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IDENTIFYING THE SUPERIOR WHEAT GENOTYPES IN MULTI-ENVIRONMENT TRIALS BY USING MODIFIED SUPERIORITY INDEX

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ABSTRACT

Eleven wheat (Triticum aestivum L.) genotypes were evaluated under irrigation and water stress conditions in eight environments as follow: four environments in 2005/2006 at Kafr El-Hamam (El-Sharkya Governorate) and El-Bostan (EL-Behera Governorate). While the other four environments were conducted during 2006/2007 and 2007/2008 at Experiment and Research Station, Faculty of Agriculture, Cairo University, (Giza Governorate). This study aimed to identify the yield stable genotypes across eight environments by using modified superiority index. Genotypes, environments and their interaction had highly significant mean squares for grain yield. Mean performance of grain yield showed that 4 genotypes (L.R. 3, L.R. 7, L.R. 8 and L.R. 10) were insignificant compared with the check variety (Sahel 1). Genotypes yield stability across the testing environments using the modified superiority index proved that four genotypes (L.R. 3, L.R. 8, L.R. 10 and Sahel 1) were stable in yield performance across the eight environments.

Kew words: ***Wheat, Superiority index, Stability, Regression, adaptation.***

INTRODUCTION

Recommendation trials are conducted routinely throughout the world aiming at the identification of superior genotypes for on farm use. However, cultivars often do not perform in a similar manner when tested in multiple environments. This phenomenon is due to the presence of genotype by environment interaction (GE). GE is differential genotypic expression across environments. If GE exists, means across trials are of limited use for meaningful recommendation tasks. GE complicates identification of superior genotypes, pointing out the need for growing different cultivars in different areas for the target region. Detection of areas in which genotypes perform similarly becomes thus a priority for cultivar evaluation and recommendation (Gauch and Zobel 1997).

Multi-environment trials (MET) play an important role in selecting the best cultivars and in assessing a cultivar's stability across environments before its commercial release (Vargas *et al* 1999). Also, multi-environment trials are important for testing general and specific cultivar adaptation. A cultivar grown in different environments may show significant fluctuation in yield performance relative to other cultivars. These changes are influenced by different environmental conditions and are referred to as genetic x environment (G x E) interaction (Carlos and Karzanowski 2003). Presence of G x E rules out simple interpretative models that have only additive main effects of genotypes and environments (Crossa 1990 and Kang and Magari, 1996). On the other hand, specific adaptation of genotypes in certain environments is a fundamental issue to be studied in plant breeding because one genotype may perform well under specific environmental conditions and show poor performance under other conditions.

New wheat varieties generally need to be evaluated at different environments for several years before being released. The new varieties with desired traits that add value to the product should be tested for the stability of these traits in the target environments (Kang 1998).

Many stability statistics have been used to determine whether or not cultivars evaluated in multi-enviroment trials are stable (Lin *et al* 1986, Hühn 1996, Flores *et al* 1998, Robert 2002, Sabaghnia *et al* 2006). Because the most stable genotype(s) may not be the highest yielding, the use of methods that integrate yield performance and stability to select superior genotypes becomes important (Kang 1988, Pham and Kang 1988, Kang and Pham 1991, Kang 1993 and Kang and Magari 1996). The more widely used method for detecting stable genotypes is the regression approach (Finaly and Wilkinson 1963). According to the definition of Eberhart and Russell (1966), a stable preferred genotype would have, approximately, values of b=1, S^2_d=0 and a high mean performance. Rao *et al* (2002) reported that identification of yield contributing traits and knowledge of G x E interaction and yield stability were important for breeding new cultivars with improved adaptation to the environmental constraints prevailing in the target environments.

Francis and Kannenberg (1978) developed a modified superiority index to evaluate the stability of tested entries maize hybrids across locations. This index involved three stability parameters (b, $S^2_{y.x}$ and C.V.) in addition to mean yield of each tested hybrid. Habliza and Khalifa (2006) used the modified superiority index to evaluate 27 maize hybrids and recommended the use of this index in selection programs. Recently, Kang (1998) suggested the use of a simultaneous index (superiority index Ys_i) that includes yield and two stability parameters to select the best genotypes from many tested ones.

This study aimed to identify the yield stable genotypes across eight environments by using modified superiority index.

