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Non-parametric Stability Analysis in Durum Wheat (*Triticum durum* Desf.) Genotypes Growing under Semi-arid Conditions

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ABSTRACT

Field experiments were carried out in National Institute of Agronomic Research of Algeria INRAA- station of Setif, Algeria where grain yield of 10 durum wheat genotypes tested during 4 cropping seasons from 2009 to 2013 and sowing in the same period in December .The objectives were to determine stable genotypes based on non-parametric stability indices. The results of the Thennarasu (NP) as following: $Si^{(1)}$ (varied from 2 to 5), $Si^{(2)}$ (varied from 3 to 17), $Si^{(3)}$ (varied from 1.2 to 9.27) and $Si^{(6)}$ (varied from 0.67 to 2.55) based on these methods the genotype $Mexicali_{75}$ is considered to be most stable and had highest grain yield. Based on NP1, NP3 and NP4 the genotype $Mexicali_{75}$ is considered to be most stable and had highest grain yield, the genotype Hoggar had low values for the index NP2 we can considered more stable but with moderate grain yield. In addition, the results of the methods of Huehn demonstrate that the genotype $Mexicali_{75}$ with the lowest values was identified as desirable. The results of Spearman's rank correlation coefficients between mean yield and the non-parametric stability statistics are shown in Table 4. The mean grain yield as well as negatively and significantly correlated with NP2, NP3 and NP4 and insignificant negative correlation with NP1. In conclusion, according to results of these different non-parametric stability measurements, genotype $Mexicali_{75}$ is recommended for commercial release as a favorable durum wheat genotype for the semi-arid condition.

KEYWORDS: Algeria, durum wheat, non-parametric, semi-arid, stability analysis

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Durum wheat is grown under varying agro climatic situations. It is an important crop grown worldwide for food (Beres et al., 2020). Algeria with its topographical and bioclimatic characteristics which make it possible to show a diversity of landscapes and cropping systems, cereal growing is the predominant speculation of agriculture. It extends over an annual area of about 3.6 million hectares compared to the useful agricultural area (UAA) (MADR, 2012). Yield stability is an important criterion for the development of cultivars intended for environments with variable rainfall. Many methods of stability analysis are proposed in the literature such as parametric and non-parametric stability indices (Benmahammad et al., 2010; Rose et al., 2008). The genotype-environment interaction reduces association between phenotypic and genotypic values and leads to bias in the estimates of gene effects and combining ability for various characters sensitive to environmental fluctuations (Wardofa et al., 2019). Highlighting a genotype-environment interaction (GEI) makes it difficult to identify superior genotypes for a range of environments and leads us to assess genotypes in many environments to estimate their true genetic potential (Yaghotipour and Farshadfar, 2007). The importance of G×E interactions in national cultivar evaluation and breeding programs have been demonstrated in almost all major crops, including wheat genotypes (Frih et al., 2021). Various statistical methods (parametric and non-parametric) have been proposed to study Genotype×environment interactions (Mohammadi and Amri, 2008; Mohammadi et al., 2010). Parametric approaches are: (1) univariate analysis (regression analysis and stability variance analysis) (Bashir et al., 2020) and (2) multivariate analysis (principal component analysis, factor analysis, canonical component analysis, cluster analysis and biplot analysis) (Chahal and Gosal, 2002). The other approach is to use nonparametric techniques, and several procedures have been proposed based on comparing ranks of genotypes in each environment, with genotypes with similar ranking across environments being considered stable (Sbaghnia, 2016; Huehn, 1996; Fox et al., 1990). in plant breeding research and in view of the increased use of nonparametric stability measures, it is very important to study the effect of the correction on these statistics. In addition, a nonparametric superiority measure for general adaptability has been suggested based on stratified ranking of the cultivars in each separate environment (Smutna et al., 2021), with the proportion of sites at which a specific cultivar occurred in the top third of the ranks (the TOP value), the middle third of the ranks (the MID value) and the lower third of the ranks (the LOW value) being calculated, a genotype with a high TOP value (i.e., occurring principally in the top third of the ranks) being considered as a widely adapted genotype (Fox et al., 1990). based on the classification of genotypes in each environment, Nassar and Huehn (1987) assume four types of nonparametric statistics of phenotypic stability ($Si^{(1)}$, $Si^{(2)}$, $Si^{(3)}$ and $Si^{(6)}$), they define stable genotypes such as those which have not changed their positions in relation to others in all the environments evaluated. Thennarasu (1995) proposed non-parametric statistics $NPi^{(1)}$, $NPi^{(2)}$, $NPi^{(3)}$ and $NPi^{(4)}$ based on ranks of adjusted means of the genotypes in each environment and defined stable genotypes using Nassar and Huehn (1987)'s definition. The objectives of this study were to identify durum wheat genotypes that have both high grain yield and stable performance across different years for semi-arid areas of Algeria and study the relationships between different nonparametric stability statistics.

