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REGULAR ARTICLE

Grain yield response and stability indices in sorghum (*Sorghum bicolor* (L.) Moench)

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ABSTRACT
Sorghum is mainly grown in the Semi-Arid Tropic of the world, particularly under rain fed conditions. It forms the most staple food crop for millions of people in these areas. Sorghum production is highly influenced by the environment where it is grown, thus, the genotype by environment interaction is highly significant when breeding for specific adaptation. This study is aimed at identifying suitable genotypes for release to farmers in Nigeria and for further genetic manipulations. Grain yield performances and stability indices for twenty diverse sorghum genotypes evaluated for three years (1998-2000) at five locations in the savanna agro-ecological zone of Nigeria. The environments, genotypes, genotype x environment interaction, genotype x environment (linear) and deviation from regression component significant were highly significantly different. Genotypic means and linear regression coefficient (*b*-value) were used to measure production response, while deviation from regression (s^2d), coefficient of determination (r^2) and ecovalence (W) were used as stability indices. The highest yielding sorghum genotype was NR 71168 (3.02 t/ha) while NR 71138 had the least average grain yield (0.63 t/ha). Based on stability indices, NR 71156, NR 71158, NR 71165, NR 71167, NR 71168 and NR 71182 were desirable, stable and adapted to wide range of environments in the savanna agro-ecologies. These genotypes may be released to farmers for cultivation.

Key Words: *adaptation analysis; genotype x environment interaction; production response.*

INTRODUCTION

Exploitation of genetic variability is the most important tool in plant breeding especially in sorghum breeding and this has to be inferred by phenotypic expression. The consequences of the phenotypic variation depend largely on the environment. This variation is further complicated by the fact that all genotypes do not react in similar way to change in environment and no two environments are exactly the same. Mean yield across environments are adequate indicator of genotypic performance only in the absence of Genotype by Environment (GE) interaction. GE is differential genotypic response across environments. Most often GE complicates breeding, testing and selection of superior genotypes. It is important for plant breeders to identify specific genotypes adapted or stable to environment(s), thereby achieving quick genetic gain through screening of genotypes for high adaptation and stability under varying environmental conditions prior to their release as cultivars (Ariyo, 1989; Flores, et al., 1998; Showemimo, et al., 2000; Mustapha et al., 2001; Yan and Kang, 2003).

The study of GE interaction depends on the use of suitable biometrical or appropriate statistical methods. Analysis of variance is useful in estimating the existence, significance and magnitude of GE interaction but does not explain the importance and implications. Thus, statistical models had been developed to describe GE interaction magnitude, its patterns and implications in plant breeding. Regression analysis is an important biometrical method of measuring a genotype's response (production response) to varying environmental condition (Eberhart and Russell, 1966). Wricke (1962; 1964) proposed the use of Ecovalence, the contribution of a genotype to the GE interaction, as a measure of phenotypic stability. Similarly, deviation from regression (s^2d) has also been used as a measure of phenotypic stability (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Nguyen et al., 1980). 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.

The objectives of this paper were to study grain yield means of sorghum genotypes, regression coefficients as measures of genotypic response across diverse environments and three stability indices to identify high yielding and stable genotypes recommended to farmers in Nigeria.

MATERIALS AND METHODS

Yield performances of twenty sorghum genotypes from diverse genetic background though homozygotes were evaluated in 5 locations in Nigeria; Samaru, Maigana, Bagauda, Kano, Ladanawa (Table 2) for 3 years (1998, 1999 and 2000), thus 15 environments in a randomize block design and replicated 3 times. The plot size was 5 rows of 6 m length with inter-row and intra-row spacing of 0.75 m x 0.30 m. Each row was over planted and later thinned to 2 plants/stand 2 weeks after emergence. 32 kg N/ha of Calcium Ammonium Nitrate (CAN) and 32 kg/ha of Phosphorous dioxide (P_2O_5) as Single super phosphate fertilizer were applied as basal fertilizer, while 32 kg N/ha of CAN was applied 3 weeks after thinning as top dressing. All other crop cultural management practices were observed to raise a successful crop (IAR, 1993). Three central rows as net plot were harvested for grain yield.