MATERIALS AND METHODS

Eleven wheat genotypes were evaluated under irrigated and water stress conditions in eight environments as follow: four environments in 2005/2006 at Kafr El-Hamam (El-Sharkya Governorate) and El-Bostan (EL-Behera Governorate) with the two irrigation systems. While the other four environments were conducted during 2006/2007 and 2007/2008 at Experiment and Research Station, Faculty of Agriculture, Cairo University, (Giza Governorate) with the same two irrigation systems. Each location in a given season was considered as an individual environment. Details of genotypes and the eight environments are given in Tables (1) and (2), respectively.

Table 1. Name, pedigree and origin of the studied wheat genotypes.

No.	Name**	Pedigree	Origin *
1	L.R. 1	22SAWSN-184	Sudan
2	L.R. 2	ELAME4SA-464	Sudan
3	L.R. 3	22SAWSN-166	Sudan
4	L.R. 4	TR135/GP NO4//CONDOR	Sudan
5	L.R. 5	FANG60/SERI-21USA	Egypt
6	L.R. 6	GAA'S'/OPATA	Sudan
7	L.R. 7	KAUZ/WEAVER	Sudan
8	L.R. 8	OASIS/SKAUZ//4*BCN	Sudan
9	L.R. 9	HP 1744-OIND	Egypt
10	L.R. 10	CMBW90Y341-OTOPM	Sudan
11	Sahel 1	CAZO/KAUZ//KAUZ	Egypt

*Source: Plant Genetic Resources Research Department (Bahteem Gene Bank), FCRI, ARC-Egypt.

Table 2. The environments used in this study.

Environment	Location	Season
E1	Kafr El-Hamam (water stress)	2005/2006
E2	Kafr El-Hamam (Irrigated)	2005/2006
E3	El-Bostan (water stress)	2005/2006
E4	El-Bostan (Irrigated)	2005/2006
E5	Giza (water stress)	2006/2007
E6	Giza (Irrigated)	2006/2007
E7	Giza (water stress)	2007/2008
E8	Giza (Irrigated)	2007/2008

The trials were established in a randomized complete blocks design with three replications at each environment. Irrigated plots were watered at planting, tillering, jointing, flowering and grain filling stages. Water stress plots received water only at planting. Sowing was done in the third week of November in all experiments. Plots consisted of four rows (3 m long and 20 cm apart).

Statistical analyses

Normality distributions in each environment were checked out by the Wilk Shapiro test (Neter *et al* 1996). An analysis of variance (ANOVA) was done for each environment separately. A combined analysis of variance was done from the mean data of each environment, to create the means for the different statistical analyses methods. Homogeneity test of variances were performed according to procedures reported by Gomez and Gomez (1984).

To evaluate the stability of tested genotypes across the eight environments, the modified superiority index developed by Francis and Kannenberg (1978) was used. This index included three stability parameters, i.e. regression coefficient (b), variance of deviation from regression ($S^2_{y.x}$) and the coefficient of variation (C.V.%) of each genotype across the testing environments in addition to the mean yield of each genotype. The values of b, $S^2_{y.x}$ and C.V.% were calculated using the model of Eberhart and Russell (1966) which depends on the linear regression that was performed using MSTAT-C software package (Freed *et al* 1989) according to the following model:

$$\mathbf{Y_{ij} = u_i + b_i I_j + S_{ij}},$$

Where:

Y_{ij} = The mean of the i^{th} genotype at the j^{th} environment.

$\mathbf{u_i}$ = mean of the i^{th} genotype over all environments.

$\mathbf{b_i}$ = regression coefficient for the response of the i^{th} genotype to the environmental index.

$\mathbf{I_j}$ = environmental index obtained as the mean of all genotypes at each environment minus the grand mean.

$\mathbf{S_{ij}}$ = the deviation from regression of the i^{th} genotype and j^{th} environment.

From the regression analysis, b and $S^2_{y.x}$ for each genotype were calculated in addition to the C.V. across environments. A weighted superiority index were calculated for each genotype which included the following four criteria:

1-The first criterion was the distance of a genotype from the overall mean, using the LSD from the ANOVA at p=(not significant, 0.10, 0.05, 0.01 and 0.001) and a yield score (I=0, 2, 4, 6, 8 + if above mean, or - if below) as coded value for the mean yield of the genotype.

2- The second criterion was a regression coefficient, estimated in the usual manner as: $b_i = \Sigma_j Y_{ij} / \Sigma_j I^2_j$

The distance of genotype regression coefficient (b) from 1 divided by the (S_b x t) represented a regression score of 4, 3, 2, 1, 0 for a probability < ns, 0.10, 0.05, 0.01, 0.001, respectively. The value of S^2_b was calculated from the S^2_e (pooled error) divided by the SS for environment index.

