ORIGINAL ARTICLE

ESTIMATING GENOTYPIC RANKS BY NONPARAMETRIC STABILITY ANALYSIS IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

This study was carried out to determine the ranks of 9 bread wheat (*Triticum aestivum* L.) genotypes across eleven environments in Central Anatolia, Turkey, in the 2000-2002 growing seasons. Experimental layout was a randomized complete block design with four replications. Analysis of Non parametric stability revealed that genotypes 4 and 8 were most stable and well adapted across eleven environments. In addition, it was concluded that plots obtained by both mean yield (kg ha^{-1}) vs. $S_1^{(1)}$ and mean yield (kg ha^{-1}) vs. $S_2^{(2)}$ values could be enhanced visual efficiency of selection based on genotype x environment interaction.

KEY WORDS: Bread Wheat (Triticum aestivum L.), yield, nonparametric stability analysis

Manuscript received: 24. February, 2003.
Accepted for publication: 3. March, 2003.

JOURNAL
Central European Agriculture
ISSN 1332-9049

INTRODUCTION

Parametric methods for estimating genotype x environment interactions and phenotypic stability are widely used in plant breeding and production. The proper use of these parametric measures requires some statistical assumptions, however, and the estimates can be unduly influenced by one or two outliers in small samples. Several nonparametric methods proposed by Huhn (1979) are based on the ranks of genotypes in each environment and use the idea of homeostasis as a measure of the stability. Genotypes with similar rankings across environments are classified as stable. The statistical properties and significance for measures of nonparametric stability analysis (NPSA) were given by Nassar and Huhn (1987).

Nonparametric measures for stability based on ranks provide a viable alternative to existing parametric measures based on absolute data. For many applications, including selection in breeding and testing programs, the rank orders of the genotypes are the most essential information. Stability measures based on ranks require no statistical assumptions about the distribution of the phenotypic values. They are easy to use and interpret and, compared with parametric measures, are less sensitive to errors of measurement. Furthermore, addition and deletion of one or a few observations is not as likely to cause great variation in the estimates as would be the case for parametric stability measures (Nassar and Huhn, 1987; Lu, 1995).

Fox et. al (1990) suggest a nonparametric superiority measure for general adaptability. They used stratified ranking of the cultivars. Ranking was done at each location separately and the number of sites at which the cultivar occurred in the top, middle, and bottom third of the ranks was computed. A genotype that occurred mostly in the top third was considered as a widely adapted cultivar.

Kang and Pham's (1991) rank-sum is another non-parametric stability statistics where both yield and Shukla's (1972) stability variance are used as selection criteria. This statistics assigns a weight of one to both yield and stability and enables the identification of high-yielding and stable genotype. The genotype with the highest yield is given a rank of 1 and a genotype with the lowest stability variance is assigned a rank of 1. All genotypes are ranked in this manner. The ranks by yield and by stability variance are added for each genotype. The genotype with the lowest rank-sum is the most desirable one.

The objectives of this study were to (i) interpret ranks obtained by NPSA of 9 bread wheat genotypes over eleven environments, (ii) visually assess how to vary rank measures vs. yield performances across eleven environments based on the plot, and (iii) determine promising genotypes with high yielding and stability.

MATERIALS AND METHODS

This study was carried out across eleven environments, including six rain-fed environments undertaken in Karaman-Kazimkarabekir, Konya-Center, Konya-Cumra and Konya-Obruk, and also three irrigated environments conducted in Konya-Cumra, Konya-Center, and Aksaray-Kocas during the 2000-2002 growing seasons. Of 9 bread wheat genotypes used, 7 were from the National Bread Wheat Improvement Program, Turkey, and 2 from the International Winter Wheat Improvement Program based on a joint project between Turkey, CIMMYT and ICARDA (Table 1). Experimental layout was a randomized complete block design with four replications. Sowing was done by an experimental drill in 1.2 m x 7 m plots, consisting of six rows with 18 cm left between the rows. Seeding rate was 450 seeds m^{-2} for irrigated and 550 seeds m^{-2} for rain-fed environments. Fertilizer application was 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} at planting and 40 kg N ha^{-1} at the stem elongation stage. Harvesting was done in 1.2 m x 5 m plots by experimental combine. Details of code, growing season, date of planting, date of harvesting and status of rainfall and/or irrigation for eleven environments are given in Table 2. Yield (kg ha^{-1}) was obtained by converting the grain yields obtained from plots to hectares.

