EVALUATION OF DURUM WHEAT GENOTYPES USING PARAMETRIC AND NONPARAMETRIC STABILITY STATISTICS

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ABSTRACT

The development of genotypes, which can be adapted to a wide range of environments, is the one of the most important goal of plant breeders in a crop improvement program. In this study, 6 six stability measures consisting of 4 parametric and 2 nonparametric were used to evaluate the genotype by environment interaction (GEI) in 20 durum wheat genotypes. The genotypes were evaluated for grain yield at fourteen environments in the Central Anatolian Region of Turkey for two years. The experimental layout was a randomized complete block design with three replications. Genotypes, environments main effects and GEI were significant at P < 0.01. Both parametric (b_i, S^2_{di}, R_i^2, P_i) and nonparametric ($S_i^{(1)}$, $S_i^{(2)}$) univariate stability statistics were used to determine stability of the durum wheat genotypes. Genotypes 20, 13 and 12 were most stables based on genotypes according to six stability measures. The level of associations among the stability measures was assessed using Spearman's rank correlation. Regression coefficient (b_i) was negatively and significantly correlated (P < 0.01) with superiority index (P_i). On the other hand, $S_i^{(1)}$, $S_i^{(2)}$ and S^2_{di} were positively and significantly correlated with P_i. As a result, these relationships reveal that only one of them could be sufficient to select genotypes of interest in a durum wheat breeding program.

Key Words: Durum Wheat, genotype by environment interactions, grain yield, stability

INTRODUCTION

The studies of GEI have assumed great importance in breeding programs because the yield performance of a genotype is the result of interaction with the genotype and environment. Environmental factors such as precipitation, temperature and soil structure play an important role in genotype performance. Therefore, the release of a genotype with consistent performance over a wide range of environments should lead to stability in production. A measure of the relative yield stability of the durum wheat genotypes under a wide range of environmental conditions is essential for determining efficiency a genotype evaluation program. Hence, a number of statistical procedures have been developed to enhance breeder's understanding of GEI, stability of genotypes and their relationships.

Many methods of analyses for stability have been proposed. The joint regression analysis of either phenotypic values or interactions on environment indices, was the first discussed by Yates and Cochran (1938) and was later modified and used by Finlay and Wilkinson (1963) and Eberhart and Russell (1966). Part of the genotype stability is expressed in terms of three empirical parameters: the mean performance, the slope of regression line (b_i), and sum of squares deviation from regression (S^2_{di}) (Crossa, 1990; Flores et al. 1998).

The parametric measures of phenotypic stability were mostly related with variance components or related statistics. These stability estimates had good properties under certain statistical assumptions, based on normal distribution of errors and interaction effects; they may not perform well, if these assumptions are violated, for example, in the presence of outliners (Huehn, 1990a). That means parametric tests for significance of variances and variance-related measures could be very sensitive to the underlying assumptions. Thus, it was wise to search for alternative approaches that were more robust to departures from common assumptions, such as non-parametric measures (Adugna and Labuschagne, 2003).

The non-parametric approaches were based on ranks of genotypes and provide an important alternative to the parametric stability. Huehn (1990a) proposed two non-parametric stability statistics of phenotypic stability [mean of absolute rank differences ($S_i^{(1)}$) and variance of ranks ($S_i^{(2)}$)], which were based on the ranks of genotypes in different environments.

The objectives of this study were to (i) interpret parametric and non-parametric stability statistics of 20 durum wheat genotypes tested in fourteen environments, (ii) determine promising genotypes with high yielding and stability (iii) evaluate the level of associations among the parametric and nonparametric stability parameters.

MATERIALS AND METHODS

Genotypes and growth conditions

20 durum wheat genotypes including 12 advanced durum wheat lines from the National Durum Wheat Advanced Yield Trial in Turkey and 8 advanced durum wheat lines from ICARDA were used in this study. Code, origin, cross, pedigree and selection history of durum wheat genotypes are given in Table 1.

During the 2000 and 2001 growing seasons, a total of 14 trials were conducted in 6 locations viz. the Konya, Cumra, Obruk, Kazımkarabekir, Haymana and Eskisehir in the Central Anatolian Region of Turkey. The growing seasons, experimental conditions, and cultural practices are presented in Table 2.

