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AGRICULTURAL ECONOMICS
AND
EXTENSION

PERFORMANCE CHARACTERISTICS OF MAIZE VARIETIES IN SAVANNA ECOLOGY OF NIGERIA

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ABSTRACT

Identification of maize genotypes with stable performance for grain yield is prerequisite to achieving stability of maize grain yield in Nigeria's Southern Guinea Savanna (SGS) where rainfall distribution is highly erratic. To this end, maize varieties belonging to three different maturity groups viz: early, extra-early and late/intermediate drought tolerant open pollinated varieties (OPVs) and hybrids, were evaluated in replicated trials at different seasons and/or years between 1999 and 2003 at the Teaching and Research Farm, University of Ilorin, in a typical SGS ecology. The objectives were to identify promising genotypes that can either be used as cultivar *per se* or parents in the development of high yielding maize varieties for the ecology. Genotypic (G) differences were significant ($P < 0.01$) for grain yield regardless of the maturity group while $G \times E$ interaction was significant ($P < 0.05$) for grain yield only in the early and extra-early maturity groups. Differences between the most favourable and unfavourable seasons for grain yield was 1.86 t.ha⁻¹ for OPVs and 3.48 t.ha⁻¹ for hybrids. Highest grain yield was recorded for the early maturing varieties in 2001 with a difference of 0.72 and 1.29 t.ha⁻¹ in 2002 and 2003, respectively. The year 2002 was the most favourable for the extra-early varieties with a difference of 0.9 t.ha⁻¹ in 2002 and 1.16 t.ha⁻¹ in 2001, which was the worst year. Partitioning of the components of mean squares of G and $G \times E$ interaction for grain yield revealed that the extra-early varieties accounted for a higher proportion of the observed variability for grain yield but the proportion of variation contributed to the significant $G \times E$ interactions for grain yield was equal between early and extra-early. However, much of the variability for grain yield among intermediate/late maturing varieties was due to within-group variation among hybrids. While none of the varieties among the intermediate/late maturity showed superiority over check varieties for grain yield, two extra-early (DMR ESR Y and 99 TZEE-Y STR) and three early (EVDT 99 STR C₀, Acr 94 TZE Comp₅-W and Acr 94 Pool 16 DT STR C₀) varieties exhibited superiority for grain yield compared to their respective checks and could, therefore, serve as replacements to the existing cultivars in this ecology.

Key words: *Zea mays* L., maturity groups, Southern Guinea Savanna, grain yield

INTRODUCTION

Maize (*Zea mays* L.) is an important food crop which is consumed in different forms in West and Central Africa (WCA) sub-region and a major component of feedstuff in the livestock industries. It has been estimated that about 70% of all maize consumption occurs in Sub-Saharan Africa (Aquino *et al.*, 2001). However, empirical evidence also showed that about 95% of the maize areas in the

tropics suffer from erratic rainfall distribution (Edemeades *et al.*, 1989), with yield reduction ranging from 10 to 50% as a result of water-limited conditions (Edemeades *et al.*, 1997). Although maize is cultivated during the short early growing season (April/July) and the full growing season (July/October) in the Southern Guinea Savanna (SGS) of Nigeria, varietal performance in the ecology is often variable due to either mid-season drought caused by irregular distribution of rain in the

short early season or the terminal drought resulting from abrupt cessation towards the end of the long rainy season. The resultant effect of the variable weather is low maize yields due in part to poor crop establishment in the hot, dry soil conditions of the early season (Bolaños and Edmeades, 1993) and asynchrony of flowering occasioned by terminal drought (Olaoye *et al.*, 2004, 2009). Previous survey (CIMMYT, 1988) has also shown that erratic rainfall distribution is the major cause of low maize yields compared to other problems like pests and low soil fertility in the tropics. Since precipitation is variable and cannot be predicted in such ecologies, a successful maize cultivar has been categorized as one that performs well under a wide range of moisture conditions (Byrne *et al.*, 1995) or able to withstand some variation in rainfall from year to year (Bänzinger *et al.*, 2000). Consequently, maize genotypes that have been targeted for cultivation in the ecologies are either the early or extra-early maturing genotypes that are able to complete their life cycle within a short period in the growing season or maize genotypes with capacity to tolerate drought stress.

Early and extra-early maturing maize varieties in particular, are unique because of their potential to fill the hunger period in July when all food reserves are depleted after the long dry period, as well as providing farmers with flexibility in the dates of planting such that they complete their life cycle and thus escape before severe drought sets in (Badu-Apraku *et al.* (2010). Empirical evidence on the other hand (Seboksa *et al.*, 2001, Worku *et al.*, 2001; Abebe *et al.*, 2005) have shown that drought tolerant (DT) maize genotypes have provided a measure of stability in grain yield in drought-prone ecologies because of their inherent genetic potential to tolerate pre or post-anthesis moisture stress. A corollary is stability to rural economics by reducing the level of chronic food deficit in more marginal production areas (Edmeades *et al.*, 1997).

Varietal performance for grain yield in different growing seasons and/or years is very important in identifying genotypes that exhibit superiority of performance under varying environmental conditions. According to Falconer (1952), information about varietal stability assists plant breeders in making informed decision on varieties that could be grown in a particular ecology while Basford and Cooper (1998) stressed the importance of understanding the cause and nature of differential response of genotypes either across cropping seasons and/or years, as an aid in selection of superior genotypes for cultivation in such ecologies. In this paper, data collected between 1999 and 2003 from trials involving maize genotypes belonging to three maturity groups were used to assess the performance of the maize genotypes in a typical savanna agro-ecology of Nigeria and to identify promising genotypes that can either be used as cultivar *per se* or parents in the development of DT varieties for cultivation in drought-prone ecologies of the Nigeria SGS.

MATERIALS AND METHODS

Description of the experimental materials

Maize varieties belonging to three different maturity groups viz: early, extra-early and late/intermediate drought tolerant (DT) open pollinated varieties (OPVs) and hybrids were used for this study. The genetic materials were initially obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria as part of the international trials. The first set comprised eleven drought tolerant (DT) germplasm materials (5 OPVs and 6 hybrids) while the second set comprised twelve each of early and extra-early maturing OPVs, respectively. A late maturing adapted cultivar (DMR-LSR-Y) previously released by the IITA, was used as check for the intermediate/late OPVs. For the early maturity group, two local checks which were previously composed by intermating