Mean yield ($\bar{x}$) and coefficient of regression (b-value) were used as measures of yield response of genotypes in varying environments and adaptation patterns. The Eberhart and Russell (1966) model was used in regression analysis. The first stability parameter was the mean square deviation from regression (s^2d), the second; was coefficient of determination (r^2). The third stability parameter; Ecovalence (W) was calculated for each genotype using the formula by Wricke (1962). If the regression coefficient is not significantly different from unity (b = 1.0), the genotype is adapted in all environments, Genotypes with $b > 1.0$ are more responsive or adapted to high yielding environments, whereas any genotype with b significantly lower than 1.0 is adapted to low yielding environments. An ideal genotype has the highest average grain yield, a b-value of approximately one, and W and s^2d values close to zero. Coefficients of determination (r^2) were obtained from the linear regression of individual yield in different environments on the mean yield of all the genotypes in each environment (Pinthus, 1973). SAS 9.1 for Windows (2003) was used for the statistical analysis.

RESULTS AND DISCUSSION

Table 1 show pooled analysis of variance; the 15 environments, 20 genotypes, genotype x environment, genotype x environment (linear) and deviation from regression showed highly significant difference for grain yield. The significant environments, genotypes and genotype x environment component of interaction indicated wide differences between the environments and differential genotypic behavior in the environments. The significant genotype x environment (linear) indicated that linear response of genotypic stability to change in environment was not the same for all genotypes evaluated. However the significant deviation from regression revealed the importance of linear regression component in determining the interaction between genotypes with environments. Significantly higher yields were obtained in Samaru and Maigana in Northern Guinea Savanna, low grain yields were obtained in Sahel Savanna (Table 2).

Table 1. Combined analysis of variance for grain yield of 20 genotypes grown in 15 environments.

Source	df	Mean square
Environment (E)	14	7.617
Rep within Env.(RE)	30	0.276
Genotype (G)	19	8.214**
G x E	266	1.011**
G x E linear	19	4.33**
G x E deviation	266	1.912**
Pooled error	480	0.21

** Significant at 0.01 probability level.

Table 2. Description of five test locations and mean grain yield performance of the evaluated sorghum genotypes across three years (1998 - 2000).

Location	Agroecological zone	Altitude (m)	Latitude	Longitude	Grain yield (t/ha)
Samaru	Northern Guinea Savanna	686	11°11′ N	07°38′ E	2.89
Maigana	Northern Guinea Savanna	677	11°02′ N	07°57′ E	2.51
Bagauda	Sudan Savanna	580	11°40′ N	08°17′ E	1.38
Ladanawa	Sudan Savanna	290	11°38′ N	08°24′ E	0.97
Kano	Sahel Savanna	500	11°59′ N	08°32′ E	1.07
$LSD_{0.05}$					0.27

This shows the presence of genetic variability among genotypes evaluated and that the genotypes interact with the environments resulting in differential genotypic response. This finding agrees with those of Nwasike and Abed (1981) in pearl millet, Kim et al., (1993) in maize, Showemimo et al., (2000) in sorghum, that location within Northern Guinea Savanna agro-ecological zone have superior yield potential than the other savanna zones. This may be due to limiting soil and atmospheric moisture in the Sudan and Sahel Savannas.

Mean yield, production response and stability indices among the genotypes are shown in Table 3.

Table 3. Mean yield of the sorghum genotypes and their stability indices. Entries were evaluated for three crop years (1998-2000) at five locations in Nigeria.