2. MATERIALS AND METHODS

2.1. Plant material

This study was carried out with 10 durum wheat (Table 1) during 4 cropping seasons from 2009 to 2013 and sowing in the same period in December.

Table 1: Name and origin of cultivars evaluated in this study

Sl. No.	Cultivar	Origin	Sl. No.	Cultivar	Origin
1.	Bousselem	ICARDA/ CIMMYT	6.	Altar84	CIMMYT
2.	Hoggar	Espagne	7.	Dukem	CIMMYT
3.	Oued Zenati	Algeria	8.	Kucuk	CIMMYT
4.	Polonicum	Algeria	9.	Mexicali 75	CIMMYT
5.	Waha	ICARDA/ CIMMYT	10.	Sooty	CIMMYT

2.2. Study area

Field experiments were carried out in the National Institute of Agronomic Research of Algeria INRAA-station of Setif, Algeria (5°37'E, 36°15'N, 981 m above mean sea level). Genotypes were grown in randomized block design with four replicates. Plots were 2.5×6 m^2 rows with 0.20 m row spacing and sowing density was adjusted to 300 g m^{-2}.

2.2. Methods and data collection

2.2.1. Non-parametric measures

Huehn (1990) proposed four non-parametric stability statistics that combine mean yield and stability ($Si^{(1)}$, $Si^{(2)}$, $Si^{(3)}$ and $Si^{(6)}$). For a two-way data set with "i" genotypes and "m" environments, we denote rij as the rank of the

i^{th} genotype in the j^{th} environment, and $\bar{r}_i$: as the mean rank across all environments for the i^{th} genotype. Other nonparametric stability measures that proposed by Thennarasu ($NPi^{(1)}$, $NPi^{(2)}$, $NPi^{(3)}$ and $NPi^{(4)}$) described in detail by Thennarasu (1995) and Mohammadi et al. (2007).

2.2.2. Statistical analysis

The data were analyzed by using the software (STABILITYSOFT) developed by Pour-Aboughadareh et al. (2019).

3. RESULTS AND DISCUSSION

3.1. Analysis of VA riance (ANOVA)

The main effect of years (Y) was high significant (p<0.001), the main effect of genotype (G) and GY interaction was only significant at p<0.05 (Table 2). Based on the grain yield ranking the genotypes $Altar_{84}$, $Mexicali_{75}$ and Sooty, respectively, were the highest yielding cultivars.

3.2. Non-parametric measures of stability

According to the $Si^{(1)}$ (varied from 2 to 5), $Si^{(2)}$ (varied from 3 to 17), $Si^{(3)}$ (varied from 1.2 to 9.27) and $Si^{(6)}$ (varied from 0.67 to 2.55) the genotype $Mexicali_{75}$ with the lowest value were identified as desirable (Table 3). In addition, and based on the some indices the genotype Bousselem with highest values indicating lower stability. According to Thennarasu's (1995) stability statistics (NP1, NP2, NP3 and NP4) (Table 4), genotypes with minimum values are considered more stable. Based on NP1, NP3 and NP4 the genotype $Mexicali_{75}$ is considered to be most stable and had highest grain yield, the genotype Hoggar had low values for the index NP2 we can considered more stable but with moderate grain yield. However, based on NP1 and NP3 methods the genotype $Altar_{85}$ was unstable. According to the other two methods NP2 and NP3 the genotype Oued Zenati was unstable.

Table 2: Mean yield (q ha^{-1}) of ten durum wheat cultivars evaluated over four cropping seasons (2009-2013)

Genotypes	Cropping seasons				Mean genotype
	(2009–2010)	(2010-2011)	(2011-2012)	(2012-2013)	(Rank)
Oued Zenati	25.83(def)	52.29(b)	21.45(b)	47.11(ab)	36.67(10)
Altar84	29.66(abcd)	53.56(b)	24.86(ab)	64.97(a)	43.26(2)
Sooty	27.53(cde)	60.80(ab)	27.33(ab)	52.92(ab)	42.14(4)
Polonicum	24.66(ef)	56.60(ab)	32.68(ab)	55.00(ab)	42.24(3)
Waha	28.41(abcde)	64.61(a)	35.24(a)	37.31(b)	41.39(5)
Dukem	22(f)	64.81(a)	29.75(ab)	44.44(b)	40.25(7)
Mexicali75	31.91(a)	60.03(ab)	32.90(ab)	49.34(ab)	43.54(1)
Kucuk	27.66(bcde)	53.80(b)	36.87(a)	36.25(b)	38.64(9)
Hoggar	30.83(abc)	56.78(ab)	30.23(ab)	47.03(ab)	41.22(6)
Bousselem	31.58(ab)	55.23(ab)	36.87(a)	37.00(b)	40.17(8)
Genotypes effect	*	*	*		*
LSD (p=0.05)	3.98	10.14	13.6	19.46	6.37
Years effect		***			/
Mean Year	28.00	57.85	30.81	47.13	40.95
LSD (p=0.05)	6.45	/			
G*Y interaction effect	*	/			