SAS software (1996) was used to perform analysis of NPSA on the mean values of yield (kg ha^{-1}) obtained over environments. PROC MEAN of SAS was run to calculate adjusted means of genotypes across environments. PROC RANK of SAS was ranked genotypes based on corrected means of genotypes within environment. Rank measures and adjusted means of yield were used to depict plot by SAS PLOT procedure (Lu, 1995). While ranking genotypes within environment, adjusted values of yield were used, instead of raw data of yield obtained from trials. The genotype with the highest adjusted yield was given a rank of 9 and a genotype with the lowest adjusted yield was assigned a rank of 1 (Table 3). All genotypes were ranked, judging from this case. A genotype is stable over environments if its ranks are similar over environments; i.e. maximum stability occurs with equal ranks over environments.

Table 1: Code, Origin, Pedigree and Selection History of Genotypes

Genotypic Code	Pedigree and Selection History of Genotypes	Origin
1	ATLAS 66//HYS/7C BDKE 900096 -2F$_5$ BD-OBD	RBWYT[1]
2	BOLAL 2973/THUNDERBIRD BDKE 900003 -1F$_5$ BD-OBD	RBWYT
3	LND/SWO791O95A/4/YM/TOB//MCD/3/LIRA ICWH90-0217 -7F$_5$ BD-OBD	RBWYT
4	KS2142/4/KRC66/3/TT-50-18/P101//11-50-18/VGDWVF BDKE 910010 -1F$_5$ BD-OBD	RBWYT
5	UNKNOWN XXX	RBWYT
6	63-122-66-2/NO//LOV2F$_1$/3/F$_1$KVZ/HYS/4/TJB916.46/CB306//2*MHB/3/BUC ‘S’ YA 20682	RBWYT
7	KKZ/AU//GRK79 BDKE 890017 -2F$_5$ BD-OBD	RBWYT
8	VEE/TSI//GRK79/3/NS55.03/5/0126.15/COFN/3/N10B/P14//P101/4/KRC66 TCI 932322 -OSE-OYC-2YC-OYC	TCI[2]
9	JI5418/MARAS TCI 922142 -OSE-OYC-3YC-OYC	TCI

[1] Regional Bread Wheat Yield Trial-Turkey; [2] TURKEY/CIMMYT/ICARDA International Winter Wheat Improvement Program

Table 2: Code, growing season, date of planting, date of harvesting, status of rainfall + irrigation for each environment

Environment	Code	Growing season	Date of planting	Date of harvesting	Rainfall + (irrigation) (mm)
Karaman-Kazimkarabekir	1*	2000-01	05.11.00	16.07.01	255
Konya-Cumra	2*	2000-01	28.10.00	15.07.01	240
Konya-Center	3*	2000-01	21.10.00	10.07.01	210
Konya-Cumra	4**	2000-01	27.10.00	24.07.01	240+100
Konya-Center	5**	2000-01	22.10.00	23.07.01	210+100
Aksaray-Kocas	6**	2000-01	08.11.00	25.07.01	265+100
Konya-Center	7*	2001-02	25.10.01	15.07.02	384
Konya-Cumra	8*	2001-02	22.10.01	12.07.02	376
Konya-Obruk	9*	2001-02	19.10.01	08.07.02	358
Konya-Center	10**	2001-02	24.10.01	16.07.02	384+100
Konya-Cumra	11**	2001-02	26.10.01	13.07.02	376+100

*,** rain-fed and irrigated, respectively

RESULTS AND DISCUSSION

Ranks of 9 bread wheat genotypes based on corrected yield (kg ha^{-1}) within each environment are given in Table 3. Genotypic ranks within environment revealed that genotype 8 invaded top of ranking, with yield ranks of 4, 7, 3, 6, 2, 7, 9, 8, 2, 4 and 8 across eleven environments, respectively, prior to genotype 7 (Table 3). However, genotype 4 occupied bottom of the ranking, with yield ranks of 1, 2, 9, 3, 5, 5, 5, 4, 5, 2 and 7 over eleven environments.

