

Grain yield stability of some exotic rice genotypes grown in the White Nile State, Sudan

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ABSTRACT

Sixteen exotic genotypes of rice (*Oryza sativa* L.) were evaluated across two locations (Ed-duim and Kosti) for two years (2008 and 2009), for their grain yield and stability performance to identify high yielding and stable genotypes. A randomized complete block design with three replicates was used in each location. Significant differences were observed for genotypes (G), locations (E) and G x E interaction. All the genotypes gave high grain yield which ranged from 2.17 to 4.03 t ha⁻¹ under irrigated conditions. Two genotypes (i.e., NERICA 14 and YUNLU 33) were classified as high yielding and stable genotypes across environments (locations and years) because of their high grain yield, with a regression coefficient close to unity, relatively low mean square deviation from regression, low ecovalence value and top average ranking.

INTRODUCTION

Rice (*Oryza sativa* L.) is the second most important cereal crop and staple food for more than one third of the world's population. Also, in Sudan rice is a promising and potential cereal crop in White Nile areas (Awok *et al.*, 1996). Its production and average yield exhibits fluctuation mainly due to cultivation of low yielding and environment sensitive genotypes. Identification of genotypes that show minimum interaction with the environment or possess greater yield stability is an important consideration in areas where environmental fluctuations are considerable.

Grain yield in rice is an expression of different yield components under given environmental conditions. Therefore, yield stability is not depending on the genotype alone, but on interaction of genotype with the particular environment. Regression analysis is an important method of measuring a genotype's response to varying environmental conditions (Eberhart and Russell, 1966). Wricke's (1962) proposed the use of ecovalence, the contribution of genotype to the genotype x environment interaction, as a measure of phenotypic stability. Similarly, deviation from regression (S^2_d) has also been used as a measure of phenotypic stability (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). Pinthus (1973) proposed the coefficient of determination (R^2), the portion of the total production variation of a given genotype that is explained by linear regression, as an index of production stability over environments. Moreover, a number of statistical methods have been proposed to measure the genotypic stability; however, no single method can adequately explain genotypes performance across environment (Abeyasiriwardena *et al.*, 1991; Lin *et al.*, 1986; Lin and Binns, 1986; Becker and Leon, 1988).

The objectives of this paper were to study grain yield means of 16 exotic rice genotypes across diverse environments (locations and years) and three stability indices to identify high yielding and stable genotypes that can be recommended to the farmers in the White Nile area, Sudan.

MATERIALS AND METHODS

The experimental material comprised sixteen exotic rice genotypes. Seven genotypes were obtained from Ivory Coast, 6 genotypes from China and 3 genotypes from the Philippines (Table 1). All genotypes were evaluated in two locations in the White Nile State [Ed-duim (long. 32°20'E, lat. 13° 39' N) and Kosti (long 32° 46,' lat 13° 6' N)] for two years (2008 and 2009). At each location, the trial was conducted in a randomized complete block design and replicated 3 times. Seeds were sown directly in the field on the second week of July of each year. Phosphorus fertilizer in the form of triple super phosphate (P_2O_5) was applied as abasal dose before sowing at the rate of 43 kg ha⁻¹. Nitrogen, in the form of urea (46% N), was applied in two equal split doses, one after three weeks from sowing

and the second after one month from the first one at the rate of 86 kg N ha⁻¹ in each location.

The plot size was 8 m² with inter-row and intra-row spacings of 0.20 x 0.20 m. Other agronomic and cultural practices i.e., weeding, irrigation and plant protection were adopted as and when required. Data were collected for plant height (cm), days to 50% flowering, days to 50% maturity, panicle length (cm), number of tillers per plant, number of grains/panicle, number of filled grains/panicle, percentage of empty grains/panicle, 1000-grain weight, number of panicles/m² and grain yield (t/ha).

Statistical analysis

Data were subjected to separate and combined analysis of variance assuming random environment (locations and years) and fixed genotype according to the procedure described by Gomez and Gomez (1984) to determine the significance of genotypes, environments and genotype x environments (G x E) interactions. The joint regression analysis method proposed by Finlay and Wilkinson (1963) and Eberhart and Russell (1966) was adopted. Hence, mean yield (\bar{x}) and coefficient of regression (bi-value) were used as measures of yield response of genotypes in varying environment and adaptation patterns.

