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RESEARCH ARTICLE — Agricultural Science Digest

Efficiency of Parametric and Non Parametric Indices as the Indicators of Grain Yield Stability of Bread Wheat (*Triticum aestivum* L.) Genotypes under Rainfall Conditions

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10.18805/ag.DF-537

ABSTRACT

Background: Under rainfall condition, stability of grain yield in diverse environments has been one of the most important objectives of breeding programs. Stability analysis is the best method to test the relative performance of genotypes over environments. Thus the aims of this study are to select adapted and stable bread wheat genotypes based on some parametric and non-parametric index.

Methods: The experiment was conducted during the four consecutive agricultural seasons (2016-17, 2017-18, 2018-19 and 2019-20) at the level of the experimental station of Setif (ITGC). Eight genotypes of bread wheat were tested following Stability soft program to calculate the parametric and non-parametric indices.

Result: The association between Wricke's ecovalence (Wi^2), the mean variance component (θ_i) and the Stability variance (σ^2_i) indices with respect to grain yield revealed that G1. G2. Hidhab. Arz. Wifak and Ain Abid are suitable genotypes for growing under variable environmental conditions. In addition, selection based on the non-parametric index and the combination selection based on highest grain yield with the parametric and non parametric indices proved that the genotypes G1. G2 and Wifak are more stable and adapted genotypes under semi-arid conditions. Further, based on the static and dynamic concepts, the parametric indices, bi and CVi are related to the dynamic concept, while the other indices are associated with static stability concept. Overall, the results of this study confirmed that the parametric and Non-parametric methods are suitable tools to identify the most stable bread wheat genotypes under various environmental conditions.

Key words: Bread wheat, Grain yield, Non-parametric, Parametric, Stability.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) (2n = 6× = 42). A self-pollinating crop belonging to the Poaceae family is the largest grown cereal crop in the world (Sharma *et al*., 2019). It is one of the most important sources of energy and protein as well as vitamins and other beneficial compounds, not only for humans, but also as animal feed worldwide. Based on the area occupied, productivity and the leading position it occupies in the international food grain trade it is popularly known as 'Stuff of life or King of the cereals'. It occupies 17% of the world's global cropping area, feeding about 40% of world's population and providing 20% of the total food calories (Gupta *et al*. 2008).

Increasing environmental stress, due to climate change affects both yield and quality of wheat in many regions of the world. Drought as well as GEI among them is the leading abiotic stress constraint limiting wheat productivity (Daryanto *et al*., 2016) and it is reflected in the annual variations in wheat grain yield. Development of varieties adaptable to a wide range of environments is the pivotal objective of the plant breeders in a crop improvement program (Lin and Binns, 1988). However, in semi-arid condition, grain yield stability is one of the most important goals of breeding programs and its analysis offers the best solution to judge the relative performance of genotypes under variable environments. There are various stability parameters to evaluate the adaptation and stability of bread wheat (Gadisa and Abebe. 2020). Several parametric and nonparametric statistical measurements are available to study GEI (Mohammadi *et al*., 2010). Therefore, the objective of the present study is to evaluate the adaptability and stability of some genotypes of bread wheat based on the some parametric and non-parametric methods and simultaneously to evaluate the efficacy of these methods.

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How to cite this article: Bendada, H., Mehanni, O., Louahdi, A.N., Selloum, S., Guemaz, S., Frih, B. and Guendouz, A. (2023). Efficiency of Parametric and Non Parametric Indices as the Indicators of Grain Yield Stability of Bread Wheat (*Triticum aestivum* L.) Genotypes under Rainfall Conditions. Agricultural Science Digest. doi:10.18805/ag.DF-537

Submitted: 03-02-2023 **Accepted:** 03-07-2023 **Online:** 20-07-2023

MATERIALS AND METHODS

Plant material and field conditions

The field experiment with eight genotypes of bread wheat (04 local landraces and 04 introduced genotypes) was conducted during four consecutive cropping seasons (2016-2017. 2017-2018. 2018-2019 and 2019-2020) at the experimental field of ITGC. Setif. Algeria (5°20′E. 36°8′N. 958 m above mean sea level). The genotypes coded as G1. G2. G3 and G4 are collections from CIMMYT and the genotypes from G5 to G8 are local collection from Algeria. A completely randomized block design (CRBD) with four replications was employed in the present study. The seeds were sown using an experimental drill in 1.2 m × 5 m plot each consisting of 6 rows with a row space of 20 cm and the seeding rate was about 300 seeds per m^2. The sowing dates for the four seasons were 23 November 2016, 11 December 2017, 03 December 2018 and 02 December 2019 respectively. The soil was classified as silty clay. The cumulative rainfall recorded during the four years of experimentation is 195.12, 442.1, 346.6 and 360.26 mm respectively. The pedigree and the origin of the genotypes tested during this study are given in Table 1.

