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STUDY OF GRAIN YIELD STABILITY OF TWO WHEAT SPECIES (DURUM AND BREAD) GROWN IN SEMI-ARID ENVIRONMENTS

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ABSTRACT :

Stability, a key concept in agricultural research, is used to analyze genotype-environment interactions (GEI) by examining the variance across different environments. A field experiment was conducted in the semi-arid region of eastern Algeria over five growing seasons (2015-2020) to assess the stability of grain yield in two cereal crops (durum wheat and bread wheat) and identify genotypes yielding high and consistent yields. Parametric indices, calculated using the STABILITYSOFT program, were used for this purpose. Based on various stability indices such as Wricke's ecovalence (Wi2), Shukla's stability variance (σ2i), and the GE variance component (θ(i)), the bread wheat genotypes Wifak and HD1220 demonstrated stability over the growing seasons. The Waha genotype exhibited high stability and adaptability with a significant average grain yield, according to the regression coefficient (bi). The relationships between different stability statistics placed the Bousselem and Waha genotypes in the dynamic stability group with the highest grain yield. In conclusion, the durum wheat genotype MBB was found to be the most stable and well-adapted to semi-arid conditions, combining high grain yield and stability indices.

Keywords : Algeria, wheat, stability, parametric.

1. Introduction

Climate change, due to its sensitivity to environmental factors, poses significant challenges to agriculture, particularly crop production. Fluctuations in precipitation patterns, temperature variations, and extreme weather events create uncertainty in crop yields, making it difficult to maintain stable food production (Molnár & Molnárné, 2015). In Algeria, cereal cultivation covers approximately 3.6 million hectares annually, dominating the agricultural sector. Cereal production is estimated at around 3.5 million tonnes, with durum wheat accounting for 45%, barley for 28%, and bread wheat for 24% (Benbelkacem, 2013). The term "stability" in plant breeding refers to genotypes that exhibit consistent yields across different environments. This concept can be considered a static notion of stability, aligning with the idea of homeostasis in quantitative genetics (Becker & Leon, 1988). However, in improved cultivation conditions, a genotype consistently performing across environments doesn't necessarily translate to increased yield. Through multi-environment trials (MET), evaluating yield stability plays a crucial role in selecting superior varieties and agronomic practices for future use (Mohammadi et al., 2010). To interpret genotype-environment interactions (GEI), statistical analysis of parametric indices is employed. These indices include the variance of deviations from regression (S^2di), Wricke's ecovalence stability index (Wi^2), Shukla's stability variance (σi^2), the regression coefficient (bi), and the environmental coefficient of variation (CVi). These indices rely on assumptions regarding the distribution of genotypic, environmental, and GxE effects. This study aims to utilize these parametric indices to compare the yield stability of two cereal crops (durum wheat and bread wheat) and identify high-yielding and stable genotypes in the semi-arid conditions of eastern Algeria.

2. Materials and methods

2.1.Plant material and field conditions

The experiment was conducted at the LARBI ABASSI pilot farm located in BORDJ BOU ARRERIDJ, eastern Algeria, with coordinates 4°76’E, 36°06’N, at an altitude of 930 meters above sea level. This area experiences a variable climate characterized by cold springs and drought towards the end of the plant growth cycle, accompanied by hot winds known as sirocco (Chourghal, 2016). The farm has moderately deep sandy-clay loam soils with low organic matter content and high calcium carbonate content, resulting in alkaline pH levels. Two cereal species were included in the study: durum wheat with three genotypes (Bousselem, Mohamed Ben Bachir (MBB), and Waha) and bread wheat with two genotypes (HD1220 and Wifak). These varieties were chosen because they are commonly used by farmers in the region and exhibit distinct productivity potentials. The experiments were conducted under rainfed conditions for five agricultural campaigns from 2015 to 2020 (Table 1 provides further details on genotypes and experimental conditions). A randomized complete block design with three replications was used, with a plot size of 7.2 m² (6 rows with a spacing of 20 cm and a row length of 6 m).

Table 1. Genotype name and origin, growing season, and precipitation.