Performance Characteristics of Maize Varieties in Savanna Ecology

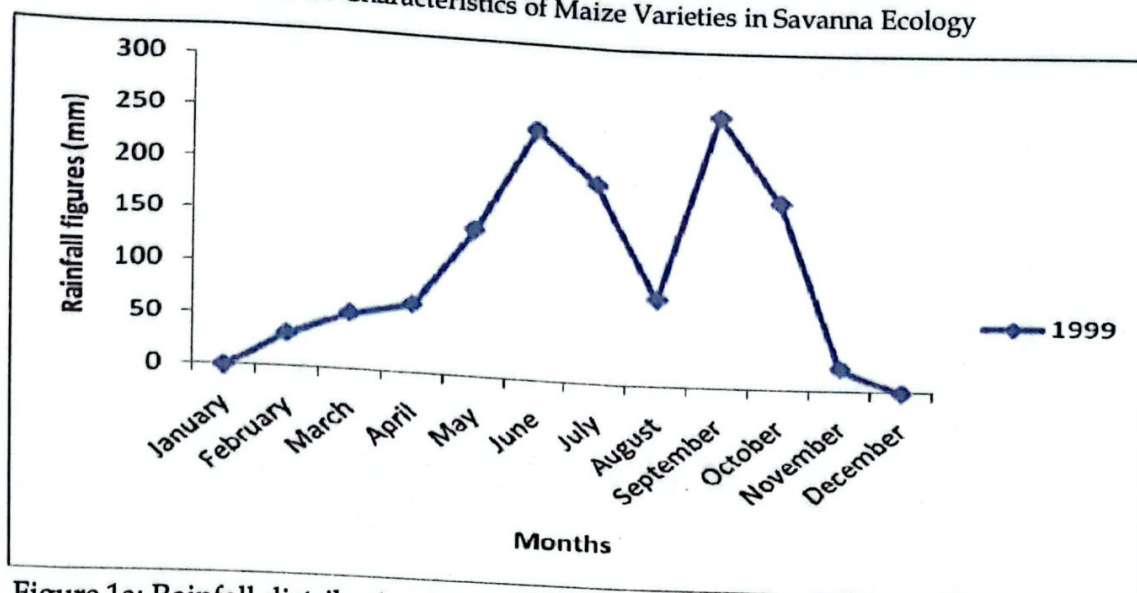


Figure 1a: Rainfall distribution in 1999 at Ilorin (Nigeria)

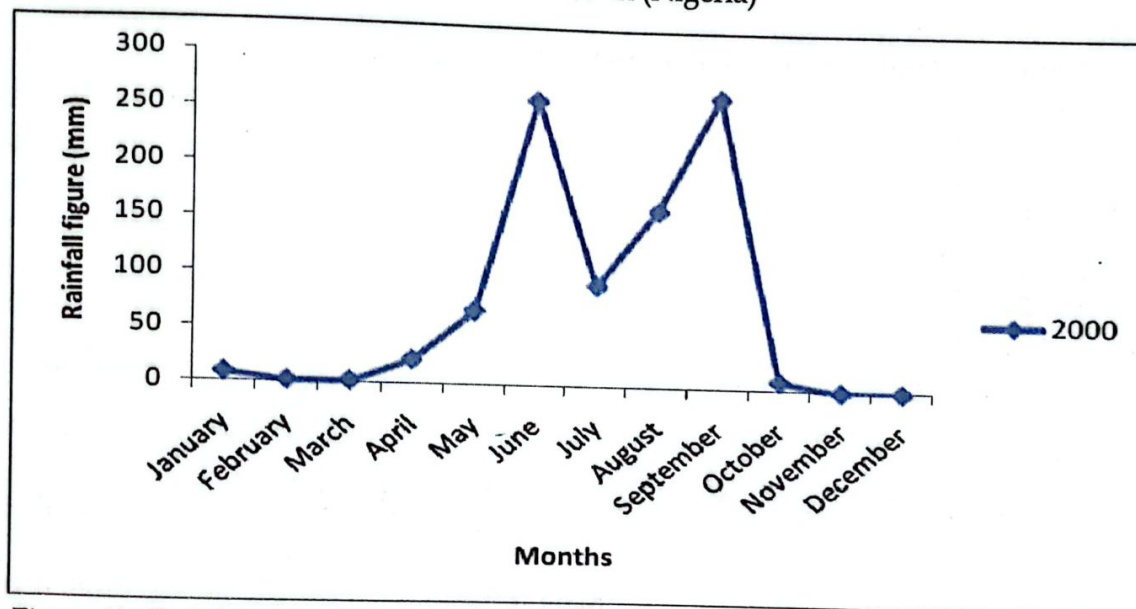


Figure 1b: Rainfall distribution in 2000 at Ilorin (Nigeria)

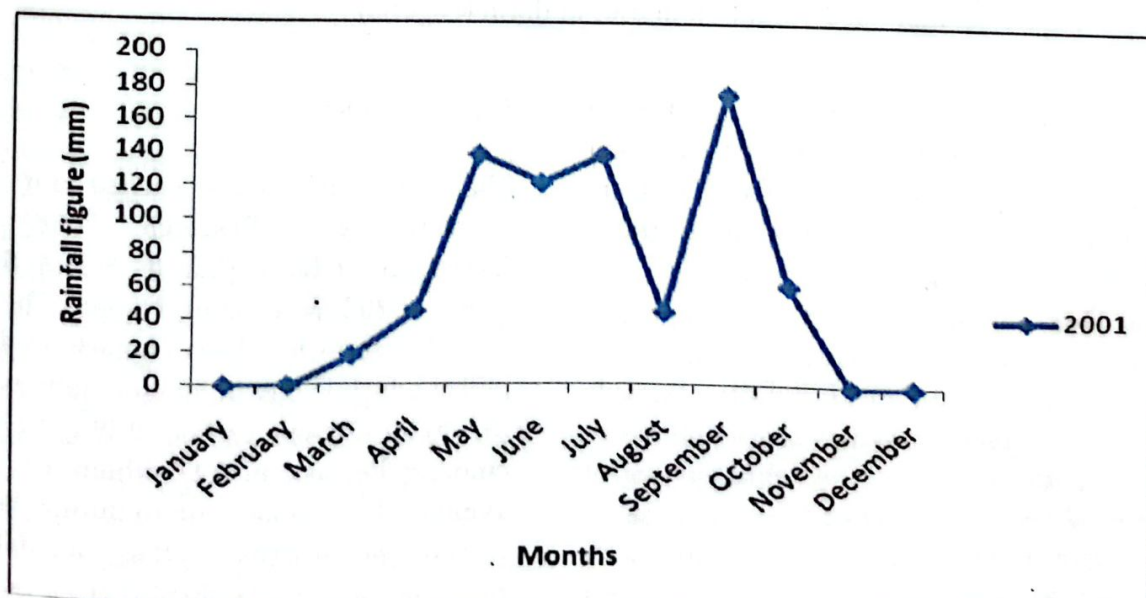


Figure 1c: Rainfall distribution in 2001 at Ilorin (Nigeria)