Therefore, three stability parameters were used to estimate the grain yield stability as follows: the first stability approach was Finlay and Wilkinson (1963) and it showed that the genotype with maximum yield potential over environment, regression coefficient equal to one would be stable, the second stability parameter was the mean square deviation from regression (S^2_d). The third stability parameter; ecovalence (W_i) was calculated for each genotype using the formula by Wricke's (1962). Thus, an ideal genotype has the highest average grain yield, a bi-value of approximately one, and W_i and S^2_d values close to zero. SAS (1997) was used for statistical analysis.

Table 1. Rice genotypes , their institute and origin.

Genotypes	Institute	Origin
NERICA 2	WARDA	Ivory Coast
NERICA 4	WARDA	Ivory Coast
NERICA 5	WARDA	Ivory Coast
NERICA 12	WARDA	Ivory Coast
NERICA 14	WARDA	Ivory Coast
NERICA 15	WARDA	Ivory Coast
NERICA 17	WARDA	Ivory Coast
YUNLU 22	YAAS	China
YUNLU 24	YAAS	China
YUNLU 26	YAAS	China
YUNLU 30	YAAS	China
YUNLU 33	YAAS	China
YUNLU 34	YAAS	China
WAB-1-38-19-14-P2-HB	IRRI	Philippines
WAB880-1-38-19-8	IRRI	Philippines
WAB891SG12	IRRI	Philippines

WARDA=West African Rice Development Association, YAAS= Yunnan Academy of Agricultural Science, IRRI= International Rice Research Institute.

RESULTS AND DISCUSSION

Mean squares for seasons, locations, genotypes and their interactions are presented in Table 2. The mean squares due to seasons were highly significant ($P=0.01$) for all studied traits except 1000 grain weight, thus indicating genotypic variation for both seasons. Highly significant location effect was observed for most traits with the exception of grain yield which varied only at $P=0.05$, while plant height, number of filled grains/panicle and 1000 grain weight were not significant. Variation in means for grain yield and other traits reflected variation in growth between locations during the experimental period.

The genotypes showed significant genotypic variation for most traits studied except the number of tillers/plant, number of grains/panicle, percentage of empty grains/panicle and number of panicles/m². This indicates wide variability among genotypes especially for the traits which were significant where selection can be made. Season x location interaction, revealed highly significant differences for all of the traits, except number of tillers/plant, panicle length and number of grains/panicle.

The genotypes by seasons (G X S) interaction was not significant for all the traits, with the exception of 1000 grain weight. Characters that showed no significance for G X S effect indicated stable performance for both seasons.

Mean squares due to (G X L) interaction were significant only for the number of grains per panicle, number of filled grains/panicle and grain yield, while the other traits were not significant. The significance of G X L effects ($P < 0.01$) demonstrated that genotypes responded differently to the variation in environmental conditions over locations and indicated the necessity of testing rice varieties at multiple locations. This showed the challenges encountered by breeders in selecting new genotypes for release; these difficulties arise mainly from the masking effect of variable environments (Goncalves *et al.*, 2003).

Mean squares due to S X L X G interactions were significant only for the number of grains/panicle and highly significant for grain yield, while the differences in the remaining traits were not significant. The significant interactions of S X L X G reflected the inconsistency of genotypes performance in different locations and/ or seasons (Reddy *et al.*, 1998).

Stability analysis

Mean genotype yield ranged from 2.17 to 4.03 t ha⁻¹. The highest yielding genotypes were NERICA 14, NERICA 4, YUNLU 33 and WAB-1-38-19-14-P2-HB (Table 3). Nine genotypes yielded between 3.21 and 4.03 t ha⁻¹, six genotypes between 2.50 and 3.10 t ha⁻¹ and one genotype less than 2.18 t ha⁻¹. In this study, the location effects were significant for the grain yield. This variability among the locations may be attributed to the differences in soil type, temperature and rainfall during the growing season, since the genotypes were evaluated for two years. Also, the significant genotype x location interaction caused a difficulty in identifying superior yielding rice genotypes. Therefore, stability parameters in addition to three stability indices were adopted to identify high yielding and stable genotypes as follows: in stability type one, Finlay and Wilkinson (1963) showed that the genotype with maximum yield potential over environments with regression coefficient equal to one would be stable. According to this model, genotypes NERICA 14 and YUNLU 33 had maximum

grain yields and regression coefficients close to one (b_i -value of 0.80 and 0.94, respectively) and they were considered as stable genotypes. While genotypes NERICA 4 and WAB-1-38-19-14-P2-HB also had high grain yields but their regression coefficients were greater than one (1.4 for both) and then considered as unstable genotypes (Table 3).

