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SHORT COMMUNICATION

GRAIN YIELD STABILITY OF NEW MAIZE VARIETIES IN NIGERIA

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ABSTRACT

Seven early maturing open pollinated (OP) and five yellow hybrid maize varieties were evaluated in 1996 under the auspices of the Nationally Coordinated Research Project (NCRP) on Maize. The experiment was conducted in 22 locations representing the different agro-ecologies of Nigeria. Significant location effects were observed for grain yield in the two sets of maize varieties tested. Grain yield was significantly higher in the northern/southern guinea savanna agro-ecologies when compared to the other agro-ecologies. Highly significant varietal differences were found among the OPs and the yellow hybrids. The highest yielding OP variety was TZE Comp.4 DMR BC1 with an average grain yield of 2.43 t ha^{-1} while the best yellow hybrid was 8522-2 with a mean grain yield of 2.82 t ha^{-1}. Comparison of the results of the OPs and the hybrids showed that the hybrid had an average of 18.2% yield advantage over the OPs. The hybrid maize varieties and four of the seven OPs were found to be stable in grain production across the locations. Significant genotype x location interaction was also observed for both sets of maize varieties. The best hybrid (8522-2) combined stability with high grain yield and wide adaptability. This variety may thus be introduced to farmers throughout the country.

Key Words: Guinea savana, Nigeria, open-pollinated, regression coefficients, yellow hybrids, yield stability, *Zea mays*

RÉSUMÉ

Sept variétés librement pollinisés précoces (OPs) et cinq variétés d'hybrides jaunes de maïs ont été évaluées en 1996 sous les auspices du Project National de Coordination de Recherche pour le maïs. L'essai a été conduit dans 22 localités représentant les differentes régions agro-écologiques du Nigeria. Des effets significatifs de localités ont été observés pour le rendement grain dans les deux groupes de variétés de maïs testés. Le rendement grain était significativement plus élevé dans les zones nord/sud de la savanne guinéene comparativement aux autres régions. Des differences variétales significativement très élevées ont été trouvées entre les OPs et les hybrides jaunes. La variété OP au plus haut rendement était TZE Comp. 4 DMRBC1 avec un rendement moyen de 2.45 t ha^{-1} alors que le meuilleur hybride jaune était 8522-2 avec un rendement moyen de 2.82 t ha^{-1}. La comparaison des résultats des variétés OPs et des hybrides jaunes a montré une moyenne de 18.2% d'avantage de rendement sur les OPs. Les variétés d'hybrides jaunes et les quatre des sept OPs ont été trouvées plus stables en production des graines à travers les localités. Une interaction entre génotype et environnement était significative pour les deux groupes de variétés de maïs. Le meilleur hybride (8522-2) combinait la stabilité avec le rendement élevé et une large adaptabilité. Cette variété peut être introduite aux agriculteurs à travers tout le pays.

Mots Clés: Savanne guinéenne, Nigeria, libres pollinisés, coefficient de regression, hybrides jaunes, stabilité de rendement, *Zea mays*

INTRODUCTION

The development and release of improved maize varieties, with a high level of performance over a broad range of environments in Nigeria, is the primary goal of the Nationally Co-ordinated Research Project (NCRP) on Maize in Nigeria. Failure of genotypes to respond consistently to variable environmental conditions is attributed to genotype x environment (G x E). It is advantageous for a cultivar to have consistently high yield in a broad range of environments. Stability of yield is important because a cultivar having a bad year soon after release may never have the opportunity to demonstrate its long term worth (Teich, 1983). In order to identify stable genotypes, the G x E must be partitioned into stability statistics that are assignable to each genotype evaluated across a range of environments (Fernandez, 1991). Stability indices have allowed researchers to identify widely adapted genotypes for use in breeding programmes and have helped to improve recommendations to growers (Yayeh and Bosland, 2000)