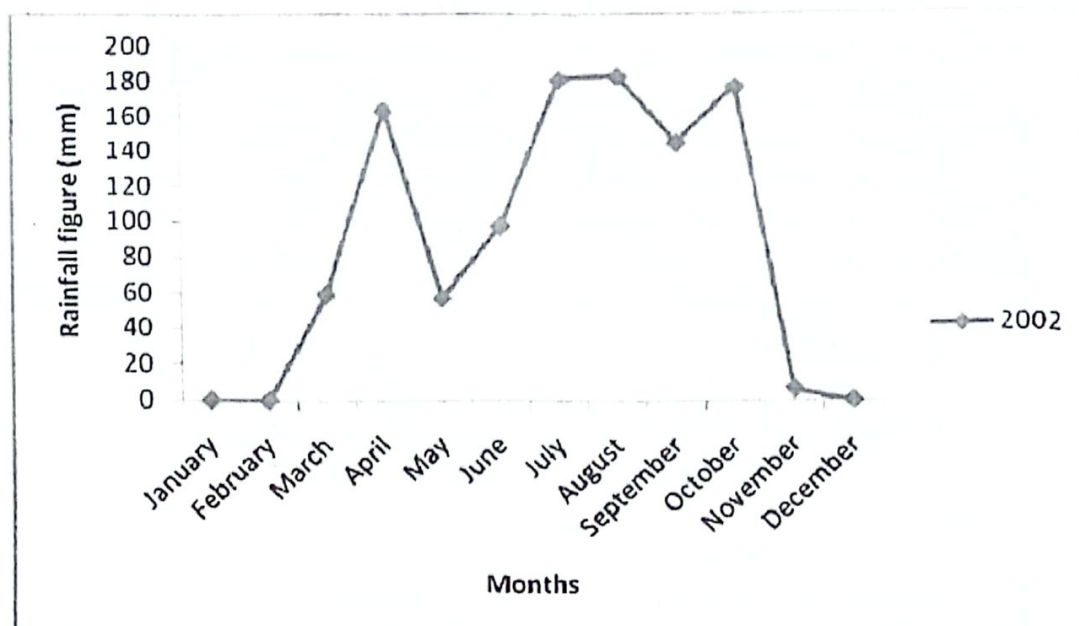


Figure 1d: Rainfall distribution in 2002 at Ilorin (Nigeria)

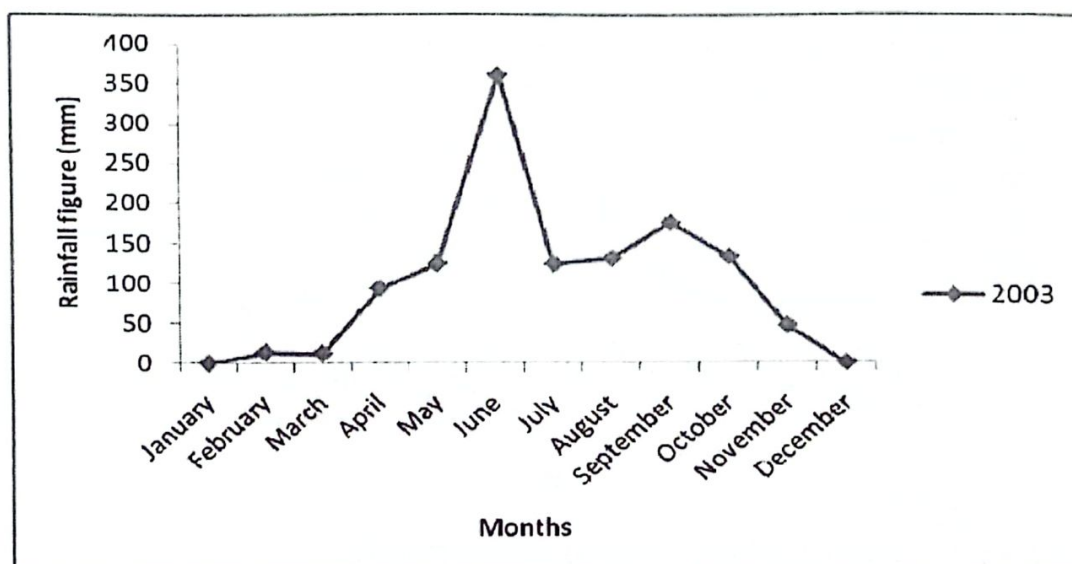


Figure 1e: Rainfall distribution in 2003 at Ilorin (Nigeria)

eight high yielding varieties selected from earlier trials at Ilorin among early maturing maize varieties (also from the IITA), in isolation followed by separation of the grains based on colour, were used as checks. Two local short stature maize varieties (AFO-W and AFO-Y) which mature within two months after sowing making them amenable for intercropping, served as checks for extra-early maturity group. The initial source of seeds of the local varieties (a farmer's field), had been improved only for uniformity with respect to days to flowering and colour during subsequent seed increase.

Experimentation

The field trials were carried out at the Teaching and Research (T&R) farm, University of Ilorin (Lat. 8° 29'N & 8° 30'N; Long. 4° 30'E & 4° 32'E), Nigeria. The soil at the T&R farm has been characterized as an alfisol which is low in inherent fertility status (8.5 g/kg Organic carbon, 0.49 g/kg N, 0.18 cmol/kg Potassium, 0.11 Sodium, 6.0 mg/kg available P). Rainfall pattern during the study period was irregular, often bimodal, with peaks in June and September (Figs 1a, b & e) but also multimodal (Figs 1c & d).

Late/intermediate drought tolerant accessions

The twelve intermediate/late DT OPVs and hybrids were evaluated in a four-replicate randomized complete block design (RCBD) for four growing seasons, over a three-year period (1999 to 2001). The trial was first conducted during the full growing season of 1999. Each plot consisted of four rows with plants spaced 0.75 m between and 0.50 m within the rows to give a plant population of approximately 53,333 plants/ha. During flowering in 1999, additional seed increase of the genetic materials was achieved by bulk pollination of plants from the two outer rows in each plot. At harvest, the seeds from each variety in the four replicates were processed and bulked for use in further evaluations during the early and late seasons of 2000 as well as in the full growing season of 2001. Trials were established on July 7, 1999, May 27 and 15th August, 2000 and on July 10, 2001 respectively, thus giving a total of four environments.

Early and extra-early maturing varieties

The early and extra-early maturing varieties along with their respective checks were also grown in four-replicate randomized complete block design (RCBD) at the T&R farm of the university for three years (2001, 2002 and 2003). Plantings were carried out on 10th August, 2001, 7th and 2nd July, 2002 and 2003, respectively. The trials were laid out as separate experiments but adjacent to each other each year. Each plot for the early and extra-early maturity groups consisted of four rows with plants spaced 0.75 m between and 0.40 m within the rows to give a plant population of approximately 63,333 plants/ha. During the flowering stage in 2001, similar procedure for seed increase as described for the Late/Intermediate DT accessions was carried out to generate sufficient seeds for evaluation in 2002 and 2003, respectively.

Trial establishment and maintenance

Planting for each maturity group was carried out for each trial at three seeds per hill. After germination, seedlings were thinned to two most vigorous stands per hill. Pre-emergence weed control was undertaken by application of a mixture of Stomp and Attrazine (wetttable powder) at the rate of 100 ml to 20 litres of water immediately after planting. Fertilizer application was carried out for each experiment as split-dosage at the rate of 80 kg N/ha, 60 kg K₂/ha and 60 kg P₂O₅/ha three weeks after planting (immediately after thinning) and at tassel emergence using 15-15-15 NPK compound fertilizer. The trials were kept weed free with supplementary hoe weeding throughout the duration of study.