In each trial, experimental layout were in randomized complete-block design with three replications. The genotypes were seeded with an experimental drill in 1.2 m x 7 m plots, consisting of six rows with 20 cm between the rows. The seeding rate was 550 seeds m^{-2} for rain-fed and 450 seeds m^{-2} for irrigated environments.

The growing seasons, environments, amounts of precipitation, together with supplementary irrigation amounts for irrigated trial soil properties, date of sowing, date of harvesting are given Table 2. Yield (t ha^{-1}) was obtained by converting the grain yields obtained from plots to hectares.

Statistical Analyses

The parametric measures were performed in accordance with Eberhart and Russell's (1966) the slope value (b_i) and deviation from regression (S^2_{di}), Pinthus's (1973) coefficients of determination (R^2) Lin and Binn's (1988) superiority index (P_i) . Also, the relationships between regression coefficients and the grain yield means of genotypes were figured.

The non-parametric approaches were done for the mean of absolute rank differences ($S_i^{(1)}$) and the variance of ranks over environments ($S_i^{(2)}$), as suggested by Huehn (1990a), respectively. Rank measures and adjusted means of grain yields were used to depict plot by SAS PLOT procedure (Lu, 1995; Akçura et al. 2008). Besides, the stability parameters were compared using Spearman's rank correlation (Steel and Torrie, 1980). All analyses were carried out by using SAS Software (Anonimous, 1999).

RESULTS AND DISCUSSION

Considering environments, grain yield of environments over genotypes ranged from 1.11 t ha^{-1} for E14 to 6.77 t ha^{-1} for E8 (Table 2). Grain yield of genotypes over environments ranged from 3.35 t ha^{-1} to 4.22 t ha^{-1} (Table 4). Taking the grain yield over environments as the first parameter genotypes, 20, 7, and 12 had higher grain yield than mean grain yields (3.96 t ha^{-1}) while, genotype 3 had the lowest grain yield over environments.

Table 1. Code, pedigree, selection history and origin of dururm wheat genotypes

Code	Cross, Pedigree and Selection History	Origin
1	VALNOVA GE 598(ITALIA)//YUMA/FATO"S"	NDWAYT[a]
	BDKM 900021 1F5BD-OBD	
2	DF9-71/3/VZ466//61-130/414-44/4/ERGENE	ICARDA[b]
	TE01061-23A-1A-12A-2A-0A	
3	ALBIT 9	ICARDA
	ICD-84-0322-ABL-5AP-TR-AR-6AP-TR-2AP-0TR	
4	BRA180/3/LOKATA/60-120//LDS/64-120//BERK/4/68111/WARD	NDWAYT
	BDMM 920001 2F5BD-OBD	
5	C16-11/GÖKALA//BRA180/WLS/3/DAWARE"S"/JO"S"/KUNDURU	ICARDA
	YE 03561 -0E 2F5BD-OBD	
6	ÜVY/61-130//APPL/3/1378/4/68111/WARD//LAM94/ROMCZ.DWF/5/UVY/61-130	NDWAYT
	BDMM 920046 TOPCR(3MG)	
7	BERK469/GDO//AKBUĞDAY"S"/HEVİDİK"S"/3/BERK469/4/OVI/61-130//MENCEKİ	NDWAYT
	"S"/5/ZF/LDS/3/FATO.SEL/185-1//61-130/LDS/4/DF15-72	
	BDMM 920054 F5BD-OBD	
8	CROSS UNKNOWN/3/68111/WARD//LM94/ROMCZDWF	ICARDA
	YE 03561 -0E F5BD-OBD	
9	BERK//68111/WARD/3/KND	ICARDA
	YE 03527 -0E 1F5BD-OBD	
10	ÜVY126/61-130//KORUND	ICARDA
	YE 03491 -0E F5BD-OBD	
11	BERK469//68140/WARD/3/WELLS	NDWAYT
	BDMM 920010 1F5BD-OBD	
12	BERK469//68140/WARD/3/66T10	NDWAYT