3- The third criterion was the variance of deviation from regression ($S^2_{y.x}$) divided by the pooled MS of error (S^2_e) with a score of 4, 3, 2, 1, 0, corresponding to ns, 0.10, 0.05, 0.01, 0.001 probability levels according to F value.

4- The fourth criterion was coefficient of variation (C.V.) for each genotype. The C.V. values were classified into four groups of score 4, 3, 2, 1 for C.V. values of <5, <10, <15, <20%, respectively.

The total of the previous four criteria would represent the modified superiority index.

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance for grain yield at each environment and their combined are presented in Table (3). Results of combined analysis showed that differences among environments were highly significant for grain yield indicating that the eight environments are different in their conditions. Highly significant ($p<0.01$) differences among genotypes were detected, at each environment and their combined analysis for grain yield, except at environment 3 which was significant only ($p<0.05$). Highly significant ($p<0.01$) mean squares due to environments X genotypes interaction were detected for grain yield, which indicated that genotypes performed differently at different environments.

It is clear from these results that the tested genotypes must be evaluated under different environments, especially for grain yield, which is regarded as the most important trait.

Mean performance

The mean performance of the eleven genotypes for grain yield at each environment and their combined means are presented in Table (4). Mean grain yield under the eight environments was 8.44, 11.43, 6.19, 9.96, 6.31, 9.36, 9.51 and 14.69 (ardab/fed.), respectively. The overall mean for grain yield of the eleven genotypes across the eight environments was 9.49 (ardab/fed.), while mean yield of the check (Sahel 1) was 10.94 (ardab/fed.) Results of tested genotypes across environments showed that four genotypes (L.R. 3, L.R. 7, L.R. 8 and L.R. 10) where, grain yield was significantly less than the check variety (Sahel 1). However, there was no genotype that exceeded the check variety for grain yield.

Table 3. Pertinent mean squares for gain yield at each environment and for combined data.

S.O.V.	Environments (E)	Reps/E.	Genotypes (G)	G X E	Error
E1	-------	-------	0.26 **	--------	0.025
E2	-------	-------	0.45 **	--------	0.046
E3	-------	-------	0.11 *	--------	0.045
E4	-------	-------	0.87 **	--------	0.059
E5	-------	-------	1.55 **	--------	0.316
E6	-------	-------	2.76 **	--------	0.603
E7	-------	-------	4.69 **	--------	0.287
E8	-------	-------	3.27**	--------	0.26
Combined data	31.96 **	1.216	3.64 **	1.05 **	0.205

-*,** significant at 0.05 and 0.01 probability levels, respectively.

-Kafr El-Hamam (Water stress) 2005/06 (E1), Kafr El-Hamam irrigated 2005/06 (E2), El-Bostan (Water stress) 2005/06 (E3), El-Bostan irrigated 2005/06 (E4), Giza (Water stress) 2006/07 (E5), Giza irrigated 2006/07 (E6), Giza (Water stress) 2007/08 (E7) and Giza irrigated 2007/08 (E8).

-+ Mean square components can not calculated for individual environment.

Table 4. Mean performance of grain yield for eleven wheat genotypes and their combined means across eight environments.

Genotypes	E1	E3	E5	E7	E2	E4	E6	E8	combined
	Water stress				Irrigated				
Line 1	8.27	4.98	7.04	4.31	9.65	9.82	9.49	10.72	8.04
Line 2	9.60	6.53	4.76	5.57	12.04	7.75	8.46	14.28	8.62
Line 3	8.10	6.91	6.14	13.68	11.87	11.01	9.56	15.49	10.35
Line 4	8.53	6.16	8.02	10.45	10.28	9.56	10.66	11.76	9.43
Line 5	6.99	6.60	4.28	7.67	9.74	9.71	8.38	13.83	8.40
Line 6	9.18	5.79	6.92	4.81	11.42	8.59	7.88	10.02	8.08
Line 7	7.65	6.66	7.58	10.90	12.90	10.45	9.50	15.99	10.20
Line 8	8.32	5.92	6.08	14.78	12.36	9.21	9.84	18.14	10.58
Line 9	9.32	6.35	4.99	9.88	11.46	8.65	7.34	15.06	9.13
Line 10	9.22	6.04	6.48	10.86	11.63	12.64	9.30	18.40	10.57
Sahel 1	7.60	6.16	7.14	11.68	12.32	12.20	12.52	17.89	10.94
Mean	8.44	6.19	6.31	9.51	11.43	9.96	9.36	14.69	9.49
L.S.D. 5%	0.76	1.01	2.68	2.55	1.02	1.16	3.70	2.43	0.72

