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Nonparametric Stability Analysis of Yield Performances in Oat (*Avena sativa* L.) Genotypes Across Environments

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Abstract: This study was carried out to determine the yield performances of 8 oat (*Avena sativa* L.) genotypes across seven environments in Konya, Turkey, in the 1995-1998 growing seasons. Experimental layout was a randomized complete block design with four replications. Non parametric stability analysis revealed that genotypes 1 and 8 were most stable and well adapted across seven environments. It was concluded that plots obtained both mean yield (kg ha^{-1}) vs. $S_1^{(1)}$ and mean yield (kg ha^{-1}) vs. $S_2^{(2)}$ values could be enhanced visually efficiency in selection based on genotype x environment interaction.

Key words: Oat (*Avena sativa* L.), yield, nonparametric stability analysis

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 variety. 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 rankings obtained by NPSA analysis of yield performances of 8 oat genotypes over seven environments, (ii) visually assess how to vary rank measures vs. yield performances across seven environments based on the plot, and (iii) determine promising genotypes with high yielding and stable.

Materials and Methods

This study was carried out to determine the yield performances of 8 oat genotypes across 7 environments, including three rain-fed environments undertaken in Konya-Center, and Konya-Obruk, and also three irrigated environments conducted in Konya-Cumra, during the 1995-1998 growing seasons (Table 1). Of 8 oat genotypes used, 5 were lines, from the Turkish National Oat Improvement Program, following breeding steps that containing pure line selection in evaluating land races collected from distinct provinces of Turkey, panicle rows, observation nursery, preliminary yield, sub regional yield, and regional yield trials, and 3 were cultivars, from

Table 1: Growing season, location, genotype (line + cultivar), entry, province where land races collected, and status of rainfall + irrigation for each environment.

Environment	Growing season	Location	Entry	Genotype(line + cultivar)	Province (land races collected)	Rain-fall +(irrigation) (mm)
1	1995-1996	Konya-Center*	1	1	Kirklareli	416
2	1995-1996	Konya-Cumra**	2	4	Bursa	281 + 100
3	1996-1997	Konya-Center*	3	6	Konya	378
4	1996-1997	Konya-Cumra**	4	7	Eskisehir	338 + 100
5	1997-1998	Konya-Center*	5	11	Samsun	316
6	1997-1998	Konya-Cumra**	6	Checota		355 + 100
7	1997-1998	Konya-Obruk*	7	Y-330		301
			8	Y-1779		

*,** rain-fed and irrigated, respectively

Eskisehir Anatolian Agricultural Research Institute (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 8 m plots, consisting of six rows with 20 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 stem elongation stage. Harvesting was done in 1.2 m x 6 m plots by experimental combine. Details of growing season, location, genotypes (lines and cultivars), entry, provinces land races collected, and status of rain-fall and/or irrigation for 7 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 obtain plot by SAS PLOT procedure (Lu, 1995).

Results and Discussion

Ranks of 8 oat genotypes based on corrected yield (kg ha^{-1}) within each environment are given in Table 2. While ranking genotypes within environment, adjusted values of yield were used, in stead of raw values of yield obtained from trials. The genotype with the highest adjusted yield was given a rank of 8 and a genotype with the lowest adjusted yield was assigned a rank of 1 (Table 2). All genotypes were ranked in 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.

Genotypic ranks within environment revealed that genotype 5 invaded top of ranking, with yield ranks of 6, 3, 8, 7, 3, 3, and 6 across seven environments, respectively, prior to genotype 1 (Table 2). However, genotype 8 occupied bottom of the ranking, with yield ranks of 4, 8, 3, 3, 2, 2, and 2 over seven environments.

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 (Huhn, 1990b).

For several reasons for practical applications, it can be preferred the use of $S_1^{(1)}$. This stability parameter 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).

The two stability rank orders of the genotypes which will be 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 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 3). It is seen that $Z_1^{(1)}$ sum = 7.91 and $Z_2^{(2)}$ sum = 9.03. Since both of these statistics were less than the critical value $X^2_{0.05,\,8} = 15.51$, no significant differences in rank stability were found among the eight genotypes grown in seven environment. 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).

Mean yield (kg ha^{-1}) is plotted vs. $S_1^{(1)}$ and $S_2^{(2)}$ values in Fig. 1 and 2. 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

Table 2: Ranking 8 oat genotypes based on corrected yield (kg ha^{-1}) within environment

Environment	Genotype	Yield (kg ha^{-1})	Corrected Yield (kg ha^{-1})	Rank
1	1	1522	1265	3
1	2	1780	1833	7
1	3	1012	1167	2
1	4	984	1286	5
1	5	1287	1299	6
1	6	1714	1999	8
1	7	1284	1081	1
1	8	1614	1264	4
2	1	4041	3783	5
2	2	3261	3314	1
2	3	3564	3719	4
2	4	3122	3424	2
2	5	3428	3440	3
2	6	4075	4360	6
2	7	4704	4501	7
2	8	5654	5304	8
3	1	3850	3592	7
3	2	3282	3336	4
3	3	3235	3390	6
3	4	2587	2889	1
3	5	3699	3711	8
3	6	2778	3063	2
3	7	3552	3349	5
3	8	3501	3151	3
4	1	3251	2993	2
4	2	3251	3304	4
4	3	3222	3377	5
4	4	3221	3523	8
4	5	3464	3476	7
4	6	2244	2529	1
4	7	3641	3438	6
4	8	3451	3101	3
5	1	1974	1714	7
5	2	1644	1697	6
5	3	1714	1869	8
5	4	1325	1627	4
5	5	1462	1474	3
5	6	1391	1676	5
5	7	1311	1108	1
5	8	1627	1277	2
6	1	3201	2943	7
6	2	2476	2529	4
6	3	2647	2802	6
6	4	2433	2735	5
6	5	2504	2516	3
6	6	2777	3062	8
6	7	2591	2388	1
6	8	2748	2398	2
7	1	3303	3045	4
7	2	3271	3324	5
7	3	2858	3013	3
7	4	3551	3853	8
7	5	3405	3417	6
7	6	2360	3645	1
7	7	3674	3468	7
7	8	3189	2839	2