Table 1. Continued

Code	Cross, Pedigree and Selection History	Origin
13	BRA180/3/LOKATA/60-120//LDS/64-120//BERK/5/KIRMIZI MISRI	ICARDA
	YE 03512 -OE F5BD-OBD	
14	68111/WARD//ALTINDANE/BERK469	NDWAYT
	BDKM 910050 4F5-OBD	
15	Unknown-1	NDWAYT
	XXX	
16	Unknown-2	NDWAYT
	XXX	
17	Unknown-3	NDWAYT
	XXX	
18	61-130/DS//GÖKALA24/3/DURUMV 24/4/PG"S"//RHAP/21565	NDWAYT
	BDKM 910082 1F5-OBD	
19	Unknown-4	NDWAYT
	XXX	
20	1530.9334	ICARDA
	980044 UKN 0D	

[a] National Durum Wheat Advanced Yield Trial-Turkey; [b] ICARDA; International Center for Agricultural Research in the Dry Areas

Combined analysis of variance for grain yield revealed that genotypes and environments main effects and GEI were significant at P < 0.01 (Table 3). In the case GEI effects suggest that there are significant differences in the responses of genotypes to environments, and hence sensitivity and instability.

Genotypic rank differences over environments indicated the presence of crossover GEIs (Crossa, 1990). This was confirmed by the significant effect of the GEI in the joint analysis of variance (Table 3) and indicated the need to assess the response of the genotypes to environmental variation. The adaptability and stability measures for a genotype are necessary for its recommendation to target environments for recommending genotypes for known cropping conditions. According to the Eberhart and Russell (1966) model, regression coefficients (b_i) approximating 1.0 coupled with deviation from regression (S^2_{di}) of zero indicate average stability. When this is associated with high mean yield, genotypes have general adaptability and when associated with low mean yield, genotypes are poorly adapted to environments. b_i values above 1.0 describe genotypes with higher sensitivity to environmental change (below average stability), and greater specificity of adaptability to high yielding environments.

Table 2. Codes, growing seasons, soil properties, site description, agronomic details and grain yield (t ha^{-1}) for environments.

Code	Growing Season	Environment	Soil Properties	Rainfall+(Irrig) (mm)	Grain Yield (t ha^{-1})
E1	2000-01	Konya [a]	pH= 8.2 clayey, alluvial	210(100)	5.13
E2	2000-01	Konya [b]	pH= 8.2 clayey, alluvial	210	3.31
E3	2000-01	Çumra [b]	pH= 8.2 clayey loam, hydro-morfic alluvial	255(100)	6.75
E4	2000-01	Çumra [a]	pH= 7.8 clayey loam, hydro-morfic alluvial	255	4.34
E5	2000-01	Kazımkarabekir [a]	pH= 8.2 clayey, red brown	240	2.23
E6	2001-02	Konya [b]	pH= 8.2 clayey, alluvial	384(100)	5.86
E7	2001-02	Konya [a]	pH= 8.2 clayey, alluvial	384	2.20
E8	2001-02	Çumra [b]	pH= 7.8 clayey loam, hydro-morfic alluvial	303(100)	6.77
E9	2001-02	Çumra [a]	pH= 7.8 clayey loam, hydro-morfic alluvial	303	3.01
E10	2001-02	Haymana [b]	pH= 7.8 clayey, brown	505 (100)	6.26
E11	2001-02	Haymana [a]	pH =7.9, clayey,brown	505	3.32
E12	2001-02	Eskişehir [b]	pH= 8.8 clayey, red brown	437(100)	2.47
E13	2001-02	Eskişehir [a]	pH= 7.8 clayey, red brown	437	2.62
E14	2001-02	Obruk [a]	pH= 7.6 clayey. brown	315	1.11

[a] Rain-fall conditions   [b] Irrigation conditions

Regression coefficients decreasing below 1.0 provide a measure of greater resistance to environmental change (above average stability), and therefore increasing specificity of adaptability to low yielding environments. Genotypes 5 and 7 had a higher grain yields (Table 4) and a coefficient values greater than one. These genotypes are sensitive to environmental changes and would be recommended for cultivation under favorable conditions.

Table 3. Combine analysis of variance for grain yield (t ha^{-1}) of 20 durum wheat genotypes in 14 environments.