Statistical analysis

Parametric measures

The parametric approach including the indices such as the regression coefficient (bi; Finlay and Wilkinson. 1963), variance of deviations from the regression (S^2di; Eberhart and Russell, 1966), Wricke's ecovalence stability index (Wi^2; Wricke, 1962), Shukla's stability variance (σi^2; Shukla, 1972), environmental coefficient of variance (CVi; Francis and Kannenberg. 1978) and mean variance component (θ_i; Plaisted and Peterson, 1959) were used in the present study.

Non-parametric measures

Huhn (1990) and Nassar and Huhn (1987) suggested four non-parametric statistics. In the present study three parameters: (1) $S^{(1)}$. The mean of the absolute rank differences of a genotype over all tested environments; (2) $S^{(3)}$. The sum of the absolute deviations for each genotype relative to the mean of ranks and (3) $S^{(6)}$, the sum of squares of rank for each genotype relative to the mean of ranks were used. The lowest value for each of these statistics reveals high stability for a certain genotype. Further, there are four NP (1-4) statistics defined by Thennarasu (1995) considered as a set of alternative non-parametric stability statistics. In the present study three parameters $NP^{(1)}$, $NP^{(2)}$ and $NP^{(4)}$) were used. These parameters are based on the ranks of adjusted means of the genotypes in each environment. Low values of these statistics reflect high stability.

Stability software analysis

The data were analyzed the using new online software (Stability soft) to calculate parametric and non parametric stability statistics for crop traits developed by Pour-Aboughadareh *et al*. (2019).

RESULTS AND DISCUSSION

Parametric measures

The values of mean grain yield and the stability parameters for the genotypes tested in this study are presented in Table 2. The regression coefficient (bi) is the response of the genotype to the environmental index derived from the average performance of all genotypes in each environment (Finlay and Wilkinson, 1963). When bi does not significantly differ from 1, the genotype is adapted to all environments. In the present experiment values of regression coefficient (bi) varied from 1.33 for the genotype G3 to -0.12 for G4. Therefore, this variation in regression coefficients indicates that genotypes had different responses to environmental changes. According to Pour-Aboughadareh *et al*. (2019) genotypes with a regression coefficient equal to zero (bi<1) are very suitable to grow under low yield environments which is in contrary to the genotypes with high values (bi>1). Therefore, it may be stated that the genotype G4 is very suitable to grow under poor condition or just under rainfall conditions would be G4, but the grain yield of this genotype is lowest among all other genotypes. The genotypes G1, G2, G3 and the local landraces (Hidhab, Arz, Wifak, Ain Abid) have greater specificity of adaptability to high-yielding environments (Irrigated conditions). According to Megahed *et al*. (2018) genotypes with regression coefficient greater than unity would be better adapted to more favorable environments conditions.

In addition to the regression coefficient, variance of deviations from the regression (S^2di) has been suggested as one of the most-used parameters for the selection of stable genotypes. The genotypes with an $S^2di = 0$ would be most stable, while an $S^2di > 0$ would indicate lower stability across the environments. Hence, genotypes with lower values for this parameter are the most desirable (Eberhart and Russell, 1966) ones. The values of (S^2di) classified the local landrace Wifak as the most desirable genotypes with mean grain yield (41.59 Q/ha) higher than the general mean of grain yield (41.29 Q/ha). The graphical distribution (Fig 1) between the S^2di and the mean grain yield of tested genotypes proved that the genotypes G1. G2 and Wifak have lowest value of S^2di and high mean grain yield (>average grain yield). According to Eberhart and Russell (1996), a genotype is considered as stable if it possesses a high mean grain yield, regression coefficient (bi) value close to the unity (bi = 1) and deviation from regression (S^2di) does not differ significantly from zero. The local landrace Wifak has regression coefficient close to unity (1.18) and small deviation from regression (0.25) and its average grain yield (41.59 Q/ha) which is higher than the general mean yield (41.29 Q/ha) and accordingly might be considered as having wider adaptability. Besides Wifak, the genotype G1 with very low regression coefficient highest yield and very low value of S^2di may also be considered as to possess very wide adaptability. 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. Shukla (1972) suggested the stability variance of genotype i as its variance across environments after the main effects of environmental means have been removed. According to this statistic, genotypes with minimum values are intended to be more stable. The combination between the Wricke's ecovalence stability index (Wi^2) on the one hand and the Stability variance (σ^2_i) on the other the mean grain yield of tested genotypes demonstrate that the adapted and stable genotypes with high mean grain yield under these conditions are G1, G2 and the local landraces (Hidhab, Arz, Wifak, Ain Abid). The genotype G4 showed high values of ecovalence

