria.

**Statistical analysis**

**Parametric measures**

**Regression coefficient (bi)**

The regression coefficient (bi) is the response of the genotype to the environmental index that is derived from the average performance of all genotypes in each environment (Finlay and Wilkinson, 1963). If bi does not significantly differ from 1, then the genotype is adapted to all environments. A bi > 1 indicates genotypes with higher sensitivity to environmental change and greater specificity of adaptability to high-yielding environments, whereas a bi < 1 describes a measure of greater resistance to environmental change, thereby increasing the specificity of adaptability to low-yielding environments.

**Deviation from regression (S^2_e)**

In addition to the regression coefficient, variance of deviations from the regression (S^2_e) has been suggested as one of the most-used parameters for the selection of stable genotypes. Genotypes with an S^2_e = 0 would be most stable, while an S^2_e > 0 would indicate lower stability across all environments. Hence, genotypes with lower values are the most desirable (Eberhart and Russell, 1966).

**Wricke's ecovalence stability index (Wi)**

Wricke (1962) proposed the concept of ecovalence as the contribution of each genotype to the GEI sum of squares. The ecovalence (Wi) of the i th genotype is its interaction with the environments, squared and summed across environments. Thus, genotypes with low values have smaller deviations from the mean across environments and are more stable.

**Environmental coefficient of variance (CV)**

The coefficient of variation is suggested by Francis and Kannenberg (1978) as a stability statistic through the combination of the coefficient of variation, mean yield and environmental variance. Genotypes with low CVi, low environmental variance (EV) and high mean yield are considered to be the most desirable.

**Non-Parametric measures**

**Nassar and Huhn’s non-parametric statistics**

Huhn (1990) and Nassar and Huhn (1987) suggested four non-parametric statistics. We use during this study two parameters: (1) S^{1(1)}, the mean of the absolute rank differences of a genotype over all tested environments; (2) S^{1(2)}, the sum of squares of rank for each genotype relative to the mean of ranks. The lowest value for each of these statistics reveals high stability for a certain genotype.

**Thennarasu’s non-parametric statistics**

Four NP (1-4) statistics are a set of alternative non-parametric stability statistics defined by Thennarasu (1995). We use just tow parameters (NP^{1(2)} and NP^{1(4)}). These parameters are based on the ranks of adjusted means of the genotypes in each environment. Low values of these statistics reflect high stability. The data were analyzed by the using of the online software (STABILITYSOFT) developed by Pour-Aboughadareh et al. (2019).

**RESULTS AND DISCUSSION**

**Parametric measures**

Based on the results illustrated in the Table 2, the values of regression coefficient (bi) varied from 1.51 for the genotype OTB4 to 0.14 for the genotype Cirta, which indicates that genotypes had different responses to environmental changes. As shown in the definition of this parameter, the genotypes with low values (bi < 1) are very suitable to low-yielding environments, but the contrary for the genotypes with high values (bi > 1). The both genotypes Gta dur and Bousselem are very suitable to growing under the poor condition or just under rainfall conditions.

In addition, the genotypes Citra and OTB4 have greater specificity of adaptability to high-yielding environments (irrigated conditions). Based on the results illustrated in the Fig 1, the suitable genotypes for the tested conditions are Bidi17, Wahbi and Gta dur. The values of deviation from regression (S^2_e) classified the genotype Waha as the most desirable genotypes. In addition, genotype Bidi17 have regression coefficient (bi) values close to unity (0.978) with small deviation from regression (S^2_e = 0) and above average yield and thus possessed fair stability and wider adaptation over different environment. Genotypes with high mean yield, a regression coefficient equal to the unity (ibi = 1) and small deviations from regression (S^2_e = 0) are considered stable (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966).

The genotype Waha also have regression coefficient close to unity (0.978) and minimum deviation from regression (0.01), but its average yield is lower than the mean yield, which was not wider adaptive. The selections of adapted and stable genotypes based on the Wricke's...
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Table 2: Parametric, Non-parametric stability index and Mean grain yield (Q/ha) for the durum wheat genotypes tested under sub-humid conditions.