For stability type two, it was emphasized that both linear (b_i) and non-linear (S^2_d) components of G x E interactions are necessary for judging the stability of a genotype (Eberhart and Russell, 1966). A regression coefficient (b_i) approximating 1.0 coupled with S^2_d of zero indicates average stability. Regression values above 1.0 describe genotypes with higher sensitivity to environmental change (below average stability) and greater specificity of adaptability to high yielding environments. A regression coefficient below 1.0 provides a measurement of greater resistance to environmental change (above average stability), and thus increases the specificity of adaptability to low yielding environments.

Therefore, in the present investigation, the regression of varietal average yield on the environment index resulted in regression coefficients (b_i values) ranging from 0.27 (NERICA 5) to 1.60 (YUNLU 34) for grain yield (Table 3). This large variation in regression coefficients indicates different responses of genotypes to environmental changes. Also, these large variations in b_i -values give the breeder an advantage to select genotypes for both adverse and favorable environments. The stable genotype as proposed by Eberhart and Russell (1966) would have a high mean performance over a range of environments, a regression coefficient of one and mean square deviation from regression of zero.

The genotype NERICA 4 and YUNLU 33 gave the highest yield over the grand mean with respective regression coefficients of 0.80 and 0.94, respectively, which were not significantly different from regression and deviation from regression coefficient value near to zero. These findings indicated that the two genotypes were high yielders as well as stable over environments (average stability). The genotype WAB-1-38-19-14-P2-HB had fourth best yield after NERICA 14, NERICA 4 and YUNLU 33 and proved to have below average stability (responsive to high yielding environments), as its regression coefficient (b_i) is above one (1.44) and have also small deviation from regression ($S^2_d= 0.43$). Also, the genotype NERICA 4

showed high yield (3.78 t ha⁻¹) and bi-value above one (1.38) and high deviation from regression ($S^2_d = 1.48$) indicating that its performance was relatively better in high yielding environments (below average stability).

Table 2. Analysis of variance for grain yield and its components combined over seasons and locations for 16 rice genotypes.

Traits	Season (S)	Location (L)	Genotype (G)
PH	19683.00**	40.33	314.44**
NTP	82.68**	225.33**	3.20
PL	1205.00**	109.50**	9.72**
NGP	100467.00**	3485.02**	237.88
NFG	79096.92**	27.75	389.16*
PEG	14093.88**	1734.00**	188.62
NP/m ²	256741.88**	428935.54**	6334.30
TGW	3.52	3.52	79.29**
GY	57.75**	5.23*	2.74**

PH=Plant height(cm), NTP=Number of tillers/plant, PL=Panicle length(cm),
NGP=Number of grains/panicle,

NFG=Number of filled grains/panicle, PEG=Percentage of empty grains/panicle,
NT/m²=Number of Panicles/m²,

TGW=1000-grains weight, GY=Grain yield (t/ha).

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 2. Continued.

Traits	S X L	G X S	G X L	S X L X G
PH	5250.08**	114.66	40.75	80.37
NTP	4.08	2.18	1.39	1.85
PL	0.04	4.81	3.05	2.36
NGP	0.75	384.04	530.38*	518.62*
NFG	3291.79**	280.09	329.96*	293.57
PEG	4651.17**	143.50	100.48	133.99
NP/m ²	565393.54**	7078.15	8550.43	1632.18
TGW	229.68**	19.78*	12.06	9.29
GY	178.83**	1.57	2.06*	2.86**

PH=Plant height(cm), NTP=Number of tillers/plant, PL=Panicle length(cm), NGP=Number of grains/panicle, NFG=Number of filled grains/panicle, PEG=Percentage of empty grains/panicle, NT/m²=Number of Panicles/m², TGW=1000-grains weight, GY=Grain yield (t/ha).

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 3. Mean yield of the rice genotypes and their stability indices.