Data collection and analysis

Data were collected from the two central rows of each plot on seedling emergence, days to flowering, plant and ear heights (cm) and grain yield. Days to anthesis and days to silking were recorded as the number of days from planting to when 50% of the plants in each plot shed pollen and had emerged silks, respectively. Anthesis-silking interval (ASI) was computed as the difference between dates of silking and pollen shed. Plant and ear heights were measured as the distance (cm) from the base of the plant to the height of the first tassel branch and the node bearing the upper ear, respectively. Ear aspect was rated visually on a scale of 1 to 5 where 1 = clean, uniform, large and well-filled ears and 5 = rotten, variable, small and partially filled ears. All ears harvested from each plot were shelled to determine percent moisture at harvest. Three hundred (300) grain-samples were collected from each plot at harvest for the determination of harvest moisture. The samples were first weighed to obtain initial weight followed by drying to a constant weight in the oven at 80°C in the laboratory and the difference between the two weights recorded as moisture at harvest. Grain yield

was obtained from cob weight per plot (assuming 80% shelling percentage) and was later converted to tonnes per ha after adjusting to 12% moisture content. Separate analyses of variance (ANOVA) were first performed on individual season (Intermediate/Late maturing group) or year (early and extra-early) basis, using the SAS GLM Proc (SAS Inst. Inc., 1997) based on a randomized complete block design. Bartlett's test to assess homogeneity of variance (Snedecor and Cochran, 1967) was also performed before a combined ANOVA using a model in which genotypes in each trial set were considered fixed effects and season or years as random. However, for the purpose of this report a subset of five variables - days to mid-silk, ASI, ear heights, ear aspect and grain yield were chosen for data analysis. The standard analysis of variance procedure with the following model was used for the individual season or year.

$$P_{ij} = m + g_i + r_j + \epsilon_{ij}$$

P_{ij} = phenotypic observation on variety i in replicate j ; $i = 1, \dots, n_g$; $j = 1, \dots, n_r$ where n_g and n_r are the number of varieties and replicates, respectively; m is the grand mean, g_i is the effect of variety i , r_j is the effect of replicate j and ϵ_{ij} is the interaction effect between variety i and replicate j .

The following model was utilized for the combined analysis:

$$P_{ijk} = m + e_j + g_i + (ge)_{ij} + \epsilon_{ijk}$$

P_{ijk} = phenotypic observation on variety i in replicate k at environment j , $i = 1, \dots, n_g$, $j = 1, \dots, n_e$, $k = 1, \dots, n_r$; where n_g , n_e and n_r are the number of varieties, environments and replicates; m is the grand mean, g_i is the effect of variety i ; e_j is the effect of environment; $(r/e)_{jk}$ is the effect of replicate k within environment j , $(ge)_{jk}$ is the interaction effect between variety and environment; ϵ_{ijk} is the interaction effect between variety and replicate within environment.

RESULTS

Environmental effect on genotypic performances

Intermediate/late maturing DT genotypes

The combined analysis of variance (ANOVA) across seasons (Table 1) revealed that differences in environmental factors in the cropping seasons (E) had pronounced effects on the expression of the characters regardless of the genotypes (OPVs versus hybrids). However, differences among genotypes (G) were significant only for days to silking (OPVs and hybrids) and grain yield (OPVs) while $G \times E$ interaction was significant for anthesis-silking-interval (ASI) in the hybrids. Days to silking was earlier in the hybrids compared to OPVs except in 2000 late cropping season but ASI was similar for the two groups of genotypes. However, ASI was shorter in the OPVs in 2000 late cropping season. The year 2001 full growing season was the most favourable for the expression of genotypic potentials for grain yield while 2000 late cropping season was the worst. Differences between the most favourable and unfavourable seasons for grain yield was 1.86 t.ha⁻¹ (OPVs) and 3.48 t.ha⁻¹ (hybrids). However, the high yields were also accompanied by corresponding higher ear placement and lowest rating for ear aspect, respectively. Hybrids showed superiority for grain yield over the OPVs during three of the four cropping seasons by 0.21 t.ha⁻¹ (1999 full growing season), 0.27 t.ha⁻¹ (2000 late cropping season) and 1.45 t.ha⁻¹ (2001 full growing season) respectively.

Four of the OPVs were similar in their yield potential but had significantly higher mean yields than genotypes IWDCO and Sin 93 TZUTSR-W which are the two low yielding varieties (Table 2). Differences between the highest yielding OPV (ACR 9128NN) and the check variety as well as overall mean yield were 0.15 t.ha⁻¹ and 0.27 t.ha⁻¹, respectively. Oba Super 2 yielded significantly higher than

Table 1: Means for grain yield and related traits (each environment) in Intermediate/Late drought tolerant OPVs and Hybrids (Ilorin, Nigeria)

Environment	Open pollinated varieties					Hybrids					
	Days to silking (no)	Anthesis-silking-interval (no)	Ear height (cm)	Ear aspect	Grain yield (t.ha ⁻¹)	Environment	Days to silking (no)	Anthesis-silking-interval (no)	Ear height (cm)	Ear aspect	Grain yield (t.ha ⁻¹)
1999 (N)	67	3	46.58	2.9	2.97	1999 (N)	66	3	46.42	2.7	3.18
2000 (E)	66	3	68.12	3.5	3.16	2000 (E)	65	3	68.33	3.6	3.43
2000 (L)	62	2	61.88	3.6	2.21	2000 (L)	64	3	59.79	3.6	2.04
2001 (N)	66	3	74.25	3.8	4.07	2001 (N)	61	3	70.04	4.1	5.52
Mean	65	3	62.71	3.5	3.10	Mean	65	3	61.1	3.5	3.54
S.E.+	0.46	0.26	1.75	0.15	0.12	S.E.+	0.45	0.48	2.29	0.16	0.61
F-Test											
Environment (E)	117.42**	8.97**	3356.08**	6.79**	14.10**		24.25**	0.26	2796.6**	8.32**	50.45**
Genotype (G)	38.54**	1.02	42.47	0.82	0.94*		19.02*	0.44	81.8	1.32	12.61
G × E	2.99	1.29	51.95	0.88	0.39		2.10	2.06**	178.7	0.85	10.68
%CV	3.40	10.2	13.7	21.3	19.6		3.40	28.9	18.3	21.8	25.8

*, **; Significant at 0.05 and 0.001 levels of probability respectively. E = Early growing season, N = Full growing season, L = Late growing season

*, ***, Significant at 0.05 and 0.001 levels of probability respectively. E = Early growing season, N = Full growing season, L = Late growing season

Table 2: Means across environments for grain yield and related traits in 12 late/intermediate drought tolerant open pollinated varieties and hybrids (Ilorin, Nigeria)