Table 1: Genotype code, their pedigree and origin of each genotype evaluated in this study.

Code	Variety/Pedigree	Origin
G1	YAMAMA/SD8036ICW96-0245-030AP-0APS-030AP-0APS-6AP-0APS-0DZ/0AP-0DZ/0KUL/0SIN/0AP-ONJ/OAP-OALK/OAP	CIMMYT
G2	4WON-IR-257/5/YMH/HYS//HYS/TUR3055/3/DGA/4/ VPM/MOSTCI-02-80-0AP-0AP-42AP-0AP-3AP-0AP	CIMMYT
G3	MUU/3/KIRITATI//ATTILA*2/F>AST () R/4/MUUCMSS07B00619T-099TOPY-099M-099Y 099M-1WGY-OB	CIMMYT
G4	OUAIU/5/FRET2*2/4/SNI/TRAP#I/3/KAUS*2/TRAP//...CMSS06B00109S-0Y-099ZTM-099N	CIMMYT
G5	HIDHAB (HD 1220)	Algeria
G6	ARZ	Algeria
G7	WIFAK	Algeria
G8	AIN ABID	Algeria

Table 2: Parametric non-parametric stability index and mean grain yield (Q/ha).

Genotype	b_i	S^2d_i	W_i^2	σ^2_i	CVi	θ_i	Mean grain yield
				Parametric index			
G1	1.11	1.631	26.60	-5.39	47.55	65.35	45.60
G2	1.16	6.94	77.80	17.35	53.06	75.10	43.01
G3	1.33	14.23	225.10	82.82	68.93	103.16	38.37
G4	-0.12	12.23	1517.22	657.09	18.55	349.28	31.78
Hidhab	1.05	13.43	97.69	26.19	48.85	78.89	43.39
Arz	1.14	9.33	90.27	22.89	54.61	77.48	41.59
Wifak	1.18	0.25	39.93	0.52	55.12	67.89	41.59
Ain abid	1.12	11.07	95.67	25.29	49.77	78.51	44.99
Mean	0.99	8.63	271.28	103.34	49.55	111.95	41.29
Max	1.33	14.23	1517.22	657.09	68.93	349.28	45.60
Min	-0.12	0.25	26.60	-5.39	18.55	65.35	31.78
Correlation with GY	0.779*	-0.405ns	-0.901**	-0.901*	0.538ns	-0.901**	//
				Non-parametric index		Mean	
	$S^{(1)}$	$S^{(3)}$	$S^{(6)}$	$NP^{(2)}$	$NP^{(3)}$	$NP^{(4)}$	Grain yield
G1	0.5	0.12	0.24	0.29	0.13	0.08	45.60
G2	1.83	1.58	1.17	0.31	0.53	0.43	43.01
G3	3.66	8.28	2.57	1	0.71	1.04	38.37
G4	3	4.5	1.5	1	0.75	0.75	31.78
Hidhab	3.5	5.21	1.57	0.35	0.48	0.73	43.39
Arz	3.83	7.23	2.58	0.61	0.56	0.90	41.59
Wifak	1.5	1.26	0.93	0.18	0.34	0.4	41.59
Ain Abid	3.83	5.85	2.09	0.5	0.40	0.73	44.99
Mean	2.7	4.25	1.58	0.53	0.48	0.63	41.29
Max	3.83	8.28	2.58	1	0.75	1.04	45.60
Min	0.5	0.12	0.24	0.29	0.13	0.08	31.78
Correlation with GY	-0.273 ns	-0.308 ns	-0.261 ns	-0.788*	-0.794*	-0.462ns	//