Analysis of variance procedure is useful for estimating the existence and magnitude of G x E interactions, however, variance components alone do not provide satisfactory explanation for G x E (Domitruk *et al.,* 2001). Hence a number of different statistical models have been developed to assist in the interpretation of G x E (Freeman, 1973; Westcoff, 1987; Gauch and Zobel, 1996; Osman *et al.*, 1997; Vargas *et al.*, 1998). One of the most widely used is the model developed by Eberhart and Russell (1966). The method consists of traditional analysis of variance followed by a joint regression analysis. The regression analysis provides two major stability parameters, the regression coefficient (b), which is a measure of environmental response or adaptation, and the mean square deviation from regression (S^2d) which is a measure of stability. They proposed that an ideal genotype is one which has the highest yield over a broad range of environments, a regression coefficient (b value) of 1.0 and a deviation mean square (S^2d) of zero. According to Langer *et al.* (1979) the regression coefficient is a measure of response to varying environments and the mean square deviation from the linear regression is a measure of production stability. A genotype with b = 1.0 is considered adapted to all environments whereas a genotype with b> 1 is adapted to high yielding environments while the one with b<1 is adapted to low yielding environments. The limitations to the use of Eberhart and Russell (1966) stability analysis is the interpretation of its parameters and the analysis also requires evaluation of test crops in several environments.

Many authors including Gama and Hallauer (1980), Borrero *et al.* (1992) and Fakorede *et al.* (1993) have used either Eberhart and Russell (1966) or a modification of this approach to assess the stability of maize genotypes across different environments. As new varieties of maize are continuously being developed, there is a need therefore, to test these maize varieties in more diverse environments representing the various agro- ecologies that exist in a particular region or country. The objectives of this study therefore were; to determine the relative magnitude of G x E interaction effects on maize grain yield, differences in stability of yield performances among newly developed maize varieties, and to identify high yielding, stable maize for possible release to farmers in Nigeria.

MATERIALS AND METHODS

The experiment was conducted under the auspices of the Nationally Coordinated Research Project (NCRP) on Maize. The maize varieties were derived from recently developed improved maize varieties nominated by the various national and international research institutes, and universities. Two sets of varieties were evaluated: (i) open-pollinated early maturing and (ii) yellow hybrid maize varieties (Tables 1 and 2). The experimental materials were collected from the International Institute of Tropical Agriculture (IITA). The trials. were conducted at 22 locations which were representative of the different agro-ecologies of mangrove, forest, southern guinea savanna, northern guinea savanna, sudan/sahel savanna and acidic/alkaline soils (Table 3).

The trials were evaluated in the major (June-November) maize growing season in 1996. A randomised complete block design with four replications was used at each location for each set of maize varieties. A plot was made up of four rows, 5 m long and a spacing of 0.75 m between rows and 0.25 m within a row. The maize seedlings were thinned to one plant per stand providing a uniform stand of about 53,333 plants ha^{-1}. NPK fertiliser was applied at the rate of 80 kg Nitrogen, 40 kg Phosphorus, and 40 kg Potassium for optimum plant growth at each location.

To reduce border effects, data were recorded only on the two central rows of the four row plots. Ears were shelled mechanically and grain yield was calculated at 15% moisture content. Altitude data were compiled from the records of the Nigerian Department of Meteorology Services Oshodi-Lagos.

Environments were considered random and the maize varieties as fixed effects. Stability analysis was performed for grain yield using the model of Eberhart and Russell (1966). Coefficients of determination were obtained from the linear regression of individual yield in different environments on the mean yields of all the lines tested in respective environments (Pinthus, 1973).

RESULTS AND DISCUSSION

Highly significant location effects were observed for grain yield in both the early maturing and the yellow hybrid maize varieties (Table 3). This was not surprising in view of the wide diversity among the 22 locations where the maize varieties were evaluated. The results of this study demonstrated the variability of environmental conditions under which maize is cultivated in Nigeria. In both cases, compared to the other agro-ecologies, significantly higher yields were obtained in the locations within the northern and southern guinea savanna agro-ecologies, although Ibadan (forest) also recorded high yields (Table 3). The superiority of the yield potential of the savanna agro-ecologies had been demonstrated by several workers (Kassam and Khowal, 1973; Fakorede *et al.*, 1993; Kim *et al.*, 1993). Low grain yields were obtained in the locations within the mangrove agro-ecology, which was probably due to the water-logged condition prevalent in that ecology. Maize prefers a well drained, aerated deep loamy soil (Obi, 1991). Both the OPs and the hybrids also recorded low yields in the acidic soil of Nsukka with pH 4.2. Borrero *et al.* (1992) also reported relatively lower yields of maize in two locations with acidic soil of pH 4.5.