Table 3: Ranking 9 bread wheat genotypes based on corrected yield (kg ha^{-1}) within environment

Env	Gen	Yield (kg ha^{-1})	Corrected Yield (kg ha^{-1})	Rank	Env	Gen	Yield (kg ha^{-1})	Corrected Yield (kg ha^{-1})	Rank
1	1	1499	1568	7	6	6	3267	3452	4
1	2	1408	1252	3	6	7	3587	3844	8
1	3	1398	1527	6	6	8	3889	3701	7
1	4	1276	1149	1	6	9	2651	2443	1
1	5	1177	1214	2					
1	6	1474	1659	9	7	1	4575	4643	4
1	7	1372	1629	8	7	2	4967	4811	6
1	8	1520	1332	4	7	3	4505	4634	3
1	9	1608	1400	5	7	4	4915	4788	5
					7	5	4782	4819	7
2	1	2352	2420	1	7	6	4275	4460	2
2	2	3002	2846	4	7	7	4182	4439	1
2	3	2761	2890	5	7	8	5170	4982	9
2	4	2691	2564	2	7	9	5162	4954	8
2	5	2913	2950	6					
2	6	3382	3567	9	8	1	2172	2240	2
2	7	2778	3035	8	8	2	3235	3079	9
2	8	3152	2964	7	8	3	2402	2531	7
2	9	2963	2755	3	8	4	2502	2375	4
					8	5	2262	2299	3
3	1	3271	3339	6	8	6	1965	2150	1
3	2	3126	2970	2	8	7	2185	2442	5
3	3	3652	3781	8	8	8	3045	2857	8
3	4	3962	3835	9	8	9	2695	2487	6
3	5	3389	3426	7					
3	6	2452	2637	1	9	1	1272	1340	3
3	7	3081	3338	5	9	2	1701	1545	4
3	8	3188	3001	3	9	3	1697	1826	6
3	9	3532	3324	4	9	4	1812	1685	5
					9	5	1015	1052	1
4	1	3262	3330	1	9	6	1705	1890	8
4	2	4552	4396	8	9	7	1652	1909	9
4	3	4048	4177	5	9	8	1441	1253	2
4	4	4097	3970	3	9	9	2074	1866	7
4	5	4269	4306	7					
4	6	4313	4498	9	10	1	7201	7269	7
4	7	3894	4151	4	10	2	6922	6766	3
4	8	4465	4277	6	10	3	5745	5874	1
4	9	3941	3733	2	10	4	6762	6635	2
					10	5	7600	7637	8
5	1	6630	6698	8	10	6	6857	7042	6
5	2	5581	5425	1	10	7	6585	6842	5
5	3	6321	6450	6	10	8	6990	6802	4
5	4	6463	6336	5	10	9	7962	7754	9
5	5	6435	6472	7					
5	6	5693	5878	3	11	1	3442	3510	5
5	7	5638	5895	4	11	2	4570	4414	9
5	8	5791	5603	2	11	3	3392	3521	6
5	9	6937	6729	9	11	4	3862	3735	7
					11	5	2827	2864	1
6	1	4212	4280	9	11	6	3217	3402	4
6	2	3292	3136	2	11	7	2855	3112	2
6	3	3298	3427	3	11	8	4057	3869	8
6	4	3692	3565	5	11	9	3402	3194	3
6	5	3565	3602	6					

Two rank stability measures from Nassar and Huhn (1987) were expressed as $S_1^{(1)}$ and $S_2^{(2)}$. The $S_1^{(1)}$ statistic measures the mean absolute rank difference of a genotype over environments. For a genotype with maximum stability, $S_1^{(1)} = 0$. $S_2^{(2)}$ gives the variance among the ranks over environments. Zero variance is indication of maximum stability. The exact variance and expectation of $S_1^{(1)}$ and $S_2^{(2)}$ were given by Huhn (1990a). The parameters $S_1^{(1)}$ and $S_2^{(2)}$ are measurements of the stability alone. They are strongly intercorrelated with each other even in the case of using the uncorrelated yield data. If one adjusts the uncorrected yield data by genotypic effects; i.e. using the corrected values, then non parametric measures $S_1^{(1)}$ and $S_2^{(2)}$ are nearly perfectly correlated between each other. The two stability rank orders of the genotypes obtained by using the uncorrected yield data and by using the corrected values are often considerably different. The correlations are medium or low (Hunh, 1990b).

For several reasons for practical applications, $S_1^{(1)}$ against $S_2^{(2)}$ parameter can be preferred. This stability parameter, $S_1^{(1)}$, is very easy to compute and allows a clear and relevant interpretation (mean absolute rank difference between the environments). Furthermore, an efficient test of significance is available (Huhn, 1990a).