S.V.	D.F.	M.S.	%
Model	307	10.89**	
Replications (E)	28	2.00	
Environment (E)	13	212.88**	91.1
Genotype (G)	19	2.37**	1.5
G x E	247	0.92**	7.5
Eror	532	0.43	
CV=16.45	R^2=0.93	Mean=3.96	

** significant at 0.01 probability level

The genotypes 20, 9 and 12 had *b* values equal to one, deviations from regression values equal to zero and high R^2 (Table 4). Therefore, they had an average capacity for adaptation to all the environments and were highly predictable. According to Eberhart and Russell (1966), they could be considered ideal genotypes, since they even maintained good performance in environments with low yields. This concept of an ideal genotype has been questioned by Hildebrand (1990), who suggested that breeders should find genotypes capable of maintaining good yield in unfavorable environments or those excellent in variable environments, rather than select materials with a *b* equal to one. Hildebrand (1990) stated that these genotypes may yield less in unfavorable environments than those with low b values, and less in favorable environments than those with higher *b* values.

Genotypes high yielding and specific adaptable to unfavorable environments were not identified by the regression analysis (Table 4). The genotype with a *b* lower than one was genotype 3, which had the lowest yield, one of the greatest variance in the S^2_{di} and also one of the lowest R_i^2. Genotypes 13 and 20 had higher yield and stability parameters defined as ideal by Eberhart and Russell (1966).

Relationship between the b_i values and mean grain yields for 20 durum wheat genotypes are shown graphically in Figure 1. Genotypes 20, 12, 15 and 13 had the higher grain yields than the grand mean and their b values were close to 1.0 at confidence limits. These genotypes, therefore, were the group of the best adaptation to all environments. The genotypes 9, 10, 18 and 19 were in the group of average adaptation while 4 and 6 were defined as the group of low adaptation to all environments. On the other hand, other genotypes were put outside of this type classification as being outside the confidence limits.

In an alternative procedure for assessing the behavior of genotypes in GEIs proposed by Lin and Binns (1988), the superiority of a genotype may be assessed by the superiority index (P_i), defined as the deviation of the i^{th} genotype relative to the genotype with maximum performance in each environment. The superior genotype would be that one with the lowest P_i value, that one which remained among the most productive in a given set of environments. The estimate of P_i could be partitioned into a portion attributed to genetic deviation, that is, the sum of the squares of the genotypes. This would be troublesome to breeders since it does not necessarily imply alteration in the genotypes ranking or in the portion attributed to GEIs. In this case, the genotypes of greatest interest would be those with the lowest P_i values, most of which would be attributed to genetic deviation (Lin and Binns, 1988). Genotypes 7, 12, 13 and 20 had the highest grain yields (Table 4) and the lowest P_i values, with its most part attributed to the genetic component. The exception was genotype 1, which had the greatest part of P_i that was attributed to the interaction. Besides, this genotype contributed only 7.21 % of the total value of the interaction (Table 4).

Table 4: Estimates of the parametric stability parameters for grain yield (t ha-1) of 20 durum wheat genotypes over 14 environments

