YIELD AND YIELD COMPONENTS OF TROPICAL MAIZE GENOTYPES AS AFFECTED BY DROUGHT AND WEED STRESSES

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ABSTRACT
Drought and weed problems have constituted a major constraint to the goal of achieving adequate food supply all year round particularly in the Sudan Savanna and dry Savannas of West and Central Africa. Thus, the improvement of maize genotypes tolerant to drought and weed stress becomes imperative. Four maize genotypes, two each of hybrids and open pollinated varieties (OPVs) were evaluated for their tolerance to drought and weed stress in 2002 and 2003. The two years average shows that drought stress reduced the grain yield of the maize cultivars by 39 % and 28 % in the unweeded and weeded treatments respectively. Weed free plots had maize with higher yield components (kernel ear^{-1}, cob length, cob diameter and 1000 kernel weight) than unweeded (2 weeks after sowing) treatments. Hybrid 9803-9 was more susceptible to drought and weed stress as indicated by the grain yield. STREVIWD an open pollinated variety and Hybrid 9134-14 were superior in performances in terms of grain yield and shorter anthesis silking interval. Irrespective of the genotype, maize (hybrid and OPV) was more tolerant of drought in a weed free environment than in unweeded conditions.

Key words: *Drought stress, Maize genotypes, Weed stress, Yield Components*

INTRODUCTION

Generally, crop and weed compete for soil moisture, light and nutrients. Soil moisture greatly affects the competitive ability of weeds (Weise and Vandiver, 1970) hence, with adequate soil water; the effect of weeds on reducing crop nutrient uptake will be great. A focal point of global food security is the ability to produce food and fodder all year round irrespective of seasonal variations. However, drought has constituted a major hindrance to this aspiration among other limiting factors, particularly in the tropics. Projections by van den Born *et al.*, (2000) indicated that there will be a decrease in precipitation from 400 to 100 mm/year by year 2050; consequently, crop yield in sub-Saharan Africa will decline by up to 2.5% over the next 20 years, 5% in 50 years and 10% in 80 years. Assessment of the recent rainfall pattern and distribution in Nigeria shows that there is a decline in the annual amount with prolonged dry periods. This is however; acclaimed to be unprecedented in duration, spatial, temporal character and seasonal expression by Jagtap (1995).

Drought is considered as one of the major abiotic constraints in the Guinea and Sudan Savanna zones of West Africa because the rainfall in this area is unpredictable in quantity and distribution. Even in the lowland locations, periodic droughts can occur at most sensitive stage of crop such as flowering and grain filling. These are particularly sensitive stages of crop growth (Grant *et al.*, 1989). Thus, the development of tropical maize (Zea mays L.) genotypes with high and stable yields under drought becomes imperative if the target of food security is to be met. As part of this effort, the International Institute of Tropical Agriculture (IITA) evaluated some hybrids, open-pollinated varieties and landraces of maize for their tolerance to terminal droughts. Consequently, some hybrid were adjudged tolerant and others susceptible. (Kamara et *al.,* 2003). The research like many other breeding studies was conducted under weed free conditions. This is hardly ever achieved by tropical farmers because of the cost of regular weeding, time allotted to such exercise and above all, the labour intensive nature of keeping weeds in check. Hence, before any general conclusion could be drawn on these potential drought tolerant/susceptible maize hybrids, their yield performance and other secondary agronomic traits (drought stress indicators) needed to be evaluated under various weed pressures. This is particularly important when it is widely believed that weeds compete with maize for moisture. This competition reduces the nutrient uptake and performance of maize. This study was designed to ascertain the true performance of some of these hybrids while simulating the conditions in an average tropical maize farmer's field in order to determine the effects of drought and weed stress on the yield and yield components of some maize genotypes.