For each genotype, $Z_1^{(1)}$ and $Z_2^{(2)}$ values were calculated based on the ranks of the corrected data and summed over genotypes to obtain Z values (Table 4). It is seen that $Z_1^{(1)}$ sum = 8.032 and $Z_2^{(2)}$ sum = 7.564. Since both of these statistics were less than the critical value $X^2_{0.05,\ 9} = 16.919$, no significant differences in rank stability were found among the nine genotypes grown in eleven environments. On inspecting the individual Z values, it was found that no genotypes were significantly unstable relative to others, because they showed small Z values, compared with the critical value $X^2_{0.01,\ 1} = 6.63$. It was used that the significance level P = 0.01 corresponds to a comparison-wise error rate of about 0.05 (Lu, 1995).

Table 4: Estimation and test of nonparametric stability measures for 9 bread wheat genotypes across environments

Genotype	Mean yield (kg ha^{-1})	Mean rank	$S_1^{(1)¥}$	$Z_1^{(1)¥}$	$S_2^{(2)¥}$	$Z_2^{(2)¥}$
1	3626	4.818	3.381	0.783	7.963	0.429
2	3850	4.636	3.381	0.783	8.454	0.815
3	3565	5.090	2.290	2.017	4.090	1.692
4	3821	4.363	2.690	0.330	5.454	0.374
5	3657	5.000	3.018	0.013	7.200	0.072
6	3509	5.090	3.616	3.267	10.490	3.731
7	3437	5.363	3.054	0.037	6.854	0.009
8	3882	5.454	3.018	0.013	6.472	0.009
9	3902	5.181	3.381	0.783	7.963	0.429
Sum				8.032		7.564
			Test statistics			
	$E(S_1^{(1)})$	$E(S_2^{(2)})$	$Var(S_1^{(1)})$	$Var(S_2^{(2)})$	X^2 Z_1, Z_2§	X^2 sum§
	2.962	6.666	0.223	3.919	7.689	16.919
			Grand mean = 3694 kg ha^{-1}			

¥ $S_1^{(1)}$ statistic measures the mean absolute rank difference of a genotype over environments, and $S_2^{(2)}$ is the common variance of the ranks; the Z-statistics are measures of stability; § X^2 Z_1, Z_2: chi-square for $Z_1^{(1)}$, $Z_2^{(2)}$; X^2 sum: chi-square for sum of $Z_1^{(1)}$, $Z_2^{(2)}$

Figures 1 and 2 represent plots portrayed by mean yield (kg ha^{-1}) vs. $S_1^{(1)}$ and $S_2^{(2)}$ values. Mean $S_1^{(1)}$ and $S_2^{(2)}$ values and grand mean yield divide both figures into four sections; section 1 refers that genotypes have high yield and small $S_1^{(1)}$ and $S_2^{(2)}$ values, section 2 signs that genotypes posses high yield and large $S_1^{(1)}$ and $S_2^{(2)}$ values, section 3 presents that genotypes exist low yield and large $S_1^{(1)}$ and $S_2^{(2)}$ values, and section 4 exhibits that genotypes are of low yield and small $S_1^{(1)}$ and $S_2^{(2)}$ values. According to these configurations, genotypes interesting in section 1 can be considered as stable. Section 1, both figures, contains that genotypes 4 and 8 are most stable, and well adapted to all environments, that is, those have general adaptable ability. Genotypes 2 and 9 appear in section 2, where describes genotypes with increasing sensitivity to environmental change, and greater specificity of adaptability to high-yielding environments. Section 3 referring poorly adapted genotypes to all environments captures genotypes 1 and 6 in figure 1, while genotypes 1, 5 and 6 in figure 2. Besides, Section 4 in figure 1 includes genotypes 3, 5 and 7 that response greater resistance to environmental fluctuation, and therefore increasing specificity of adaptability to low-yielding environments. However, genotypes 3 and 7 appear in the corresponding section of the figure 2, except that genotype 5 has exhibited tendency to section 4 in figure 1, while to section 3 in the figure 2. Nassar and Huhn (1987) suggest that $S_1^{(1)}$ statistic measure should be utilized in any case that a genotype represents unfair fluctuations among sections, regarding $S_1^{(1)}$ and $S_2^{(2)}$ values.