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 have low yield and small $S_1^{(1)}$ and $S_2^{(2)}$ values. According to these explanations, genotypes fell in section 1 can be considered as stable. Section 1, both figures, contains

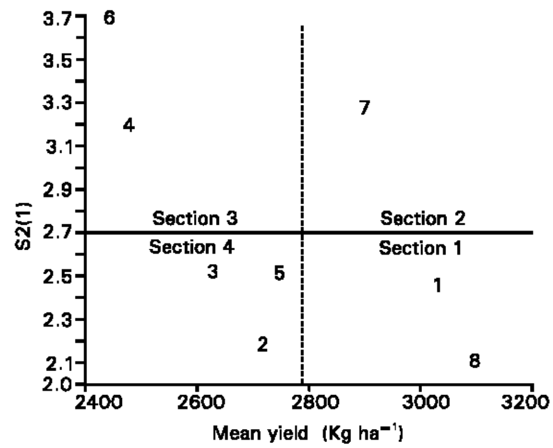

Fig. 1: Plot of $S_1^{(1)}$ vs. mean yield (kg ha^{-1}) for 8 oat genotypes over all environments

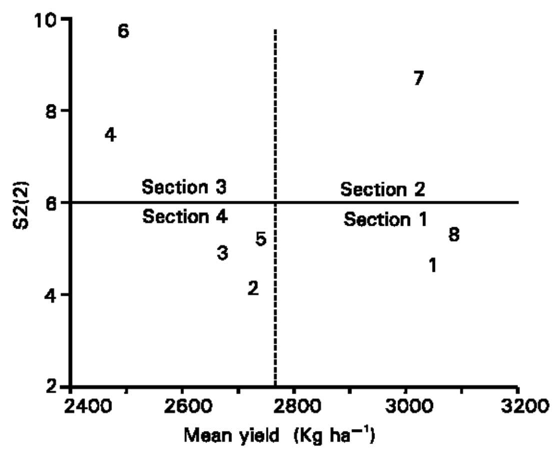

Fig. 2: Plot of $S_2^{(2)}$ vs. mean yield (kg ha^{-1}) for 8 oat genotypes over all environments

that genotype 1 and 8 are most stable, and well adapted to all environments, that is, those have general adaptable ability. Genotype 7 appears in section 2, where describes genotypes with increasing sensitivity to environmental change, and greater specificity of adaptability to high-yielding environments. Genotypes 4 and 6 fall section 3 in which refers poorly adapted genotypes to all environments. Section 4 includes genotypes 2, 3 and 5 that response greater resistance to environmental fluctuation, and therefore increasing specificity of adaptability to low-yielding environments.

Non parametric measures for stability based on ranks provide a useful alternative to parametric measures currently used which are based on absolute data. Although, non parametric vs. parametric stability statistics have some advantages (see, Huhn, 1990b), selections based on ranking genotypes in each environment may not be achieved, due to the fact that any

Table 3: Estimation and test of nonparametric measures for 8 oat genotypes across environments

Genotype	Mean yield (kg ha^{-1})	Mean rank	$S_1^{(1)¥}$	$Z_1^{(1)¥}$	$S_2^{(2)¥}$	$Z_2^{(2)¥}$
1	3020	5.0714	2.3809	0.1786	4.0357	0.3419
2	2709	4.4285	2.1904	0.5664	3.6190	0.6168
3	2607	4.8571	2.4761	0.0664	4.1428	0.2842
4	2460	4.7142	3.2381	1.1276	7.2381	0.9165
5	2749	5.1428	2.4761	0.0664	4.4761	0.1388
6	2477	4.4285	3.7142	3.5596	9.6190	4.4263
7	2964	4.0000	3.3333	1.5052	8.3333	2.2045
8	3112	3.3571	2.0952	0.8419	4.5595	0.1105
Sum				7.9124		9.0397
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§
	2.6250	5.2500	0.3333	4.3125	7.4767	15.5073

Grand mean = 2762 kg ha^{-1}¥. The $S_1^{(1)}$ 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 $Z_1^{(1)}$, $Z_2^{(2)}$

genotype may exhibit differential response one environment to other, thus shifting ranks of genotypes among environments. For instance, genotype 5 regarding ranking genotypes over all environments take over top of ranking, whereas genotypes 1 and 8 are most stable and well adapted across environments, as presented in Fig. 1 and 2. As a result, 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 mean yield (kg ha^{-1}) against $S_1^{(1)}$ and mean yield (kg ha^{-1}) against $S_2^{(2)}$ values can be enhanced visually efficiency in selection.

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