Genotype	Open pollinated varieties					Hybrids					
	Days to silking (no)	Anthesis-silking-interval (no)	Ear height (cm)	Ear aspect	Grain yield (t.ha ⁻¹)	Genotype	Days to silking (no)	Anthesis-silking-interval (no)	Ear height (cm)	Ear aspect	Grain yield (t.ha ⁻¹)
AK 9943-DMRSR	66	2	60.69	3.3	3.33	9164-2	66	3	66.2	3.3	3.23
ACR 922-SR	64	3	63.06	3.6	3.05	8522-2	64	3	63.7	3.4	3.27
IWDC0	65	2	64.63	3.8	2.86	9111-1	67	3	66.5	3.9	3.16
ACR 9128 NN	65	3	64.05	3.3	3.37	8981-5	64	3	64.4	3.4	3.09
Sin 93 TZUTSR-W	65	2	63.26	3.7	2.79	9033-26	65	3	64.9	3.9	3.16
DMR-LSR-Y (Check)	68	2	63.06	3.7	3.22	Oba Super 2	65	3	64.5	3.3	5.35
S.E.+	0.46	0.26	1.75	0.15	0.42	S.E.+	0.45	0.16	2.29	0.22	0.61

all other hybrids. Except for Oba Super 2 which had mean yield that was higher than the overall mean by 1.81 t.ha⁻¹, grain yield recorded for other hybrids were lower. Differences between Oba Super 2 and other hybrids for grain yield ranged between 2.26 t.ha⁻¹ in 8981-5 and 2.08 t.ha⁻¹ in 8522-2. Incidentally, hybrid 9111-1 which was the latest to attain days to silking was among the low yielding hybrids.

Early and extra-early maturing varieties:

Environmental (Y) factors in the three years of evaluation had significant effects on the expression of all the traits except ear aspect (extra-early) and ASI (early) maturing groups (Table 3). Genotypic (G) differences were also significant for days to silking and ear height (early and extra-early) and for ear aspect (extra-early). However, G x Y interaction was significant for grain yield in both maturity groups as well as for ASI in extra-early varieties. The 2002 growing season with the shortest ASI, was the most favourable for the expression of genotypic potential for grain yield in the extra-early, with a difference of 0.9 t.ha⁻¹ (2003) and 1.16 t.ha⁻¹ (2001) in grain yield, representing 30 and 39.5% yield advantage, respectively. Grain yield in the early maturing varieties was highest in 2001 growing season and lowest in 2003 with a difference of 0.72 and 1.29 t.ha⁻¹ between the best year (2001) and those of 2002 and 2003 respectively which also translated to 21.8 and 39.1% yield advantage. Ear placement was lowest in 2003 for the two maturity groups but rating for cob appearance varied between years in each maturity group.

Three genotypes among the extra-early (DMRSER-W, 99 TZEE-Y STR and Sine TZEE-W STR) had marginal yield increase over the better check (AFO-W) and higher than the mean grain yield by 0.32, 0.27 and 0.22 t.ha⁻¹, respectively (Table 4). Genotype DMRSER-W, which is the highest yielding genotype also had the shortest ASI while vars. 99 TZEE-Y

Table 3: Means for grain yield and related traits (each year) in early and extra-early maturing maize varieties (Ilorin, Nigeria)

Year	Extra-early					Early				
	Days to silking (no)	Anthesis-silking interval (no)	Ear height (cm)	Ear aspect	Grain yield (t.ha ⁻¹)	Days to silking (no)	Anthesis-silking interval (no)	Ear height (cm)	Ear aspect	Grain yield (t.ha ⁻¹)
2001	60	2	33.80	3.0	1.77	63	3	39.68	3.2	3.30
2002	53	2	61.03	3.2	2.93	57	2	64.29	3.1	2.58
2003	56	3	37.41	3.3	2.03	59	3	47.68	3.6	2.01
Mean	56	3	44.08	3.2	2.24	60	3	50.55	3.3	2.63
S.E. _±	0.21	0.18	0.94	0.10	0.22	0.34	0.30	1.21	0.15	0.09
F-Test										
Year (Y)	690.67**	36.61**	12252.3**	1.53	21.26**	640.33**	7.04	8822.88**	3.36*	23.43**
Genotype (G)	15.26**	7.55	117.73*	1.08*	0.71	40.55**	1.93	174.25**	1.02	0.48
G x Y	3.08	4.95**	52.80	0.38	0.91**	5.96	2.82	53.20	0.59	0.94**
%CV	2.70	32.9	16.0	22.8	26.3	4.20	34.5	17.9	24.2	25.7

*, ***, Significant at 0.05 and 0.001 levels of probability, respectively

Table 4: Means across years for grain yield and related traits in early and extra-early maturing maize varieties in 2001, 2002 and 2003 (Ilorin, Nigeria)

Genotype	Extra-early				Early			
	Days to silking (no)	Anthesis-silking interval (no)	Ear height (cm)	Ear aspect	Grain yield (t ha ⁻¹)	Genotype	Days to silking (no)	Anthesis-silking interval (no)
99 TZEF-Y STR Co	54	2	45.92	3.1	1.97	2000 SYN WEC	60	3
Sine TZEE-W STR	56	3	45.25	3.3	2.46	TZE-W Pop x 1368 STR C ₁	61	3
Ferke TZEE-W STR	57	3	47.58	2.8	2.08	99 SYN WEC	60	3
98 TZEE-W STR	56	4	42.33	3.0	2.19	EVDT 99 STR Co	63	3
99 TZEE-Y STR	57	3	42.75	3.1	2.51	Acr 94 TZE Comp _s -W	61	3
2000 SYN EE-W	56	4	51.75	3.2	2.40	Acr 94 TZE Comp _s -Y	61	2
99 SYN EE-W	56	3	41.42	3.6	2.29	EVDT 97 STR C ₁	59	2
TZEE-W SR BC _s	57	3	40.67	2.5	2.21	98 SYN WEC	58	2
DMR ESR-Y	58	2	42.92	3.3	1.64	EVDT-W 2000 STR	58	2
DMR ESR-W	58	1	45.98	3.1	2.56	Acr94 Pool 16 DT STR	62	3
97 TZEE-W ₂ C ₁	57	2	43.83	3.3	2.21	EVDT-Y 2000 STR	62	3
97 TZEE-W ₃ C ₁	56	2	45.67	3.7	2.25	Kaimboise 88 Pool 16 DT	59	3
AFO-Y (Check 1)	57	2	43.50	3.2	2.09	Check 1 (Y)	60	3
AFO-W (Check 2)	54	2	38.50	3.4	2.43	Check 2 (W)	56	3
S.E.+	0.45	0.4	2.06	0.2	0.16	S.E.+	0.71	0.64
							2.59	0.23
								0.19

STR C₀ and AFO-W (better check) were the earliest to silk. Four genotypes among the early maturing group (Acr 94 Pool 16 DT-STR, EVDT 99 STR C₀, Acr 94 TZE Comp_s-W and 2000 SYN WEC) in that order yielded higher than the better check (Check 1) by 0.34, 0.13 0.07 and 0.03 tonnes/ha⁻¹ and than the mean grain yield by 0.44, 0.23, 0.17 and 0.13 t ha⁻¹, representing 16.7%, 8.75%, 6.46% and 4.94% yield advantage, respectively. Acr 94 Pool 16 DT-STR was among the latest to attain silking while check 2 was the earliest. None of the genotypes with short ASI were among the top yielding genotypes in this group.