MATERIALS AND METHODS

Field studies were conducted at IITA's experimental site at Ikenne, Southwest Nigeria (06° 53' N, 03° 42' E, and altitude of 60m) in 2002 and 2003 dry seasons (December – March, each year). The soil of the experimental site was sampled and analysed for its physicochemical characteristics by standard procedures. The experiment was a Randomized Complete Block Design in a split plot with four replicates. It was set up in 2 blocks separated by a 15m border. The watering regimes were: Fully watered throughout the growing season. (Adequate watering every 7 days) and a water deficit treatment, this was only irrigated for the first four weeks after sowing. Sprinkler irrigation was used to supply adequate watering every week (soil field capacity). The main plot was the weeding regimes; these were weeded throughout the growing season and weeded once at 2 weeks after sowing (WAS) termed unweeded treatment. The subplot was two maize hybrids (9803-9 and 9134-14) and two maize open pollinated varieties (STREVIWD and IYFDCO1). Nitrogen was applied to the maize by side placement at the rate of 120 kg N/ha in two equal splits at planting and 3 WAS. Potassium and Phosphorus were also applied, at 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} to the plots at planting by broadcasting. Tillage consisted of plowing and harrowing. Each plot was 4.5 m X 3 m and consisted of six rows of maize 75 cm apart and 25 cm apart within the row. Two maize seeds were sown per hole on the 1st of December in both years and later thinned to one at 2WAS. The plant population was 53,333 plants/ha. The number of days to tasselling and midsilking were recorded to determine the anthesis-silking interval (ASI) under stressed and non-stressed conditions. The chlorophyll content of the maize was taken on the four middle rows using chlorophyll meter (SPAD 502, Minolta) at midsilking. At harvest (12 WAS), the number of ears per plant (EPP) was recorded in order to determine barrenness. Yield was taken from all cobs from the four middle rows while the number of cobs proportionate to 10% of the total yield per

plot was selected and used for determining the cob diameter, cob length (with a venier caliper), number of kernels per cob (by counting) and 1000 kernel weight. The cobs harvested from the four middle rows were weighed.
Data generated were analysed using the General Linear Model procedure (GLM); Statistical Analysis systems Package (SAS Institute, 1990), significant differences between treatments and their interactions were compared using Standard Errors of the Means.

RESULTS

Some of the physicochemical properties of the soils used for the experiments are shown in Table 1. In year 2002, the soil pH was 5.33 at Ikenne. In 2003, it was 5.90. The soils were generally low in organic carbon, which was 1.25 % in 2003 and 0.98 % in 2003. The total nitrogen, available phosphorus and Mehlich extractable were also low in the two years. The soil was classified as Eutric Nitisol and Typic Paleudalfs. Table 2 shows the rainfall of the area for the period of research. The rain free period in December of the two years allowed for some soil dryness coupled with the low clay content and evaluation of drought stress on the genotypes. The average monthly (day time maximum) temperature for the two years ranged from 33.5°C to 36.0°C. This value however indicates that the temperature was suitable for optimal growth and development of maize.

Table 3 shows the yield components of the maize at harvest. There was no significant difference in the number of kernel per ear, cob length and cob diameter between the weeding treatments, under drought stress. However, the reduction in these values compared to the watered treatments varied. The reduction in cob length in unweeded plots is higher (13%) compared to weeded plots (10 %). The 1000 kernel weight was significantly reduced in the unweeded plots, while the percent reduction was 27 %. Under drought stress, weeded plots had 235.94 g/1000 seeds while unweeded plots had 222.18g/1000 seeds. There were also significant genotypic variations in all theses parameters. Hybrid 9803-9 and STREVIWD had a significantly higher kernel number per ear than the other genotypes. Drought stress had the least effect on STREVIWD (11 % reduction). It also had a significantly higher ($p<0.05$) cob diameter and 1000 kernel weight compared to other genotypes. Cob diameter reduction due to drought stress ranged from 7 % in STREVIWD to 16% in IYFDCO1.

The grain yield (12 % moisture content) at harvest in 2002 (Table 4) was higher in weeded plots (under drought stress) compared to the unweeded plots ($p<0.05$). Among the genotypes evaluated, there was only a significant difference in grain yield among droughted plants in 2002. In 2002 there was no difference in grain yield among irrigated cultivars and in 2003 there was no difference among cultivars under either irrigation treatment or drought stressed treatments. The highest yields were from the hybrid 9134-14 and the OPV IYFDCO1 with a mean yield of 2.59 Mg/ha.

The spider chart in figure 1 shows ranked genotype performance under drought stress, it revealed that STREVIWD had the best performance in terms of kernel number, cob diameter, Ears per plant and ASI. Hybrid 9134-14 was the best genotype in yield and cob length while IYFDCO1 had good chlorophyll content. However, when weed pressure was also imposed (figure 2), the performance of STREVIWD was still the best and better in 9134-14while IYFDCO1 had the lowest values in most of the parameters.

Table 1.Physicochemical properties of the soils (0-20cm).