Highly significant varietal differences were found among the OPs and the yellow hybrid maize varieties (Table 4). The highest yielding

TABLE 1. Open pollinated early maturing maize varieties evaluated in 22 locations in Nigeria in 1996

Variety	Parent population	Grain type
TZE Comp.4 DMR BC1	EV8430-SR, IK8149-SR	Dent
TZE Comp.3 C1	TZE SR-W, DMR-ESR-W	Dent
DMR-ESR-Y	DMR x TZ SR	Flint
Suwan-2-SR	Suwan-2	Flint
EV 8730-SR	Pop.30	Flint/Dent
Acr 92 TZE Comp.5-W	TZE Comp.5	Dent
Acr 90 Pool 16-DT	Pool 16	Dent

TZE = Tropical early maturing *Zea mays* variety, DMR = Downy mildew resistance maize variety, EV = Experimental varieties, Acr = Across year 90 or 92 evaluation, DT = drought tolerance

TABLE 2. Yellow hybrid maize varieties evaluated in 22 locations in Nigeria in 1996

Hybrid	Pedigree	Grain type
8425-8	Tzi 25 STR x TZEi 18	Dent
8522-2	Tzi 18 x Tzi 34	Flint
8644-27	Tzi 18 x Tzi 35	Flint
8644-31	Tzi 25 x Tzi35	Dent
8644-32	(Tzi 18 x Tzi 25) x Tzi 35	Dent/Flint

Tzi = Tropical maize inbred, STR = Striga resistance

OP variety was TZE Comp.4 DMR-BCI, with an average grain yield of 2.4 t ha^{-1} while the best yellow hybrid maize variety was 8522-2 with an average grain yield of 2.8 t ha^{-1}. Comparison of the results of the OPs and the hybrids showed that the hybrid maize had an average of 18.2% yield advantage over the OPs. Several workers have reported the superiority of the hybrids over OPs, for example, Fakorede and Adeyemo (1986) reported 16-25% hybrid yield advantage over the OPs. Kim *et al.* (1993) also observed an average of 22% yield advantage for the hybrids. Significant genotype x location interaction was also recorded for both sets of maize varieties showing that the maize varieties in each set responded differently to different environmental conditions. This

TABLE 3. Mean performance of the maize varieties evaluated in 22 locations in Nigeria in 1996

Location	Agro-ecology	Altitude (m)	Latitude	Longitude	OP yield (t ha^{-1})	Hybrid yield (t ha^{-1})
Ibadan	Forest	224	7E 22N N	3E 55NE	3.36	5.28
Ife	Forest		7E 28N N	4 33NE	3.06	2.1
Orin Ekiti	Forest	-	-	-	1.22	3.4
Abeokuta	Forest	106	7E 08N N	3 20NE	1.25	1.65
Ikenne	Forest	60	6E 54N N	3E 42NE	1.19	2.0
Benin City	Mangrove	78	6E 20N N	5E 40NE	2.27	2.98
Asaba	Mangrove	97.6	6E 10N N	6E 45NE	0.32	0.48
P.Harcourt	Mangrove	29	4E 46N N	7E 03NE	1.41	0.64
Ilorin	S.G. Savanna	344.4	8E 30N N	4E 33NE	3.29	5.04
Mokwa	S.G. Savanna	302	9E 17N N	5E 04NE	3.06	3.16
Makurdi-1	N.G. Savanna	106	7E 42N N	8E 34NE	2.32	2.06
Makurdi-2	N.G. Savanna	106	7E 42N N	8E 34NE	2.34	5.15
Gboko	N.G. Savanna	-	7E 19N N	8E 57NE	2.39	1.47
Samaru	N.G. Savanna	675	11E05NN	7E 42NE	4.23	3.29
Zaria	N.G. Savanna	655	11E05NN	7E 42NE	4.47	5.74
Yola	Sudan Savanna	190	9E 13N N	12E 28NE	2.57	1.82
Biu	Sudan Savanna		10E 35NN	12E 11NE	-	2.88
Gembu	Mid Altitude		6E 43N N	11E 15NE	2.96	2.45
Saminaka	Mid Altitude	-	10E 45NN	8E 50NE	2.16	2.92
Heipang	Mid Altitude	1290	9E 54N N	8E 53NE	1.50	1.89
Nsukka-1	Forest (Acidic soil)	390	6E 50N N	7E 23NE	1.12	0.53
Nsukka-2	Forest (Acidic soil)	390	6E 50N N	7E 23NE	0.53	
Umudike	Forest (acidic soil)	120	5E 31N N	7E 26NE		1.56
LSD					1.57	1.65