Code	$\bar{x}$	b_i	R_i^2	S^2_{di}	P_i	Genetic	Interaction	C.E. (%)	$S_i^{(1)}$	Z_1	$S_i^{(2)}$	Z_2
1	4.17	0.86*	0.92	0.24	0.61	0.29	0.32	7.21	6.8 (12)	0.0	32.8 (11)	0.0
2	3.87	0.84*	0.86	0.37	0.96	0.58	0.38	8.71	8.8 (20)	5.5	56.5 (20)	7.2
3	3.35	0.77**	0.87	0.42*	1.66	1.26	0.40	9.17	7.4 (14)	0.6	42.5 (17)	1.2
4	3.74	1.00	0.91	0.36	0.96	0.71	0.25	5.61	7.6 (17)	1.0	42.3 (16)	1.1
5	4.07	1.18*	0.92	0.49*	0.58	0.37	0.21	4.6	6.5 (10)	0.0	35.2 (13)	0.1
6	3.41	1.01	0.87	0.61**	1.46	1.16	0.30	6.82	8.3 (19)	3.3	49.6 (19)	3.6
7	4.22	1.16*	0.97	0.17	0.37	0.26	0.11	2.53	6.7 (11)	0.0	31.3 (9)	0.1
8	3.81	0.91	0.94	0.20	0.91	0.63	0.28	6.34	6.2 (5)	0.2	27.8 (3)	0.4
9	3.99	0.99	0.96	0.16	0.66	0.45	0.21	4.68	6.2 (6)	0.3	27.9 (5)	0.4
10	3.89	0.98	0.93	0.28	0.79	0.55	0.24	5.47	7.4 (15)	0.8	41.3 (15)	0.9
11	3.98	1.11*	0.95	0.23	0.57	0.46	0.11	2.57	6.3 (7)	0.1	31.0 (8)	0.1
12	4.20	1.01	0.93	0.29	0.52	0.27	0.25	5.61	6.1 (3)	0.4	27.8 (4)	0.4
13	4.14	0.98	0.94	0.24	0.52	0.32	0.21	4.71	5.8 (1)	0.8	26.0 (1)	0.7
14	3.95	0.89*	0.94	0.19	0.74	0.49	0.26	5.85	6.4 (9)	0.1	31.7 (10)	0.0
15	4.09	1.05	0.95	0.21	0.52	0.36	0.16	3.65	7.4 (16)	0.7	39.8 (14)	0.6
16	4.08	1.12*	0.98	0.11	0.52	0.37	0.14	3.17	6.8 (13)	0.0	32.9 (12)	0.0
17	3.98	1.07*	0.96	0.19	0.63	0.46	0.17	3.93	6.1 (4)	0.3	28.3 (6)	0.3
18	4.03	1.01	0.95	0.19	0.54	0.42	0.12	2.81	6.3 (8)	0.2	28.7 (7)	0.3
19	3.94	1.03	0.92	0.38	0.70	0.50	0.20	4.61	7.8 (18)	1.5	43.6 (18)	1.4
20	4.22	1.03	0.96	0.16	0.34	0.25	0.09	1.96	6.0 (2)	0.6	26.2 (2)	0.7
$\bar{x}$	3.96 ± 0.10	1.00 ± 0.5							6.8	0.8	35.2	1.0
Sums								100		16		19

Test statistics for $S_i^{(1)}$ and $S_i^{(2)}$

$E(S_i^{(1)})$	$E(S_i^{(2)})$	$Var(S_i^{(1)})$	$Var(S_i^{(2)})$	$X^2 Z^{(1)}, Z^{(2)}$	X^2 sum $Z^{(1)}, Z^{(2)}$
6.8	33.2	0.825	74.85	9.15	31.41

C.E.: Contribution to interaction (%) ** significant at 0.01 probability level; *significant at 0.05 probability level

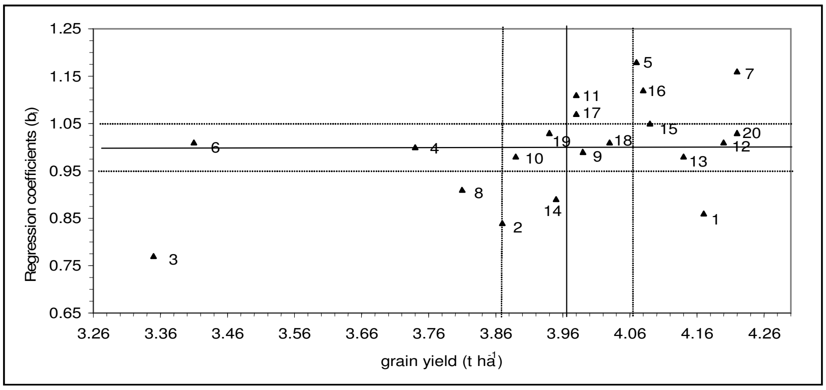
Table 5. Sperman's correlation coefficients among parametric and nonparametric parameters

	S^2_{di}	R_i^2	P_i	$S_i^{(1)}$	$S_i^{(2)}$
b_i	-0.26	0.60*	-0.61*	-0.16	-0.17
S^2_{di}		-0.90**	0.52*	0.50*	0.61*
R_i^2			-0.71**	-0.55*	-0.63**
P_i				0.57*	0.62*
$S_i^{(1)}$					0.97**