Bi: Regression coefficient, S^2d_i; Deviation from regression, W_i^2: Wricke's ecovalence index, σ^2_i: Shukla's stability variance, CVi: Environmental coefficient of variance, θ_i: Mean variance component, $S^{(1)}$, $S^{(3)}$ and $S^{(6)}$: Nassar and Huhn's non-parametric statistics. $NP^{(2)}$, $NP^{(3)}$ and $NP^{(4)}$: Thennarasu's non-parametric statistics.

and the stability variance and is therefore classified as an unstable genotype with a low average grain yield (31.78 Q/ha). The lowest values of W_i^2 and σ^2_i are registered in the genotype G1; its grain yield (45.6 Q/ha) is higher than the general mean of grain yield (41.29 Q/ha). Based on the environmental coefficient of variance (CVi) the genotype G4 was considered desirable due to its low CVi, but its grain yield (31.78 Q/ha) is lower than the general mean of grain yield (41.29 Q/ha). According to association between the coefficient of variance (CVi) with mean grain yield, the genotypes G1 and Hidhab show lowest values of CVi with the highest mean grain yield (45.6 and 43.39 Q/ha. respectively) are considered more stable. When a comparison between the two genotypes. G1 emerges as better.

Plaisted and Peterson (1959) proposed the variance component of genotype environment interactions for interactions between each of the possible pairs of genotypes and considered the average of the estimate for all combinations with a common genotype to be a measure of stability. Accordingly, the genotypes which would show lower value for the θ_i are considered more stable. Further. Francis and Kannenberg (1978) suggested the coefficient of variation as a stability statistic through the combination of the coefficient of variation, mean yield and environmental variance. Accordingly, genotypes with low CVi, low environmental variance (EV) and high mean yield are considered to be the most desirable.

In the present experiment the genotypes G1, G2 and the local landraces (Hidhab, Arz, Wifak, Ain Abid) had lower θ_i and were considered to be stable (Table 2); conversely, G3 and G4 were considered instable due to higher values for θ_{ii}. Quite a number of studies confirmed the efficacy of using parametric index to select adapted and stable barley genotypes (Guendouz and Bendada, 2022), bread wheat (Gadisa and Abebe, 2020) and wheat genotypes (Guendouz and Hafsi, 2017). Therefore considering all the parametric indices along with yield, the genotypes G1 and G2 among the introduced ones and Wifak among the local collections proved to be stable as well as high yielding.

Non-parametric measures

The nonparametric measure proposed by Huhn (1990) and Nassar and Huhn (1987) is based on the ranks of cultivars across environments and it gives equal weight to each environment. Accordingly, value of $Si^{(1)}$. $Si^{(3)}$ and $Si^{(6)}$ of the evaluated genotypes (Table 1) revealed that G1 is the most stable genotype with the lowest value for the above parameters over all genotypes and the highest mean grain yield (45.6 Q/ha). On the contrary, G2 and Arz had the highest values of $Si^{(1)}$, $Si^{(3)}$ and $Si^{(6)}$ and therefore, they were classified as unstable genotypes. In addition, the association between the Nassar and Huhn's non-parametric index $Si^{(1)}$, $Si^{(3)}$, $Si^{(6)}$ and the mean grain yield of tested genotypes showed that the introduced genotypes. G1. G2 and the local landrace Wifak were the most adapted and stable genotypes with respect to mean grain yield under these conditions (Fig 2). The present findings are in conformity with Khalili and Pour-Aboughadareh (2016), who advocated that the indices of Nassar and Huhn's are very suitable to select stable and adapted barley genotypes. The results illustrated in the Table 2, showed that the introduced genotype G1 had the lowest values for the Thennarasu's non-parametric statistics ($NP^{(2)}$, $NP^{(3)}$ and $NP^{(4)}$) with highest grain yield over all genotypes tested. In addition, the selection based on the distribution between the Thennarasu's non-parametric index and the mean grain yield of tested genotypes showed that the adapted and stable genotypes are G1, G2 and Wifak. Many researchers have suggested that the nonparametric measures cited below were used in the selection of stable and adapted soybean genotypes (El-Hashash *et al*., 2019) and durum wheat (Hannachi *et al*., 2019) are highly suitable for arid and semi-arid conditions. Therefore, considering both parametric and nonparametric indices G1, G2 and Wifak are the most promising genotypes with respect to both yield and stability.