Genotype	Mean	Rank	Eberhart & Russell		Finlay-Wilkinson		Wi
			bi	S ² d	bi	S ² d	
NERICA 2	2.50	15	0.7	1.61	0.73	0.39	0.69
NERICA 4	3.78	2	1.4	1.48	1.38	0.93	2.46
NERICA 5	2.17	16	0.3	2.05	0.27	0.87	4.21
NERICA 12	3.10	11	-0.4	6.84	-0.36	0.61	10.11
NERICA 14	4.03	1	0.8	7.61	0.80	0.61	0.95
NERICA 15	3.24	8	1.2	1.58	1.16	0.30	0.31
NERICA 17	2.50	14	0.8	1.28	0.80	0.25	0.31
YUNLU 22	3.06	12	1.4	0.96	1.37	0.29	0.87
YUNLU 24	3.30	6	1.5	1.43	1.51	0.57	1.95
YUNLU 26	3.10	10	1.3	1.53	1.33	1.10	3.0
YUNLU 30	3.21	9	0.6	4.63	0.62	0.66	1.61
YUNLU 33	3.55	3	0.9	4.19	0.94	0.69	0.94
YUNLU 34	3.30	7	1.6	2.08	1.60	0.25	1.96
WAB880-1-38-19-8	3.33	4	1.3	0.34	1.31	1.06	2.76
WAB891SG12	2.87	5	1.1	0.52	1.11	0.16	0.11
WAB-1-38-19-14-P2-HB	3.51	13	1.4	0.43	1.44	0.20	1.07

bi= Regression coefficient, S²d= Deviation from regression, Wi= ecovalence.

In reference to high the grain yield obtained by the sixteen rice genotypes (ranged from 2.17 to 4.03 t h⁻¹) under the White Nile areas, the genotype WAB891SG12 had a mean yield of 2.87 t h⁻¹, with bi-value near to one (1.11) and low deviation from regression (0.52) indicating a relatively stable performance over environments.

The third stability type; ecovalence (W_i) was calculated for each genotype using the formula by Wrike's (1962). This approach measures the contribution of genotype in the trial to G x E interaction by measuring the deviation of the individual genotype from the location means of all genotypes in the test. With this statistic, the genotype that is most stable is the one that revealed smaller values of the statistic. Regarding the ecovalence (W_i), genotype WAB891SG12 was the most stable ($W_i = 0.11$) followed by NERICA 15 and NERICA 17 (with $W_i = 0.31$ for both) and in spite of their low yields, NERICA 15 had a higher grain yield in comparison with NERICA 17 (Table 3). In contrast, the genotype NERICA 12 was considered as the least stable ($W_i = 10.11$) in spite of its high mean yield (3.11 t ha⁻¹) which was better than WAB891SG12 (2.8 t ha⁻¹).

CONCLUSION

Two genotypes (NERICA 14 and YUNLU 33) yielded approximately more than 3.50 t ha⁻¹ with approximately bi-value of 1.00, relatively low mean square deviation from regression, low ecovalence value and top average ranking. Thus, these genotypes performed best across environments (locations and seasons) indicating wide adaptability. Also, the study showed that any of the stability indices or approach type could be used without any loss of efficiency. Hence, the two genotypes could be used in the breeding program and / or may be released to farmers for cultivation in the White Nile State.

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ثبات إنتاجية الحبوب لبعض سلالات الأرز المستقدمة والمزروعة في ولاية النيل الأبيض، السودان

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الخلاصة

اختبرت 16 سلالة أرز مستوردة في موقعين (الدويم وكوستي) خلال عامي (2008 و 2009) لتحديد أكثر هذه السلالات إنتاجية وثباتاً في الإنتاجية. استخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات في كل موقع. أظهرت نتائج تحليل التباين المشترك فروقات معنوية في السلالات و الموقع والتفاعل بين السلالات والموقع. كل السلالات أعطت إنتاجية عالية حيث تراوحت بين 2.17-4.03 طن/هكتار تحت ظروف الري. صنفت السلالتان (NERICA 14, YUNLU 33) كأعلى الأصناف إنتاجية وثباتاً في الإنتاجية خلال البيئات (المواقع والسنين) لأنها أعطت أعلى إنتاجية، معامل انحدار اقرب للواحد الصحيح، أقل متوسط مربع انحراف عن الانحدار واقل قيمي ل (Wi) واعلى ترتيب للمتوسطات.