Measurements followed by the same letter in each column belong to a homogeneous group at the 5% probability level

3.3. Interrelationship among non-parametric methods and grain yield

The results of Spearman's rank correlation coefficients between mean yield and the non-parametric stability statistics are shown in Table 4. The mean grain yield as well as negatively and significantly correlated with NP2, NP3 and NP4 (r=-0.76, r=-0.69 and r=-0.60) and insignificant negative correlation with NP1. Similarly, Segherloo et al. (2008) found a highly significant correlation between mean grain yield and Huehn-rank. Mahtabi et al. (2013) found significantly and negatively correlated between mean yield and $Si^{(3)}$, $Si^{(6)}$, NP2 and NP4 (Table 3). In addition, significant negative correlation between grain yield and $Si^{(6)}$, and insignificant negative correlation registered between

Table 3: Mean grain yield (q ha^{-1}), Huehn's (Si) non-parametric stability parameters and correlation values for the ten genotypes

Genotypes	GY	Huehn's (Si) methods							
		$Si^{(1)}$	Ranks	$Si^{(2)}$	Ranks	$Si^{(3)}$	Ranks	$Si^{(6)}$	Ranks
Oued Zenati	36.67	2.33	2	3.67	3	4.40	4	2.40	9
Altar84	43.26	4.50	9	12.25	9	6.39	8	1.91	7
Sooty	42.14	3.00	4	6.00	4	3.00	3	1.33	3
Polonucum	42.24	3.67	5	8.33	5	4.55	5	1.45	4
Waha	41.39	4.33	8	11.67	8	5.38	7	1.54	5
Dukem	40.25	4.17	7	11.58	7	8.18	9	2.24	8
Mexicali75	43.54	2.00	1	3.00	1	1.20	1	0.67	1
Kucuk	38.64	3.83	6	8.92	6	5.10	6	1.71	6
Hoggar	41.22	2.33	2	3.33	2	1.67	2	1.00	2
Bousselem	40.17	5.00	10	17.00	10	9.27	10	2.55	10
Mean	40.95	3.52		8.58		4.91		1.68	
Min	36.67	2.00	/	3.00	/	1.20	/	0.67	/
Max	43.54	5.00		17.00		9.27		2.55	
Correlation Test with GY	1	-0.03^{ns}	/	-0.02^{ns}	/	-0.27^{ns}	/	-0.62^{*}	/

Table 4: Mean grain yield (q ha^{-1}). Thennarasu's (NP) non-parametric stability parameters and correlation values for the ten genotypes

Genotypes	GY	Thennarasu's (NP) methods							
		$NP^{(1)}$	Ranks	$NP^{(2)}$	Ranks	$NP^{(3)}$	Ranks	$NP^{(4)}$	Ranks
Oued Zenati	36.67	2.75	6	1.75	10	1.14	10	0.93	9
Altar84	43.26	3.50	9	0.55	7	0.66	9	0.78	7
Sooty	42.14	2.25	3	0.31	3	0.38	3	0.50	3
Polonucum	42.24	3.00	7	0.36	5	0.57	6	0.67	4
Waha	41.39	3.00	7	0.36	4	0.49	4	0.67	4
Dukem	40.25	2.50	5	0.71	9	0.64	7	0.98	10
Mexicali75	43.54	1.00	1	0.29	2	0.16	1	0.27	1
Kucuk	38.64	2.25	3	0.45	6	0.49	5	0.73	6
Hoggar	41.22	1.50	2	0.25	1	0.25	2	0.39	2
Bousselem	40.17	3.50	9	0.58	8	0.65	8	0.91	8
Mean	40.95	2.53		0.56		0.54		0.68	
Min	36.67	1.00		0.25		0.16		0.27	
Max	43.54	3.50		1.75		1.14		0.98	
Correlation Test with GY	1	-0.16^{ns}	/	-0.76^{*}	/	-0.69^{*}	/	0.60^{*}	/

grain yield and Si[3]. Our results are in agreement with the results of Mohammadi and Amri (2008).

4. CONCLUSION

Based on the methods of Huehn the genotypes Mexicali$_{75}$ with the lowest values were identified as desirable and the genotype Bousselem with highest values indicating lower stability. Thennarasu Stability statistics demonstrate that the genotypes with minimum values are considered stable. The genotype Mexicali$_{75}$ is considered to be most stable and had highest grain yield Based on NP1, NP3 and NP4, the genotype Hoggar had low values for the index NP2 we can considered more stable but with moderate GY.

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