Partitioning of the components of mean squares of G and G x E interaction effects for grain yield in the two major groups revealed that much of the variability for grain yield among the intermediate/late maturing varieties (OPVs and hybrids) was due to within-group variation among hybrids as well as the large differences in stability of performance between the OPVs and the hybrids during the period of evaluation. Similarly, differential response of hybrids to environmental conditions in the growing seasons as well as the large residual accounted for the significant G x E interaction for grain yield in this maturity group. The extra-early varieties were highly variable in their performance for grain yield compared to the early maturing varieties, thus accounting for a higher proportion of the observed variability for grain yield. However, the proportion of variation contributed to the significant G x E interactions for grain yield in this maturity group was equal between the two groups.

Trend in yield potential of genotypes in the different maturity groups Intermediate/late maturing DT genotypes:

The trend in the expression of genotypic potential for grain yield in the DT OPVs showed that although the genotypes changed

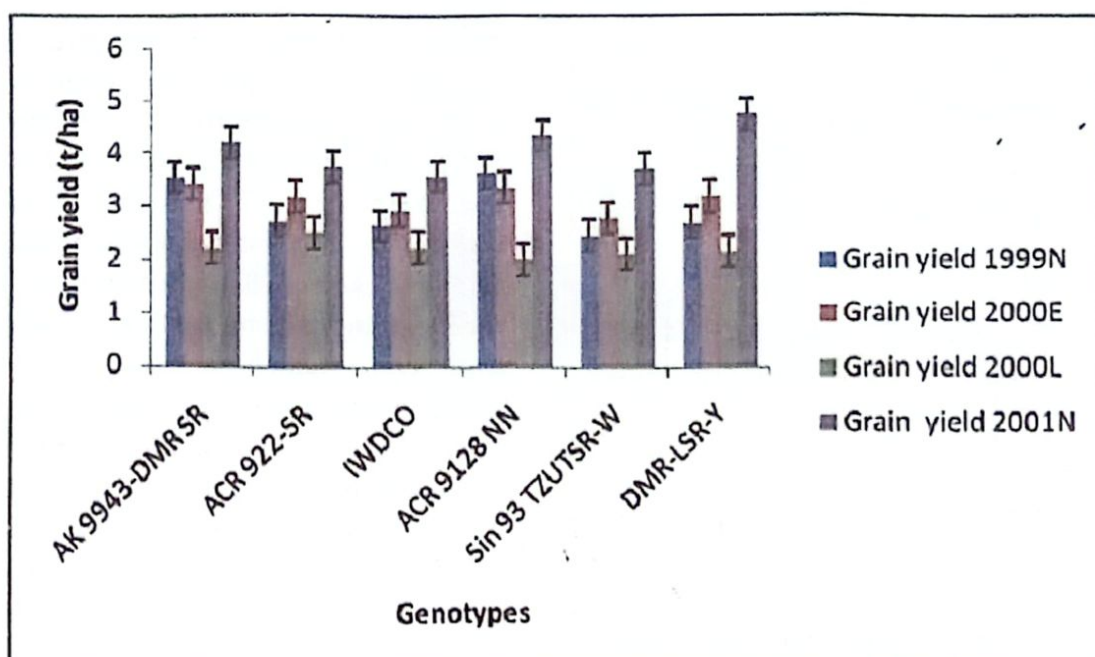


Figure 2: Seasonal trend in grain yield of six Intermediate/late maturing drought tolerant open pollinated maize varieties (Ilorin, Nigeria)

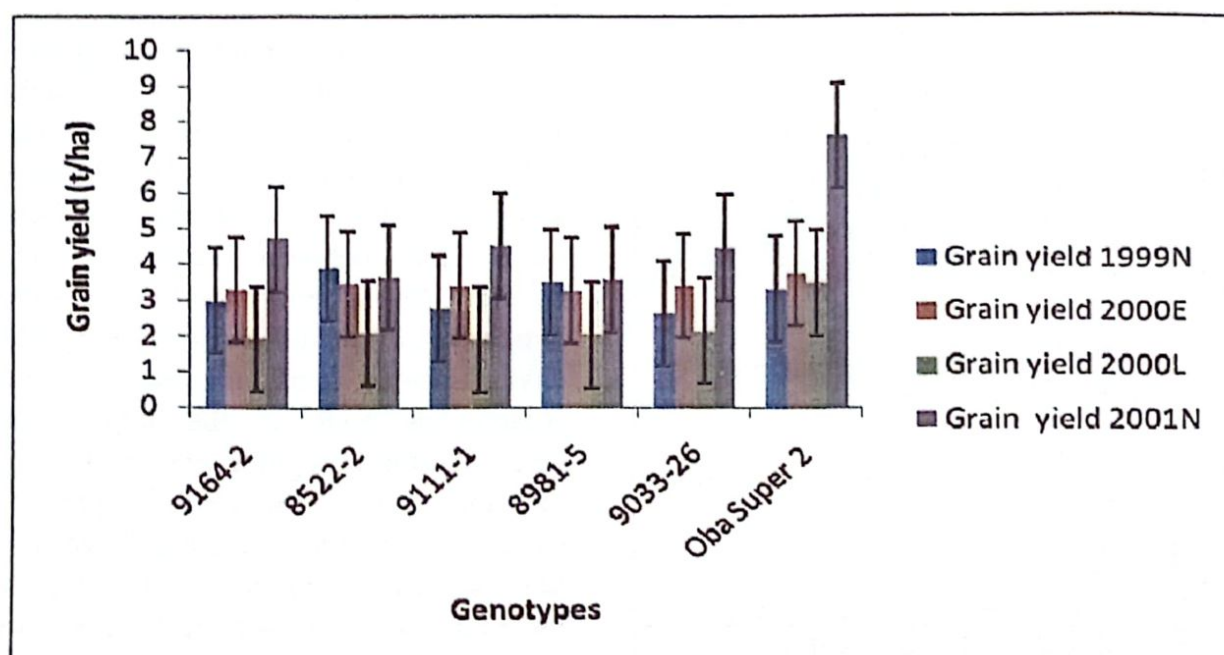


Figure 3: Seasonal trend in grain yield of six drought tolerant hybrids (Ilorin, Nigeria)

rank in the different cropping seasons, differences were not significant (Table 5). However, all the genotypes recorded their highest grain yields in 2000 full growing season (Figure 2). Genotypes AK 9943 DMR SR and ACR 9128 NN were similar in their yield potential in 1999 full growing season as well as in 2000 late season. However, genotype ACR 9922-SR had a slight yield advantage ($t\cdot ha^{-1}$) over other varieties in the 2000 late season. Grain yields recorded for

genotypes AK 9943 DMR SR, ACR 9128 NN and DMR-LSR-Y were similar.