Genotype	Specie	Origine	Cropping season	Railfull
Boussalem	Triticum turgidum var. durum	CIMMYT-ICARDA	2015-2016	237,74
MBB	Triticum turgidum var. durum	INRA Algeria	2016-2017	341,35
Waha	Triticum turgidum var.	CIMMYT	2017-2018	339,08

	durum			
HD1220	Triticum aestivum L.	ITGC Sétif	2018-2019	280,07
Wifak	Triticum aestivum L.	Cimmyt	2019-2020	243,97

2.2. Statistical procedures

To assess the stability of genotypes in this study, we followed the concept of stability proposed by Eberhart and Russell (1966) and calculated two parametric indices. Firstly, the regression coefficient (bi) was calculated, where a bi value of 1 indicates average adaptation to all environments. A bi value greater than 1 suggests adaptability to favorable conditions, while a bi value less than 1 indicates adaptability to unfavorable conditions. Secondly, the variance of deviations from regression (S^2di) was calculated, where a stable genotype would have a S^2di value of 0, while a higher S^2di value indicates less stability across environments. Therefore, genotypes with lower S^2di values were considered more desirable. The ecovalence index (Wi^2), proposed by Wricke (1962), was also used to estimate stability, representing the contribution of a genotype to the sum of squares of the interaction. A lower value of Wi^2 indicated higher relative stability. Stability was also assessed by combining the coefficient of variation (CV) and the mean yield, where genotypes with low CV and high yield were considered preferable (Francis & Kannenberg, 1978). Shukla's stability variance (σ^2i) (1972) quantified the variance of genotype i across environments after removing the main effects of environmental means. Genotypes with the minimum values of σ^2i were considered more stable. The genotype-environment interaction variance component (θi) was proposed by Plaisted and Peterson (1959) as a measure of stability. A lower value of θi indicated greater stability. Similarly, the GE variance component $\theta(i)$ was calculated by removing the ith genotype from the dataset and evaluating the GEI variance of the remaining subset. Genotypes with higher values of $\theta(i)$ were considered more stable. The data were analyzed using the online software STABILITYSOFT, developed by Pour-Aboughadareh et al. (2019).

3. Results and discussion

3.1Mean yield and stability performance

To analyze the stability of wheat cultivation, data on average genotypic yield and stability indices (Table 2) were used. The regression coefficient (bi) values ranged from 1.084 for the Waha genotype to 0.88 for the HD1220 genotype, indicating that each species responded differently to environmental changes. The interpretation of this parameter suggests that genotypes with high values (bi > 1) show greater adaptability specificity to high-yielding environments, as in the case of the durum wheat genotypes Waha and Bousselem. Conversely, genotypes with low values (bi < 1) exhibit greater resistance to environmental fluctuations and are better adapted to low-yielding environments, as observed for the bread wheat genotypes HD1220 and Wifak. The graphical distribution (Figure 1) between the regression coefficient and the average grain yield of the studied species confirmed that the MBB and Bousselem genotypes have a positive environmental effect on their yield, suggesting good adaptation to environmental conditions. They are the most stable and adaptable, exhibiting high grain yield under these conditions. The intra-varietal coefficient of variation (CVi) parametric index indicates that the HD1220 genotype is classified as unstable because it displays a high CVi value and the lowest grain yield (1.18). This analysis revealed that among the adapted and stable genotypes with high grain yield under these conditions, Bousselem and Waha are found. According to the criteria defined by Finlay and Wilkinson (1963) and Eberhart and Russell (1966), which define stable genotypes as those with high average yield, a regression coefficient equal to unity (bi = 1), and low deviations from regression (S^2di = 0); Mohamed Ben Bachir (MBB) can be considered the most stable genotype with the lowest CVi value (51.75), a bi value close to unity (1.06), a null S²di value, and an average grain yield of 1.46 (compared to the overall average of 1.38). The values of deviations from regression (S²di) also classified the MBB genotype as the most desirable with low sensitivity to environmental variations. Moreover, the selection of adapted and stable genotypes based on Wricke's ecovalence stability index (Wi²), Shukla's stability variance (σ²i), the GE variance component (θ(i)), and the average variance component (θi) revealed that the durum wheat genotype MBB had lower deviations from the mean across growing seasons and showed greater stability (Table 2). In contrast, the Waha and HD1220 genotypes displayed high values and were classified as unstable genotypes under these conditions. Several studies have validated the effectiveness of using these parametric indices to select adapted and stable wheat genotypes (Benkadja et al., 2022; Guendouz & Hafsi, 2017).