Characteristics	2002	2003
Total N (%)	0.19	0.10
Available P (mg/kg)	*(Bray-1)* 4.45	*(Mehlich)* 15.20
Organic C (%)	1.25	0.98
pH	5.33	5.90
ECEC (Cmol+/kg)	2.85	3.55
Sand *(%)*	84.0	74.0
Silt *(%)*	9.4	16.0
Clay *(%)*	6.6	10.0
	Classification	
USDA (1994)		Typic paleudalfs
FAO/UNESCO (1994)		Eutric Nitisol

Table 2. Mean monthly rainfall data at Ikenne, Nigeria during the cropping period (December 2002- March 2003 and December 2003- March 2004)

	Rainfall (mm)	
	2002/2003	2003/2004
December	0.0	0.0
January	42.0	29.4
February	26.0	42.4
March	39.2	61.0
Mean	26.8	33.2

Source: IAR&T. Ikenne station

Table 3. Yield components of maize genotypes under well watered and drought stress conditions (mean of two years).

Treatment	Kernel ear^{-1}			Cob length (mm)			Cob diameter (mm)			1000 kernel weight (g)		
	WW	DT	% reduction	WW	DT	% reduction	WW	DT	% reduction	WW	DT	% reduction
Weed pressure (W)												
Unweeded	466.99	385.43	17	154.78	134.24	13	32.57	29.00	11	304.24	222.18	27
Weeded	468.65	412.66	20	154.19	139.21	10	33.15	29.42	11	300.40	235.94	21
SE (±)	10.40	10.87		1.57	2.06		0.60	0.50		5.26	4.17	
Genotypes (G)												
Hybrids												
9803-9	485.87	422.88	13	147.82	132.94	10	33.37	29.58	11	312.07	216.67	31
9134-14	465.58	390.77	16	162.05	149.22	8	31.65	28.43	10	302.07	235.76	22
Open pollinated varieties												
STREVIWD	459.91	409.45	11	148.96	131.74	12	33.12	30.92	7	300.56	246.97	18
IYFDCO1	459.94	373.07	19	159.12	132.99	16	33.29	27.92	16	294.58	216.85	26
SE (±)	14.70	15.37		2.22	2.92		0.85	0.71				
7.44 5.89												
(W X G) SE (±)	20.79	21.73		3.15	4.13		1.20	1.00		10.53	8.34	

WW= watered treatment
DT= Drought treatment

Table 4. Grain yield of maize genotypes under watered condition and drought stress.

Treatment	Grain yield (Mg/ha) 2002		2003	
	WW	DT	WW	DT
Weed pressure (W)				
Unweeded	2.86	1.96	4.07	2.28
Weeded	3.25	2.73	4.06	2.55
SE (±)	0.12	0.13	0.17	0.15
Genotypes (G)				
Hybrids				
9803-9	2.83	1.95	4.32	2.34
9134-14	3.06	2.75	4.20	2.56
Open pollinated varieties				
STREVIWD	3.21	2.26	3.83	2.57
IYFDCO1	3.13	2.42	3.90	2.21
SE (±)	0.18	0.19	0.24	0.22
(W X G) SE (±)	0.25	0.26	0.34	0.31

WW= watered treatment
DT= Drought treatment.