Although the hybrids with the exception of Oba Super 2 changed rank in each of the growing season for grain yield, differences between seasons were non-significant (Table 5). Grain yields for each of the hybrids was highest in 2001 full growing season and worst in 2000 late season (Figure 3). None of the hybrids yielded higher than $2 t\cdot ha^{-1}$ in 2000

Table 5: Mean squares for the components of genotypic (G) and genotype x environment (GE) effects for grain yield in maize varieties belonging to different maturity groups (Ilorin, Nigeria)

Source	Intermediate/Late OPVs and Hybrids		Early and Extra-early	
	df	Source	df	
Environment (Env)	3	Environment (Env)	2	16.74**
Rep/Env	12	Rep/Env	9	1.50
Genotype (G)	11	Genotype (G)	27	14.28**
OPVs	5	Early	13	0.48
Hybrids	5	Extra-early	13	0.71*
OPVs vrs Hybrids	1	Early vrs Extra-early	1	37.00**
Env x Genotype	33	Env x Genotype	54	29.79**
Env x OPVs	15	Env x Early	26	0.94**
Env x Hybrids	15	Env x Extra-early	26	0.91**
Env x OPVs vrs Hybrids	1	Env x Early vrs Extra-early	2	156.01**
Pooled Error	132	Pooled Error	335	1.92

*, ***, Significant at 0.05, 0.01 and 0.001 levels of probability, respectively

late season compared to grain yield of 7 t.ha⁻¹ recorded for Oba Super 2 in 2001 full growing season. This value was significantly higher than those of other hybrids by between 4.3 t.ha⁻¹ (8981-5) and 3.0 t.ha⁻¹ (9164-2) representing 60% and 57.3% yield advantage, respectively.

Early and extra-early maturing varieties:

Grain yield recorded for individual genotypes within the extra-early varieties were generally high in 2002 and low in 2001 except for genotype DMR ESR W (Figure 4). All the genotypes except three, yielded below 2 t.ha⁻¹ in 2001 while all but one had yields that were higher than 2 t.ha⁻¹ in 2002, with mean yield for the year close to 3 t.ha⁻¹. Six genotypes on the other hand yielded higher than 2 t.ha⁻¹ in 2003. Genotypes DMR ESR-W was among the top three yielding varieties in two of the three years within this group and also the top yielding genotype when yields were averaged across years (Table 4). Another genotype (99 TZEE-Y STR) was also among the three top yielding genotypes in two of the three years (2001 and 2003) respectively. Three genotypes (99 TZEE Y-STR, DMR ESR W 99 Syn EE -W) with mean yield higher than 2 t.ha⁻¹ in 2001, three (Sine TZEE-W STR, 2000 Syn EE-W and 97 TZEE W₃ C1) with mean yield above 3 t.ha⁻¹ in 2002 and three (AFO-W, 99 TZEF-Y and TZEE W SR BC₅) in 2003 with mean yield above 2.3 t.ha⁻¹ were the top yielding genotypes each year among this group.

Genotypic performance for grain yield among the early maturing varieties (Figure 5), were similar in 2001 and 2002 although there were individual genotypes with yields higher than 3.5 t.ha⁻¹ in 2001. Three genotypes (2000 Syn WEC, Acr 94 TZE Comp₅-W and Acr 94 TZE Comp₅-Y) with mean yields ranging between 3.9 and 4.0 t.ha⁻¹ in 2001, three (Acr 94 Pool 16 DT STR, EVDT 99 STR C₀ and Acr 94 TZE Comp₅-W) in 2002 with grain yield between 3.1 to 3.5 t.ha⁻¹ and Check 1, EVDT 99 STR C₀

and 99 SYN WEC in 2003 (2.3 to 2.7 t.ha⁻¹) were the top three genotypes each year in this group. Var. Acr 94 Pool 16 DT STR which was the highest yielding variety when yields were averaged across years in this group (Table 4) was also among the three top yielding genotypes in two of the three years. Other genotypes with similar performance for grain yield in two of the three years were EVDT 99 STR C₀ and Acr 94 TZE Comp5-W.

DISCUSSION

Rainfall distribution during the growing period was the major environmental factor in the expression of genotypic potential for grain yield especially in the intermediate/late maturing maize genotypes in this study. Denmead and Shaw (1960) noted that moisture stress decreased dry matter production directly by decreasing cell

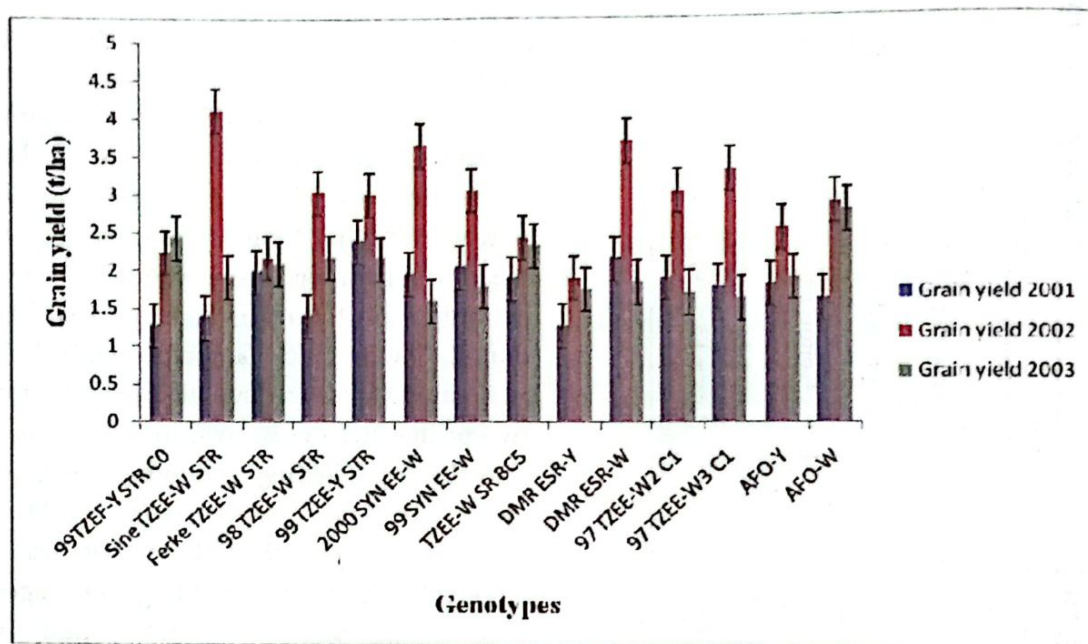


Figure 4: Seasonal trend in grain yield of 14 extra-early maturing maize varieties (Ilorin, Nigeria)