Table 2: Average grain yield (t.ha⁻ ¹) and parametric stability index for the two cereals tested under semi-arid conditions

Genotype	Y	b_i	CVi	s^2d_i	W_i^2	σ^2_i	$\theta_{(i)}$	θ_i
Bousselem	1,484	1,083	52,341	0,002	0,030	-0,001	0,052	0,032
MBB	1,466	1,061	51,751	0,000	0,009	-0,010	0,054	0,029
Waha	1,554	1,084	53,043	0,045	0,329	0,123	0,021	0,079
HD1220	1,182	0,880	56,628	0,030	0,236	0,085	0,030	0,064
Wifak	1,217	0,892	52,937	0,005	0,056	0,009	0,049	0,036

Y : Mean grain yield (t.ha^{-1}), Wi²: Wricke's ecovalence index, σ^2_i : Shukla's stability variance, bi: Regression coefficient, S²di: Deviation from regression, , CVi: Environmental coefficient of variance, $\theta_{(i)}$: GE variance component, θi : Mean variance component

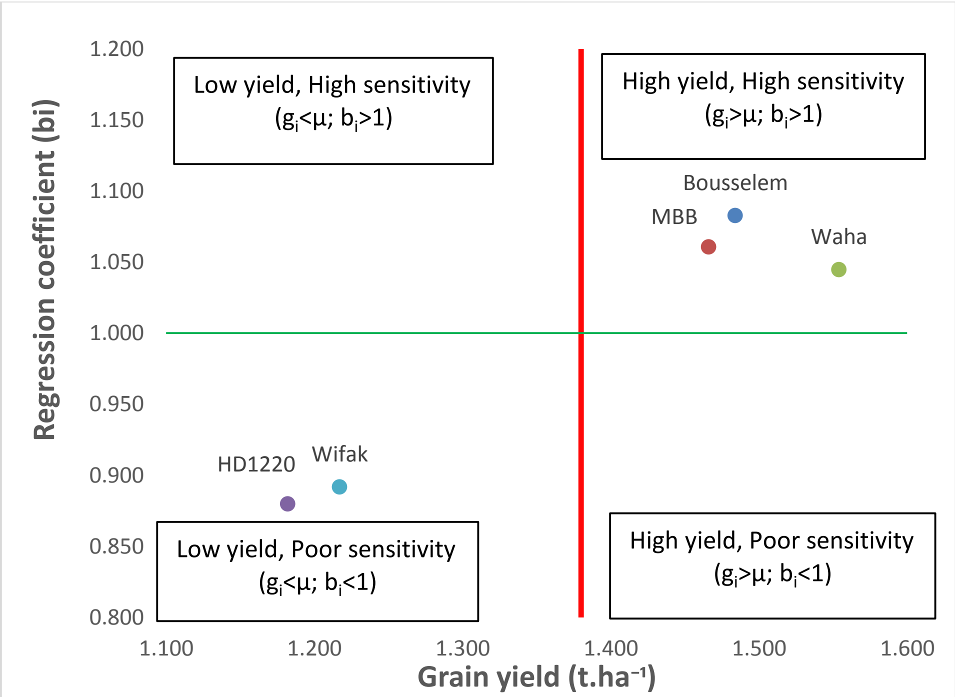

Figure 1: Relationship between regression coefficients and average grain yield (t.ha⁻ ¹) for tested genotypes

3.2.Stability indices and genotype ranking

The ranking of genotypes provides a comprehensive overview of each genotype's performance for each parameter. It allows for comparing genotypes and identifying the most successful ones for each criterion. The analysis of stability parameters revealed similarities in genotype ranking, indicating that different stability parameters have varying abilities to discriminate between genotypes. Among the parametric indices (Wi^2, $\sigma^2 i$, θ(i), and θi), similar genotype rankings were observed (Table 3). Both durum wheat varieties, Bousselem and MBB, rank first for all parameters, suggesting they are high-performing genotypes for most of the studied criteria. They exhibit good yield (Y), low variance due to the environment ($s^2 d_i$), a positive environmental effect (b_i), and low intra-varietal variance (W_i^2). These genotypes appear to be a good choice for maximizing yield and stability. The two bread wheat varieties, Wifak and HD 1220, rank in the middle for most parameters, indicating they are average genotypes in terms of performance. In contrast, Waha ranks last for most parameters, suggesting it is a less successful genotype than the others. It has a high yield (Y) but exhibits high variance due to the environment ($s^2 d_i$), a positive environmental effect (b_i), and high intra-varietal variance (W_i^2) (Table 3).