Genotype	Yield (t/ha)	*b*	s^2d	r^2	*W*
NR 71168	3.02[a]	1.02**	0.007	0.897**	0.051
NR 71167	3.00[a]	1.04**	0.061	0.714**	0.118
NR 71182	2.65[a]	0.98**	0.009	0.819**	0.076
NR 71176	2.56[a]	0.96**	0.012	0.727**	0.092
NR 71165	2.56[a]	1.01**	0.011	0.891**	0.214
NR 71156	2.49[a]	1.00**	0.012	0.651*	0.145
NR 71158	2.33[a]	1.03**	0.005	0.906**	0.170
NR 71152	2.00[b]	0.65	0.055	0.418	0.691
NR 71181	1.90[b]	0.71	0.032	0.432	0.722
NR 71171	1.82[b]	0.87**	0.021	0.817**	0.115
NR 71150	1.72[b]	0.78**	0.040	0.818**	0.132
NR 71164	1.67[b]	0.76*	0.045	0.711**	0.320
NR 71170	1.66[b]	0.77*	0.016	0.646*	0.102
NR 71155	1.65[b]	0.81**	0.049	0.661*	0.521
NR 71144	1.61[b]	0.98**	0.018	0.920**	0.320
NR 71143	1.51[b]	0.89**	0.019	0.881**	0.515
NR 71151	1.42[bc]	0.73	0.037	0.507	0.701
NR 71147	1.00[c]	0.82**	0.027	0.771**	0.221
NR 71142	0.92[c]	0.90**	0.021	0.614*	0.495
NR 71138	0.63[c]	0.71	0.041	0.766**	0.801
Mean	1.91	0.89	0.027	0.718	0.326

*, ** Significant at 0.05 and 0.01 probability level, respectively, based on a t-test.

[a,b,c] Means followed by same letter are not statistically different using LSD at 0.05 probability level.

The genotypes were ranked and sorted into three discernable, logical and homogenous grouping using ANOVA and Tukey's pairwise comparison test (LSD at 5% probability level) of the mean grain yield. Seven genotypes yielded between 2.33 and 3.00 t/ha, nine genotypes yield between 1.5 and 2.00 t/ha and four genotypes yielded less than 1.50 t/ha. Eight genotypes had grain yield between 2 and 3 t/ha, out of which six genotypes (NR 71168, 71167, 71165, 71182 and 71176) yielded approximately 3 t/ha with approximately b-value of 1.00, very low mean square deviation from regression, low ecovalence value and highly significant coefficient of determination. Thus, these genotypes performed best across the environments indicating wide adaptability. These genotypes could be introduced to farmers in these agro-ecological zones. Genotypes NR 71181 and NR 71171 has high yields with low response indices, therefore, they are most promising genotypes under poor environmental condition. Coefficient of determination ranged between 41.8% for NR 71152 and 92.0% NR 71144 suggesting that linear regression accounted for 42–92% variation in sorghum yield.

Rank correlation values in Table 4 revealed positive, low and non-significant associations between mean yield and coefficient of regression (*b*), deviation from regression (s^2d), coefficient of determination (r^2), and ecovalence (*W*). Coefficient of regression (*b*) and deviation from regression (s^2d), coefficient of determination (r^2), and ecovalence (*W*) were positive and highly significantly correlated, thus, indicating that the relative stability ranking of these sorghum genotypes are consistent when the different stability indices are used separately. Similar results were reported by Langer et al., (1979) in oats.

Table 4. Rank correlation coefficients between stability indices for grain yield of sorghum genotypes.

Parameter	*b*	s^2d	r^2	*W*
Mean	0.33	0.51	0.26	0.26
b		0.80**	0.78**	0.82**
s^2d			0.71**	0.69**
r^2				0.67**

** Significant at 0.01 probability level.

CONCLUSIONS

Twenty sorghum genotypes were evaluated across five locations for three year (fifteen environments) to study their grain yield response and stability performance with the aim of selecting superior genotypes. Mean performance and coefficient of regression (*b*) were used as production response indices while deviation from regression (s^2d), coefficient of determination (r^2), and ecovalence (*W*) were used as stability indices. Any of the stability indices could be used without any loss of efficiency. The six genotypes NR 71168, 71167, 71165, 71182 and 71176 performed consistently well across the diverse environments indicating good stability and adaptation. These genotypes are therefore recommended for release to farmers in Nigeria, while further testing of the unstable genotypes is necessary for further breeding manipulations.

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