Association among stability parameters and grain yield

The results of Spearman's coefficient of correlations between mean grain yield and the different parametric and non-parametric stability indices used in this study are presented in Table 2. The mean grain yield revealed significantly negative correlation with $NP^{(2)}$ and $NP^{(3)}$ while the remaining non-parametric indices exhibited no significant correlation. Earlier, Khalili and Pour-Aboughadareh (2016) observvred such significantly negative correlation in case of Barley. Thus, selection based on these stability parameters may

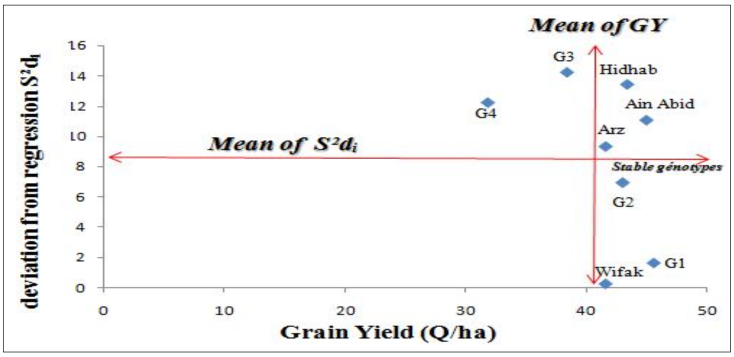

Fig 1: The relationship between the deviation from regression (S^2di) and mean grain yield (Q/ha) for the genotypes tested.

not enable bread wheat breeders to identify genotypes that are both high-yielding and stable in nature. From a study on durum wheat genotypes using the same stability parameters Kilic *et al*. (2010) found that the genotypes with lower than the average yield were most stable and the highest yielding genotypes were more unstable. In addition, the mean grain yield was positively correlated with the regression coefficient (b_i) and negatively with the parametric indices (W_i^2. σ^2_i) (Table 3). The Table further revealed a significant and positive correlation of $S^{(1)}$ with $S^{(3)}$ and $S^{(6)}$ (0.944*** and 0.930*** respectively) and of $NP^{(4)}$ with $S^{(1)}$, $S^{(3)}$ and $S^{(6)}$ (0.942***. 0.969*** and 0.956***) respectively, $NP^{(4)}$ also registered positive correlation with $NP^{(2)}$ and $NP^{(3)}$ (0.734*. 0.815*). In this regard, Kilic (2012) reported that such significant positive correlation between these stability parameters would suggest that these parameters might play similar roles to select adapted and stable genotypes. The regression coefficient (b_i) had significant and negative correlation with W_i^2, σ^2_i and θ_i (-0.963***. -0.963*** and -0.963*** respectively), Interestingly, deviation from the regression (S^2d_i) had positive correlation with all non parametric indices; $S^{(1)}$ (0.869**), $S^{(3)}$ (0.841**), $S^{(6)}$ (0.753*), $NP^{(2)}$ (0.715*), $NP^{(3)}$ (0.760*), $NP^{(4)}$ (0.851**). Conspicuously, ecovalence (Wi^2), stability variance (σ_i^2), stability parameters of θ_i were highly correlated with each other (r = 1.00***). The strong association between these parametric stability indices conclusively indicated that one of these three parameters would be sufficient to select stable and appropriate bread wheat genotype in a breeding program.

Classification based on principal component analysis (PCA)

Principal component (PC) analysis based on the correlation matrix was performed and presented in Fig 3. The results proved that the first two principal components (PC1 and PC2) of the rank correlation represented respectively 57.69% and 34.12% of the variation, making a total of 91.81% of the total variance among the stability parameters. The static and dynamic yield stability concepts describe the differential response of genotypes to variable environments (Becker *et al*., 2001). Based on the PC analysis the parametric indices bi and CVi are associated with dynamic stability, while the other indices are associated with static stability. In addition, the principal component analysis further classified the local landraces Ain Abid and Hidhab belonging to dynamic stability group had higher grain yield. The high yield performance of released genotypes is one of the most important targets of breeders; therefore. A dynamic concept of stability is preferred by the breeders because this concept of stability means the genotype would show high response to high

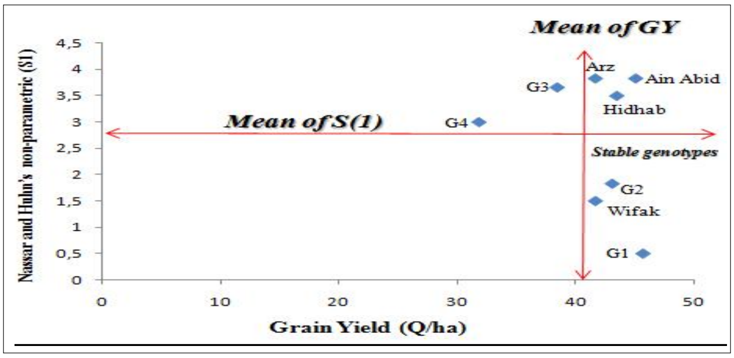

Fig 2: The relationship between the Nassar and Huhn's non-parametric index ($Si^{(1)}$) and mean grain yield (Q/ha).