Prior to selection, it is quite crucial to be aware of genotypes ranking in each environment and figures 1 and 2 provided by mean yield (kg ha^{-1}) vs. $S_1^{(1)}$ and mean yield (kg ha^{-1}) vs. $S_2^{(2)}$ values are of great accordance. To illustrate, genotypes 4 and 8 are most stable and well adapted across environments, as presented in Figure 1 and 2. Genotype 8 has the highest mean rank, while genotype 4 the lowest. Rather, genotype 8 with regard to genotype 4 may be selected on account of the fact that genotype 8 has revealed higher mean yield across environments than genotype 4.

Figure 1: Plot of $S_1^{(1)}$ vs. mean yield (kg/ha) for 9 bread wheat genotypes over environments

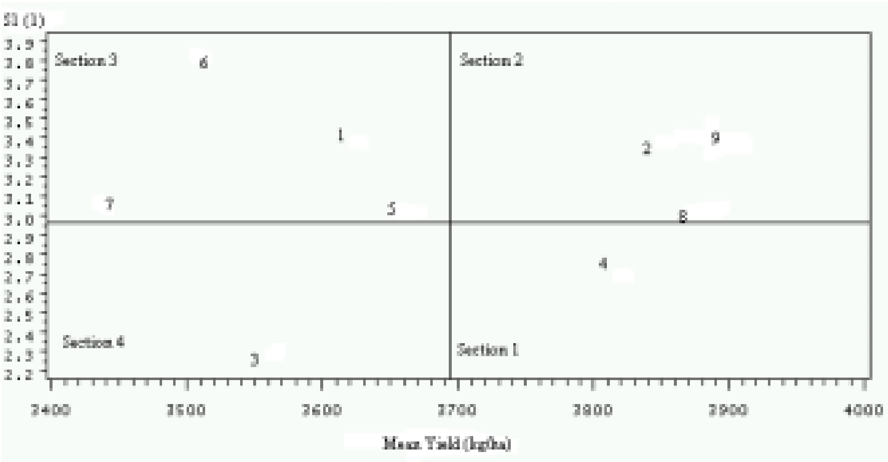
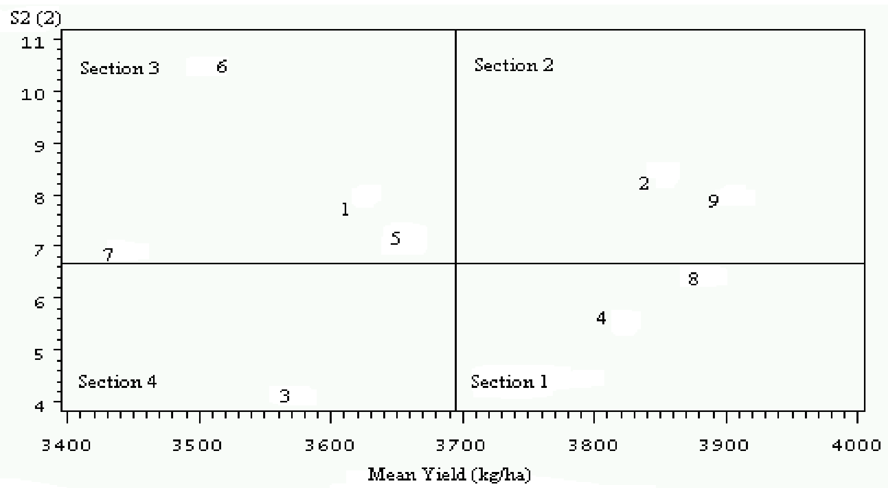


Figure 2: Plot of $S_2^{(2)}$ vs. mean yield (kg/ha) for 9 bread wheat genotypes over environments



CONCLUSION

Nonparametric measures for stability based on ranks provide a useful alternative to parametric measures currently used which are based on absolute data. Moreover, nonparametric vs. parametric stability statistics exist some advantages (see more details, Huhn, 1990b). As a consequence, for an estimation of the non parametric stability statistics of genotypes grown in different environments, use of non parametric statistics $S_1^{(1)}$ and $S_2^{(2)}$ values, together with ranks, can be recommend to breeders and agronomists who make selection based upon genotype x environment interaction. In addition, plots provided by mean yield (kg ha^{-1}) against $S_1^{(1)}$ and mean yield (kg ha^{-1}) against $S_2^{(2)}$ values are likely to enhance visual efficiency of selection.

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