** Significant at 0.01 probability level; *significant at 0.05 probability level

Huehn (1990a) proposed that the stability of a genotype in response to environmental changes could be assessed based on its classification in various environments. Both $S_i^{(1)}$ (mean absolute rank differences) and $S_i^{(2)}$ (variance of ranks) values of the genotypes across the environments were used as a measure of stability (Huehn, 1990b). The $S_i^{(1)}$ and $S_i^{(2)}$ statistics were based on ranks of the genotypes across environments and they give equal weight to each environment. Genotypes with fewer changes in rank were considered to be more stable (Becker and Leon, 1988). The estimates of $S_i^{(1)}$ were all possible pair- waise rank differences across locations for each genotype, whereas that of $S_i^{(2)}$ are variance of ranks for each genotype across locations (Nassar and Huhn,1987). According to Huehn (1990b), $S_i^{(1)}$ was preferred to $S_i^{(2)}$ for many practical applications; it was reported to be easy to calculate, interpret and it had an efficient test of significance. Two nonparametric stability measurements ($S_i^{(1)}$ and $S_i^{(2)}$) were proposed such that the i^{-th} genotype could be considered stable in n environments under analysis if its classifications were similar in all environments, i.e., it would correspond to maximum stability. For a genotype with maximum stability $S_i^{(1)} = S_i^{(2)} = 0$.

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 was appeared that $Z_i^{(1)}$ sum = 16.0 and $Z_i^{(2)}$ sum = 19.0. Since both of these statistics were less than the critical value $X^2_{0.05,\ 20} = 31.41$, no significant differences in rank stability were found among the 20 genotypes grown in 14 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).



Confidence limit for regression coefficient: 1.00 ± 0.5
Confidence limit for grain yield: 3.96 ± 0.10

Figure 1. Plot of regression coefficients vs. grain yield for 20 durum wheat genotypes tested in 14 environments

Figures 2 and 3 represent plots portrayed by mean yield (t ha^{-1}), vs. $S_i^{(1)}$ and $S_i^{(2)}$ values. Mean $S_i^{(1)}$ and $S_i^{(2)}$ values and grand mean yield divide both figures into four sections; Section 1 referred that genotypes have high yield and small $S_i^{(1)}$ and $S_i^{(2)}$ values, section 2 signs that genotypes have high yield and large $S_i^{(1)}$ and $S_i^{(2)}$ values, section 3 presents that genotypes exist low yield and large $S_i^{(1)}$ and $S_i^{(2)}$ values, and section 4 exhibits that genotypes are of low yield and small $S_i^{(1)}$ and $S_i^{(2)}$ values. According to these configurations, genotypes interesting in section 1 can be considered as stable (Akçura and Kaya 2008).

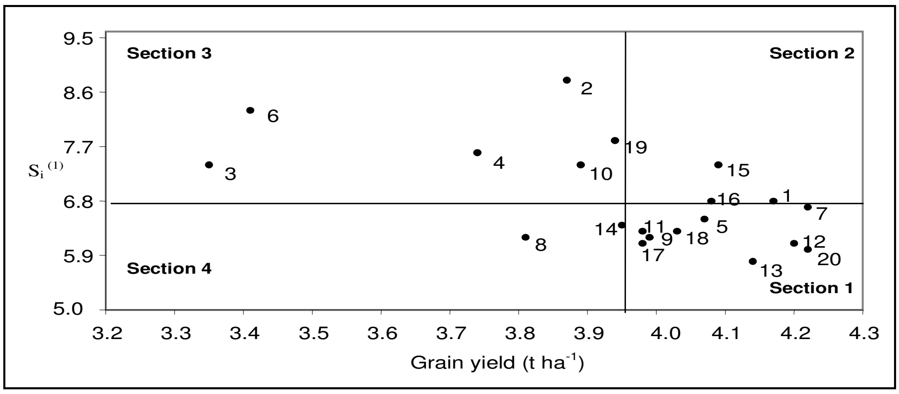


Figure 2. Plot of $S_i^{(1)}$ vs. grain yield for 20 durum wheat genotypes tested in 14 environments

Section 1, both figures, contained that genotypes 7, 12, 13 and 20 were the most stable, and well adapted to all environments, that is, those had general adaptable ability. Genotypes 15, 16 and 1 appeared in section 2, where described 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 captured genotypes 2, 3, 4, 6, 10 and 19 in figure 2 and 3. Section 4 included genotypes 8 and 14 that response greater resistance to environmental fluctuation, and therefore they were increasing specificity of adaptability to low-yielding environments.