Table 3: Comparison of stability indices in discriminating genotypes within and between cultivated species

Genotype	Y	W_i^2	σ^2_i	$s^2 d_i$	CVi	$\theta_{(i)}$	θ_i
Bousselem	2	2	2	2	2	2	4
MBB	3	1	1	1	1	1	5
Waha	1	5	5	5	4	5	1
HD1220	5	4	4	4	5	4	2
Wifak	4	3	3	3	3	3	3

Y : Mean grain yield ($t.ha^{-1}$), Wi^2: Wricke's ecovalence index, σ^2_i: Shukla's stability variance, bi: Regression coefficient, $S^2 di$: Deviation from regression, , CVi: Environmental coefficient of variance, $\theta_{(i)}$: GE variance component, θi : Mean variance component

3.3.Interrelations between stability measures

Table 4 illustrates the Spearman rank correlation coefficients between the parametric stability indices and the mean yield. Strong correlations were observed between several important relationships, including b_i, CVi, and mean grain yield, constituting Group 1. Another group, designated as Group 2, consists of Wi^2, $\sigma^2 i$, $s^2 di$, θ(i), and θi (Table 4). Our results align with those of Bouchareb and Guendouz (2021), suggesting that selection based on these stability parameters might be less valuable when the primary selection objective is yield. Becker and Leon (1988) proposed categorizing yield stability measures into static and dynamic approaches to describe how genotypes respond differently to varied environments. In our study, the coefficient of variation (CVi) was moderately correlated with the parametric indices Wi^2, $\sigma^2 i$, $s^2 di$, θ(i), and θi. According to Kilic (2012), this suggests that these parameters play similar roles in classifying the stability of genotypes. The indices in Group 1 are strongly correlated with mean yield and are associated with the dynamic concept of stability, while the indices in Group 2 are not related to mean yield and can be defined in terms of homeostasis. Our findings are consistent with those of Mohammadi et al. (2010), who conducted a study in Iran involving three crops (durum wheat, bread wheat, and barley) and found no association between the group comprising Pi, GAI, and grain yield, and the group comprising ASV, $S^2 di$, and Wi^2. Static genotypic stability refers to a stable genotype that consistently performs well under diverse environmental conditions. However, farmers might not prefer this type of stability as it implies that a genotype would not respond to different levels of inputs such as fertilizers, temperature, and humidity (Becker and Leon, 1988).

Table 4: Spearman rank correlation coefficients between mean yield and stability parameters tested during this study

	Y	**W_i^2**	**σ^2_i**	**s^2d_i**	**bi**	**CVi**	**$\theta_{(i)}$**	**θ_i**
Y	1	0,05	0,05	0,11	0,99	-0,68	-0,05	0,05
W_i^2		1	1	1	-0,06	0,56	-1	1
σ^2_i			1	1	-0,06	0,56	-1	1
s^2d_i				1	-0,01	0,52	-1	1
bi					1	-0,7	0,06	-0,06
CVi						1	-0,56	0,56
$\theta_{(i)}$							1	-1
θ_i								1

4. Conclusion

An analysis of the stability of two wheat cultivars was conducted using data on average grain yield and parametric stability indices. The durum wheat genotypes, Mohamed Ben Bachir and Bousselem, exhibited the highest yield capabilities, and the selection of stable and adapted genotypes based on parametric indices consistently ranked them as the most stable. The relationships between the different stability statistics revealed that the Waha genotype is classified in the dynamic stability group due to its high grain yield and parametric index bi value. The bread wheat genotypes, Wifak and HD1220, with acceptable grain yield, were placed in the static stability group, determined by the indices W_i^2, σ^2_i, s^2d_i, and θi. The results of this study indicate that parametric methods were effective in identifying stable genotypes under various environmental conditions.

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