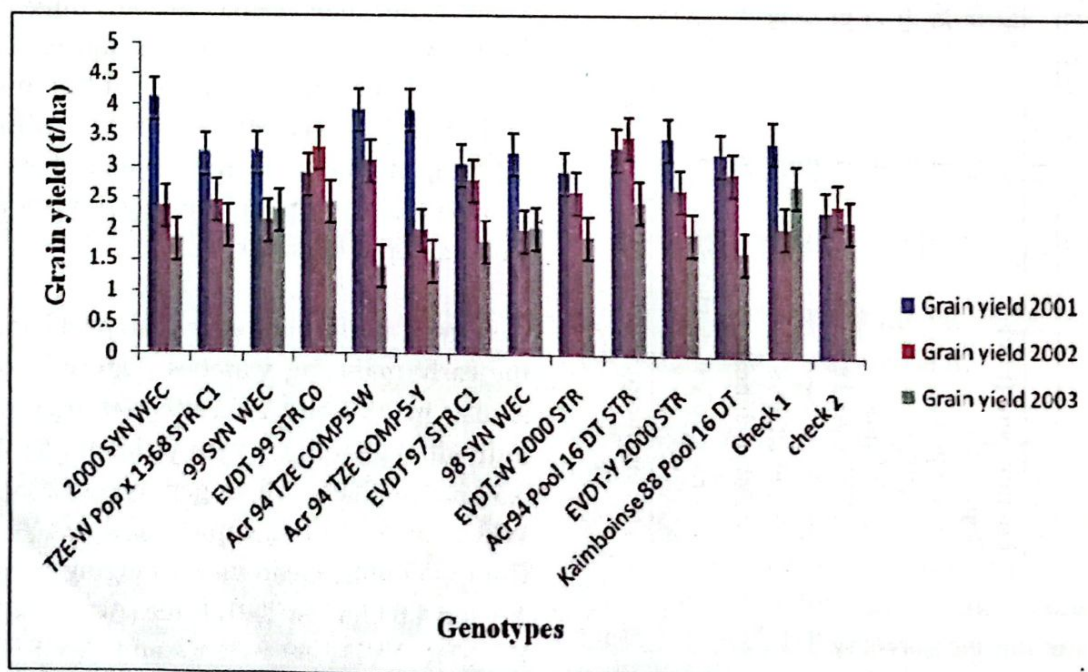


Figure 5: Seasonal trend in grain yield of 14 early maturing maize varieties (Ilorin, Nigeria)

division and enlargement and indirectly by reducing rate of photosynthesis. This was probably the case with this group where grain yields in both OPVs and hybrids were low in 2000 late season due to terminal drought which occurred early that year, with the station recording less than 10 mm of rainfall in October. This period coincided with the reproductive phase in both groups. Consequently, the crops had to depend on residual moisture in the soil for grain formation and development. Reports from previous studies which assessed the performances of early and extra early maturing varieties in this ecology (Olaoye and Omuetti, 2006) have also revealed significant differences in grain yields between early and late growing seasons. Conversely, there was sufficient moisture during the reproductive phase in the remaining growing seasons which permitted the expression of genotypic potential for grain yield.

Only two of the hybrids (9164-2 and 9033-26) showed consistency in synchronization of flowering in each season, indicating that the significant $G \times E$ interaction observed for ASI in respect of the hybrids was due to lack of consistency for ASI in the remaining hybrids. For example, while each hybrid showed similarity for ASI across seasons (3 days), one of the lowest yielding hybrids (8981-5) exhibited asynchrony of flowering ranging between 5 days in 2000 growing season and 2 days in 2001 late growing season (data not shown).

Mungo and Njoroge, (1997), hypothesized that a short growth period (such as in early and extra-early varieties), dictates lower biomass and grain yield even under well-watered conditions due to reduced period for photosynthesis. The findings in this study corroborates this observation because the magnitude of grain yields were in the order of intermediate/late maturity > early > extra-early varieties and also support earlier report of Dowker (1971), that while growing early

maturing maize cultivars would increase the reliability of maize yields in low rainfall areas, drought tolerant genotypes that are slightly later to flower could increase production in highly variable environments by boosting yields in both dry and well-watered seasons. Furthermore, the hybrids yielded higher than the OPVs in each of the growing seasons except 2000 late season corroborating earlier report (Olaoye *et al.*, 2004), which showed that hybrids gave higher yields even under low N-Fertilizer regimes compared to the OPVs. However, the higher yields recorded for the OPVs in 2000 late season may also be related to the fact that hybrids were more sensitive to moisture stress than the OPVs which are more variable (that is, heterozygous at most of their loci). Moss & Downey (1971), had earlier hypothesized that OPVs with greater flowering variability could probably tolerate 10-12 days ASI before pollen supply becomes limiting thus adversely affecting grain set.

Changes in the relative rankings of genotypes' response are an indication of significant $G \times E$ interaction, which may be detected as significantly different patterns of response among the genotypes across environments. Biologically this will occur among the genotypes (or level of expression) if the genes regulating the trait differs among environments (Bisford and Cooper, 1998). Thus, it is not only average performance that is important in genotype evaluation but also the magnitude of the interactions (Gauch and Zobel, 1997). Although environmental factors during the growing period in the three years of evaluating early and extra-early varieties had significant effects on the expression of all characters including grain yield, differences between years as well as between and within-groups could not be attributed solely to moisture availability. This is because moisture was not limited during the period of study. Therefore, the observed change in ranking within each group is probably due to inherent genetic potential of the individual

varieties for grain yield. However, the large residuals obtained in the mean squares for G and G x E interaction effects for grain yield in this group may also be due in part to inconsistency in their performances for grain yield arising from differential response to other environmental factors apart from rainfall during the period of study. Kang and Gorman (1989) in a previous study which assessed the effect of various environmental factors on yield performance of seventeen hybrids grown in 12 environments, also reported that hybrids were differentially affected more by differential fertility and/or cultural practices (environmental index) than by weather factors.

CONCLUSION

The results of the current study demonstrated that rainfall distribution (rather than the amount) during the growing period was the determining factor in the performance of the intermediate/late maturing DT genotypes maize genotypes for grain yield. However, none of the varieties in this maturity group showed superiority for grain yield over the existing check varieties (DMR-LSR-Y for the OPVs and Oba Super 2 for the hybrids), suggesting the necessity to evaluate newer generations of varieties in this maturity group for adaptation to the SGS ecology. Conversely, two varieties among the extra-early (DMR ESR Y and 99 TZEE-Y STR) and three among the early (EVDT 99 STR C₀, Acr 94 TZE Comp₅-W and Acr 94 Pool 16 DT STR C₀) exhibited superiority for grain yield compared to their respective checks. They could therefore serve as replacements to the existing cultivars in this ecology. Acr 94 Pool 16 DT STR C₀ in particular has shown consistency for high grain yield under farmers' condition in the savanna ecologies of Nigeria.

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