| Genotype  | Parametric index | Genotype  | Non-Parametric index | Mean Grain Yield (Q/ha) |
|-----------|------------------|-----------|----------------------|-------------------------|
|           | bb²              | S²db²     | Wb²                  | CVi         | S⁽¹⁾ | S⁽²⁾ | NP⁽²⁾ | NP⁽⁴⁾ |                     |
| Vitron    | 0.945            | 0.666     | 5.295                | 31.176      | Vitron | 2.000 | 1.000 | 0.733 | 0.600 | 31.163 |
| Gta dur   | 0.885            | 1.869     | 15.790               | 28.148      | Gta dur | 2.000 | 0.714 | 0.556 | 0.429 | 33.220 |
| Waha      | 0.978            | 0.010     | 0.175                | 32.444      | Waha    | 1.333 | 0.667 | 0.500 | 0.444 | 30.620 |
| Cirta     | 1.453            | 0.865     | 48.490               | 43.627      | Cirta   | 4.667 | 1.294 | 0.370 | 0.824 | 34.077 |
| Bidi 17   | 0.987            | 0.190     | 1.366                | 28.840      | Bidi 17 | 2.000 | 0.455 | 0.259 | 0.273 | 34.893 |
| Wahbi     | 0.959            | 0.300     | 2.455                | 26.709      | Wahbi   | 0.000 | 0.000 | 0.250 | 0.000 | 36.657 |
| OTB4      | 1.513            | 0.561     | 58.320               | 50.305      | OTB4    | 4.000 | 1.538 | 0.667 | 0.923 | 30.687 |
| Bousselem | 0.146            | 0.569     | 54.494               | 7.138       | Bousselem | 5.333 | 2.909 | 0.593 | 1.455 | 28.677 |
| Mean      | 0.983            | 0.629     | 35.798               | 31.049      | Mean    | 2.667 | 1.072 | 0.491 | 0.618 | 32.499 |
| Min       | 0.146            | 0.010     | 0.175                | 3.138       | Min     | 0.000 | 0.000 | 0.250 | 0.000 | 28.677 |
| Max       | 1.513            | 1.869     | 154.494              | 50.305      | Max     | 5.333 | 2.909 | 0.733 | 1.455 | 36.857 |

bi: Regression coefficient, S²db²: Deviation from regression, Wb²: Wricke’s ecovalence index, CVi: Environmental coefficient of variance, S⁽¹⁾ and S⁽²⁾: Nassar and Huhn’s non-parametric statistics, NP⁽²⁾ and NP⁽⁴⁾: Thennarasu’s non-parametric statistics.

ecovalence stability index (W⁽²⁾) demonstrate that the genotypes Waha and Bidi17 have smaller deviations from the mean across cropping seasons and are more stable. Bousselem genotype displayed high ecovalence and is classified as unstable genotype. The graphic classification based on the relationship between Wricke’s ecovalence and the grain yield proved that the best genotypes for growing under these conditions are Bidi17, Wahbi and Gta dur (Fig 2). In contrary, based on the environmental coefficient of variance (CVi) the genotype Bousselem is very stable. Many studies proved the efficiency of using the parametric measures cited below in the selection of stable durum wheat genotypes (Guendouz and Hafsi, 2017; Hannachi et al., 2019). Overall, the selection based on the parametric index showed that the genotypes Bidi17, Wahbi and Gta dur are the best genotypes for growing under the climatic effects of the tested areas.

Non-Parametric measures

The nonparametric measure S⁽¹⁾ (Nassar and Huehn, 1987) is based on the ranks of cultivars across environments and it gives equal weight to each environment. Accordingly, S⁽¹⁾ of the tested genotypes revealed that Wahbi and Waha are the most stable genotypes with the lowest S⁽²⁾ values over all cultivars. Hover, Bousselem and Cirta had the highest S⁽¹⁾ values and hence, they were classified as unstable cultivars (Table 2). The values of S⁽³⁾ nonparametric statistic, which combined yield and stability based on yield ranks of genotypes in each environment (Nassar and Huehn, 1987), ranged from 0.00 for Wahbi to 2.9 for the genotype Bousselem. Based on S⁽³⁾, the cultivars Wahbi and Bidi17 were considered to be the most stable with highest mean yield. The results illustrated in the Table 2, showed that the both genotypes Wahbi and Bidi17 have the lowest values for the Thennarasu’s non-parametric statistics with highest grain yield over all genotypes tested. In addition, these results proved that the genotypes Wahbi and Bidi17 are the suitable genotypes for growing under these conditions.

Association among stability parameters

As illustrated in the Table 3, significant correlation registered between the different indexes. Many studies revealed that S⁽¹⁾ and S⁽²⁾ were positively and significantly correlated with each other and with NP⁽²⁾ and NP⁽⁴⁾ (Pour-Aboughadareh et al.,...
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Fig 2: The relationship between the Wricke’s ecovalence stability index ($W_i^2$) and mean grain yield (Q/ha) for the durum wheat genotypes.