Stability of tested genotypes

Modified superiority index was used to test yield superiority of the testing genotypes. This index combined the yield mean with three stability parameters in one parameter to designate a superiority score. However, double weight was given to yield with respect to each stability parameter. This score is expected to be an easy and practical criterion to be used to screen promising genotypes. Results of stability parameters and the obtained stability score for each genotype are presented in Table (5). The super group which had a score above 15 included four genotypes namely L.R. 3, L.R. 8, L.R. 10 and Sahel 1 (control). The intermediate group which had a score between 10 to 14 included genotypes L.R. 4, L.R.7 and L.R. 9. The poor group which had a score below 10 included L.R. 1, L.R. 2, L.R. 5 and L.R. 6. Obviously, it can be concluded that genotypes of both super and intermediate scores are considered stable and were selected. However, it is recommended to evaluate these genotypes over a wide range of different environments in the final stages of testing before recommending for commercial production.

Similar results on different genotypes were reached by using the modified superiority index through Sinha *et al.* (1986), Bruckner and Frehberg (1987), Ehdaie *et al.* (1988), Shehata *et al.* (2005), Habliza and Khalifa (2006) and Seiam and Khalifa (2007).

Table 5. Mean grain yield, stability parameters (b,$S^2_{y.x}$, CV and r^2) of the modified superiority index for the wheat genotypes evaluated at eight environments.

Genotypes	Grain yield (ardab/fed.)		Regression coefficient (bi)		Variance of deviation from regression ($S^2_{y.x}$)		Coefficient of variation (CV%)		Modified superiority index (score)
	Mean	Score	b_i	Score	$S^2_{y.x}$	Score	CV%	Score	Index
L.R. 1	2.87	-8	0.58	2	0.27	4	3.19	4	2
L.R. 2	3.08	-6	1.01	4	0.30	4	3.76	4	6
L.R. 3	3.70	+6	1.08	4	0.24	4	3.15	4	18
L.R. 4	3.37	0	0.56	2	0.22	4	2.47	4	10
L.R. 5	3.00	-6	0.98	4	0.21	4	3.32	4	6
L.R. 6	2.88	-8	0.51	1	0.22	4	2.83	4	1
L.R. 7	3.64	+4	1.10	0	0.19	4	3.38	4	12
L.R. 8	3.78	+6	1.40	2	0.27	4	3.94	4	16
L.R. 9	3.26	0	1.08	4	0.26	4	3.68	4	12
L.R. 10	3.78	+6	1.38	2	0.21	4	3.69	4	16
Sahel 1	3.91	+8	1.33	3	0.42	4	3.79	4	19
Mean	3.39		1.00		0.26		3.38		

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استخدام معامل المفاضلة المعدل للتعرف على التراكيب الوراثية المتفوقة من القمح في تجارب البيئات المتعددة

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تم تقييم احدي عشر تركيب وراثي من القمح في ثمانية بيئات مختلفة تحت الظروف المروية وغير المروية كالتالي: أربع بيئات أجريت في موسم ٢٠٠٦/٢٠٠٥ في موقعي كفر الحمام (محافظة الشرقية) و البستان (محافظة البحيرة) تحت كل من نظامي الري. أما الأربع بيئات الأخرى فكانت في موسمي ٢٠٠٧/٢٠٠٦ و ٢٠٠٨/٢٠٠٧ في محطة البحوث و التجارب الزراعية بكلية الزراعة جامعة القاهرة (محافظة الجيزة) تحت كل من نظامي الري. تهدف الدراسة إلى التعرف على ثبات التراكيب الوراثية في البيئات المختلفة باستخدام معامل المفاضلة المعدل.

أظهرت النتائج وجود اختلافات عالية معنوية بين التراكيب الوراثية و البيئات و التفاعل بينهما لمحصول الحبوب. كما أوضحت النتائج أن أربعة تراكيب وراثية (L.R.3, L.R.7, L.R.8 and L.,R.10) تساوت في محصول الحبوب مع صنف المقارنة (ساحل ١).

أوضحت نتائج معامل المفاضلة المعدل المستخدم لاختيار مدى ثبات التراكيب الوراثية في البيئات المختلفة أن التراكيب الوراثية L.R. 3 و L.R. 8 و L.R. 10 بالإضافة إلى صنف المقارنة (ساحل ١) هي اكثر التراكيب المستخدمة ثباتاً في صفة محصول الحبوب عبر البيئات المختلفة.

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