- information not available

TABLE 4. Mean square values for grain yield of the OP and yellow hybrid maize varieties

Sources of variation	OP maize		Yellow hybrid	
	D. F	MS	D.F.	MS
Location	20	35.90**	21	46.70**
Genotype	6	1.45**	4	0.86**
G x E	120	0.55**	84	0.40*
Error	378	0.24	264	0.32

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

suggests that maize varieties should only be released for environments where the performance was optimal.

In both the early maturing and the yellow hybrid maize varieties, the linear component of variation due to environment was highly significant (P<01) (Table 5) showing that the distribution of the environment means was adequately described by linear model. The significant (P<01) variety x environment linear for the OP suggested that the OPs had different environmental responses. The non-significant variety x environment linear for the hybrids is an indication that the hybrids did not differ in their linear response to varied environments.

The stability parameters for the OP early maize varieties are presented in Table 6. The results showed that four out of the seven OP maize varieties evaluated had non significant deviation from regression indicating stability while all the five yellow hybrids were found to be stable in grain production across the locations (data not shown). The highest yielding OP variety (TZE comp. 4-DMR- BCI) was however, observed to be unstable. The highest yielding hybrid (8522-2), combined stability with high mean grain yield and wide adaptability. This variety may thus be introduced to farmers all over the country.

Coefficients of determination ranged from 0.83-0.96 for the OP early maturing maize varieties. It was observed in the two sets of maize varieties studied that the most stable varieties were associated with high coefficient of determination. Langer *et al.* (1979) and Nguyen (1980) reported high correlation between S^2d and r^2. The effectiveness of the use of r^2 as an index of stability was demonstrated by the observation that all the yellow hybrid maize varieties which were shown to be stable by the Eberhart and Russell (1966) stability analysis also had high coefficients of determination ranging from 0.95-0.98, suggesting that linear regression accounted for 95-98% of variation in maize yield of the varieties.

TABLE 5. Mean squares of stability parameters for grain yield of maize varieties evaluated in Nigeria in 1996

Sources of variation	OP maize		Hybrid maize	
	D.F	MS	D.F	MS
Varieties (Var.)	6	1.45**	4	0.86**
Env. (Var. x Env.)	140	0.53**	105	9.66**
Env. (linear)	1	179.50**	1	245.15**
Var. x Env. (linear)	6	0.45**	4	0.05
Pooled dev.	133	0.12**	100	0.82
Pooled error	441	0.08	330	0.12

** significant at 0.01 probability level

TABLE 6. Mean grain yield (t ha^{-1}) and stability parameters for OP early maturing maize varieties evaluated in Nigeria in 1996

Maize varieties	Mean Yield (t ha^{-1})	b	S^2d	r^2
TZE Comp.4-DMR-BC1	2.43	0.91	0.07**	0.90
TZE Comp.3 C1	2.24	1.06	-0.06	0.94
DMR-ESR-Y	2.19	1.09	0.01	0.96
Suwan-2-SR	2.31	1.04	0.05*	0.92
EV 8730-SR	2.20	0.97	0.03	0.92
Acr 92 TZE Comp.5-W	2.28	1.12	-0.02	0.96
Acr 90 pool 16-DT	2.00	0.83	0.21**	0.83

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

The results presented here may be of limited use mostly because of the few number of varieties used. However, we could only evaluate the number of varieties that were nominated by the National Agricultural Research System. A major objective of this research was to identify high yielding and stable maize varieties for farmers. Given the diverse environments where the two sets of maize varieties were evaluated, the results can be used to recommend the best OPs and hybrids for the different agro-ecologies of Nigeria.

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