Table 3: Association among stability parameters tested during this study.

| Variables          | Parametric index | Non-parametric index |
|--------------------|------------------|----------------------|
|                    | $b_i$            | $S^2d_i$             | $W_i^2$ | CVi   | $S^{(1)}$ | $S^{(6)}$ | NP$^{(2)}$ | NP$^{(4)}$ |
| $b_i$              | 1                |                      |        |       |           |           |            |            |
| $S^{2d}_i$         | 0.0074           | 1                    |        |       |           |           |            |            |
| CVi                | 0.0834           | 0.2178               | 1      |       |           |           |            |            |
| $W_i^2$            | **0.9833**       | 0.0204               | 0.1614 | 1     |           |           |            |            |
| $S^{(1)}$          | -0.0800          | 0.1877               | **0.9085** | 0.0006 | 1        |           |            |            |
| $S^{(6)}$          | -0.4354          | 0.0956               | **0.8043** | -0.3258 | **0.8950** | 1        |            |            |
| NP$^{(2)}$         | -0.1122          | 0.3000               | 0.3456 | 0.0526 | 0.3659   | 0.5335   | 1          |            |
| NP$^{(4)}$         | -0.3126          | 0.1139               | **0.8428** | -0.1953 | **0.9303** | **0.9892** | 0.5709 | 1          |
| Grain Yield        | 0.3724           | 0.0297               | -0.4592 | 0.2036 | -0.5698 | -0.7832 | -0.8157 | -0.7953 |

$b_i$: Regression coefficient, $S^2d_i$: Deviation from regression, $W_i^2$: Wricke’s ecovalence index, CVi: Environmental coefficient of variance, $S^{(1)}$ and $S^{(6)}$: Nassar and Huhn’s non-parametric statistics, NP$^{(2)}$ and NP$^{(4)}$: Thennarasu’s non-parametric statistics.

During this study, significant and positive correlation registered between $S^{(1)}$ and $S^{(6)}$ ($r = 0.89^{**}$) and among $S^{(6)}$ and NP$^{(4)}$ ($r = 0.98^{***}$). This significant positive correlation between these stability parameters suggests that these parameters would play similar roles in stability ranking of genotypes as previously reported (Kilic, 2012). The significant and negative correlations between the grain yield and $S^{(6)}$, NP$^{(2)}$ and NP$^{(4)}$ suggest that the selection based on these stability parameters would be less useful when yield is the primary target of selection. As shown in Table 3, the Wricke’s ecovalence stability index ($W_i^2$) registered positive and significant correlation with $S^{(1)}$ and $S^{(6)}$, which suggests that these parameters would play similar roles in stability ranking of genotypes. In addition, significant and positive correlation is registered between $W_i^2$ and NP$^{(4)}$ ($r = 0.84^{**}$), but there was no significant correlation between the mean grain yield and all parametric index.

Principal component analysis of the rank correlations

For the best understanding of the associations among both parametric and nonparametric stability parameters, we use the principal component analysis (PCA) based on the rank correlation matrix (Fig 3). The results of this analysis proved that the first and second principal components of the rank correlation accounted for 52.7 % and 23.19 % of the variation, respectively, making a total of 75.89% of the original variance among the stability parameters. Many studies have been reported like these results in durum wheat viz., Kilic et al. (2010) and barley (Mut et al., 2010).

Becker and Leon (1988) suggested grouping the measures of yield stability into static and dynamic approaches. Based on the Fig 3, the stability parameters were separated into two stability concepts: at left, parameters that corresponded with the dynamic/agronomic stability concept were assigned to two subgroups and at right, the remaining stability parameters corresponding with the static/biological stability concept were assigned to one subgroup. The principal component analysis classified the genotypes Wahbi and Bidi17 in dynamic stability group with highest grain yield. Therefore, genotypes with $b$ values close to 1 (Wahbi, $b = 0.95$ and Bidi17, $b = 0.98$) are preferred since they are indicative of wide adaptation (dynamic stability), provided their mean yield is over the general mean. In contrary, the genotypes Cirta, Bousselem and OTB4 were classified in static stability group but with lowest mean grain yield. The static genotypic stability exists when a stable
genotype possesses consistent performance at various environmental conditions. This type of stability may not be desired by farmers because this concept of stability means that a genotype would not show any response to different levels of inputs such as fertilizer, temperature and humidity (Becker and Leon, 1988).

CONCLUSION

Based on the mean grain yield of each genotypes tested in comparison with the general grain yield, the genotypes Wahbi, Bidi17, Cirta and Gta dur had the highest grain yield. The selection of adapted and stable genotypes based on the parametric index proved that the genotypes Wahbi and Bidi17 are the most stable genotypes with highest grain yield over all genotypes tested. In addition, the classification of genotypes studied based on the Non-parametric index showed that the genotypes Wahbi and Bidi17 are the most stable genotypes with highest grain yield. In addition, the principal component analysis classified the genotypes Wahbi and Bidi17 in dynamic stability group with highest mean grain yield. In contrary, the genotypes Cirta, Boussemel and OTB4 are classified in static stability group but with lowest mean grain yield. The results of this study revealed that the parametric and Non-parametric methods proved to be suitable tools to identify the most stable genotypes at various environmental conditions.

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