Nassar and Huhn (1987) suggested that $S_i^{(1)}$ statistic measure should be utilised in any case that a genotype represents unfair fluctuations among sections, regarding $S_i^{(1)}$ and $S_i^{(2)}$ values. To illustrate, genotypes 7, 12, 13 and 20 were the most stable and well adapted across environments, as presented in Figure 2 and 3. Genotypes 12 and 20 higher mean rank values than genotype 13 which was the lowest. Genotypes 12 and 20 comparing to genotype 13 may be selected on account of the fact that genotypes 12 and 20 revealed higher mean yield across environments than genotype 13.

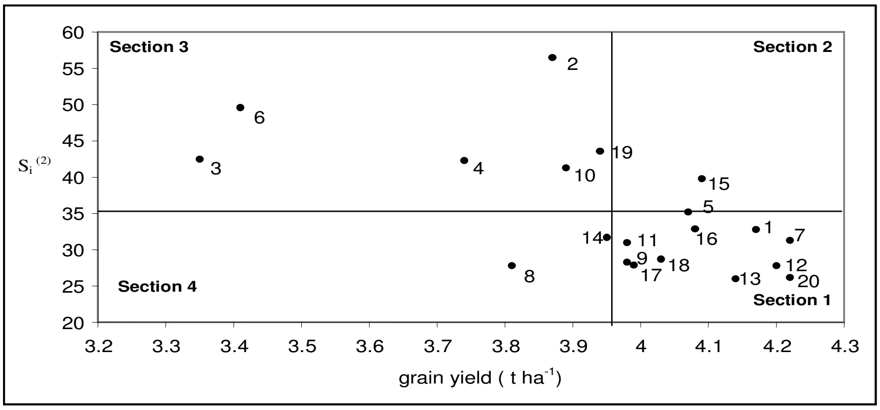


Figure 3. Plot of $S_i^{(2)}$ vs. grain yield for 20 durum wheat genotypes tested in 14 environments

The correlation among stability estimates of the different models may indicate if more estimates should be obtained to improve confidence in the prediction of genotypes behavior. The Spearman's rank correlation between the regression coefficient (b_i) and the superiority index (P_i) was negative and significant ($P < 0.05$) (Table 5). This estimate indicates that more responsive genotypes tended to have lower P_i values. Similar results were obtained in maize (*Zea mays* L.) (Scapim et al. 2000), barley (*Hordeum vulgare*) (Lin and Binns, 1988), timothy (*Phleum pratense* L.) (Helgadottir and Kristjansdottir, 1991). P_i was positively and significantly correlated with $S_i^{(1)}$, $S_i^{(2)}$ and S^2_{di}, but negatively and significantly correlated with R_i^2. The presence of a correlation between P_i and $S_i^{(1)}$, $S_i^{(2)}$ and S^2_{di} seems to indicate that superior genotypes (with lower P_i) could also be stable (with lower $S_i^{(1)}$, $S_i^{(2)}$ and S^2_{di}).

Four measures were similar in classifying the genotypes according to their stability under different environmental conditions (Table 5). Consequently, only one of these parameters would be sufficient to select the stable genotypes in a breeding program. Similar results were obtained in the maize (*Zea mays* L.) (Scapim et al. 2000), and soybean (*Glycine max* L.) (Yue et al., 1997).

In conclusion, non-parametric stability measurements seem to be useful alternatives to parametric measurements (Yue et al., 1997), although they do not supply information about genotype adaptability. According to both parametric and non-parametric stability parameters genotypes 20, 13 and 12 were most stable ones for grain yield.

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