Table 3: Spearman's rank correlation coefficients among parametric and non parametric stability indices used in this study.

	b_i	S^2d_i	W_i^2	σ^2_i	CVi	θ_i	$S^{(1)}$	$S^{(3)}$	$S^{(6)}$	$NP^{(2)}$	$NP^{(3)}$	$NP^{(4)}$	GY
b_1	1												
S^2d_1	-0.242	1											
W_1^2	-0.963***	0.363	1										
σ^2_1	-0.963***	0.363	1.000***	1									
CVi	0.948***	-0.078	-0.831*	-0.831*	1								
θ_1	-0.963***	0.363	1.000***	1.000***	-0.831*	1							
$S^{(1)}$	-0.069	0.869**	0.172	0.172	0.074	0.172	1						
$S^{(3)}$	0.030	0.841**	0.129	0.129	0.228	0.129	0.944***	1					
$S^{(6)}$	0.110	0.753*	0.050	0.050	0.303	0.050	0.930***	0.965***	1				
$NP^{(2)}$	-0.487	0.715*	0.680	0.680	-0.227	0.680	0.582	0.703	0.625	1			
$NP^{(3)}$	-0.435	0.760*	0.608	0.608	-0.172	0.608	0.671	0.678	0.686	0.816*	1		
$NP^{(4)}$	-0.079	0.851**	0.249	0.249	0.152	0.249	0.942***	0.969***	0.956***	0.734*	0.815*	1	
GY	0.776*	-0.406	-0.901**	-0.901**	0.538	-0.901**	-0.273	-0.309	-0.262	-0.788*	-0.794*	-0.462	1

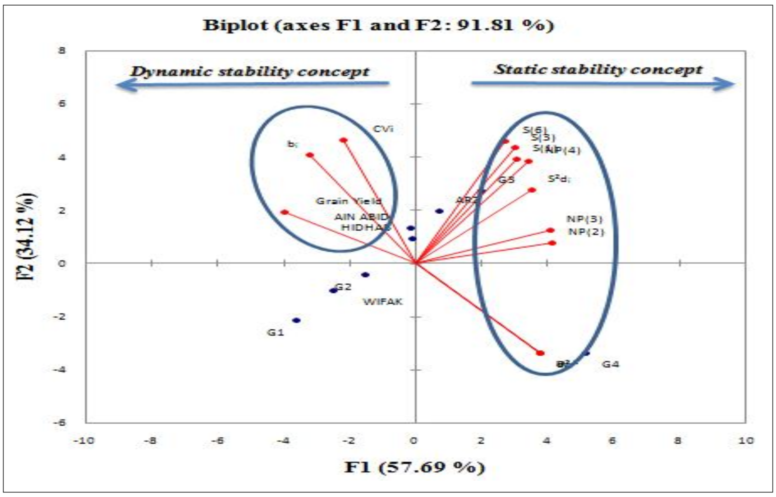

Fig 3: Biplot of IPC1 (F1) and IPC2 (F2) of the rank correlation matrix of the stability parameters with grain yield.

levels of agronomic inputs such as fertilizer or better environmental conditions.

CONCLUSION

The direct selection based on the mean grain yield of each genotype tested compared to the general grain yield showed that the introduced genotypes G1, G2 and the local landraces (Hidhab, Arz, Wifak, Ain Abid) had the highest grain yield. Based on the non-parametric indices, the genotypes G1, G2 and Wifak can be opined as the most stable genotypes. Conspicuously, selection based on the high grain yield, the parametric and non parametric indices the introduced genotypes G1, G2 and the local landrace Wifak appeared to be the most stable and adapted genotypes. On the basis of the Principal component (PC) analysis the local landraces Ain Abid and Hidhab may be classified as having dynamic stability.

Conflict of interest: None.

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