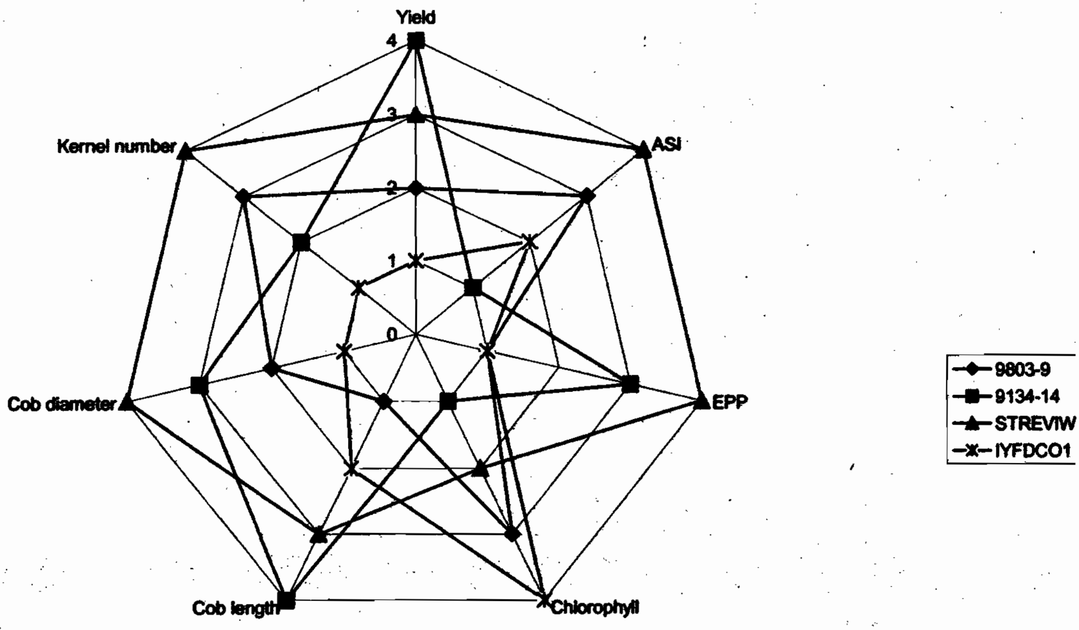

Figure 1. Spider chart showing ranked performance of genotypes under drought stress.

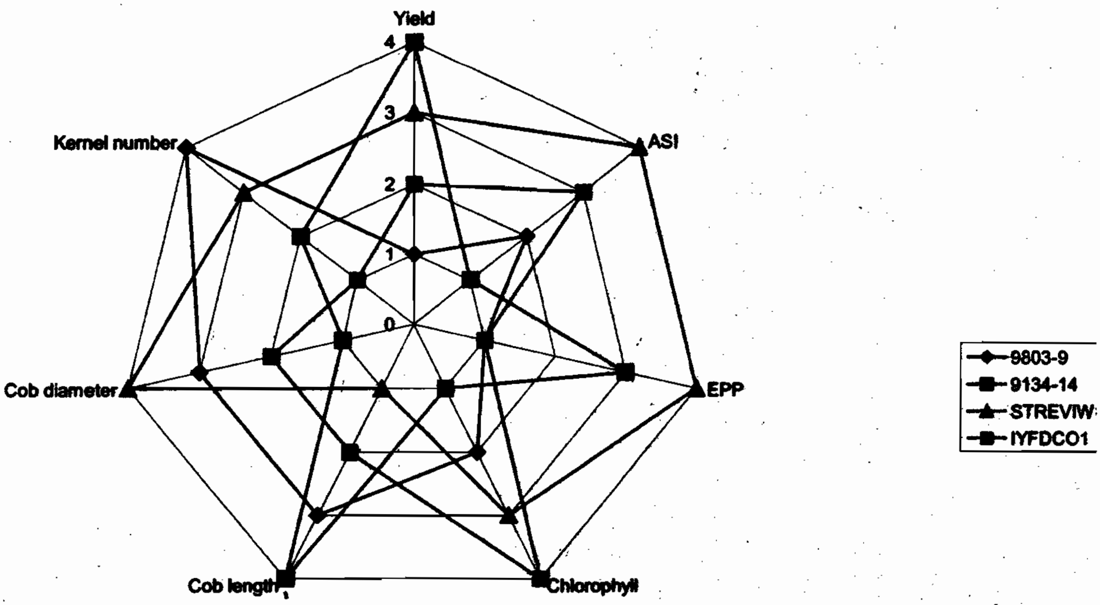

Figure 2. Spider chart showing ranked performance of genotypes under weed and drought stress.

DISCUSSION

Imposed water stress significantly affected maize growth. Generally, water deficit led to a significant reduction in all the maize physiological traits both under weed competition and weed free situations. Maize is particularly sensitive to water stress even at 1-2 weeks after flowering (Grant *et al* 1989), hence the low yield recorded. Drought induces a reduction in dry matter production, Turner *et al.*, (1986) reported that biomass production decreased with decreased water availability. The major cause of this reduction is the flux of assimilate to the developing parts below some threshold level necessary to sustain grain formation and maize growth. (Westgate and Bassetti, 1990; Schussler and Westgate, 1995).

Maize is characterized by a greater number of potential ears per plant and kernel per ear than what is usually observed at maturity (Fischer and Palmer 1983), and both yield components are particularly sensitive to environmental stress. Generally, considerable genetic variability exists for maize in the number of ears per plant and the number of kernels per ear under good environmental conditions (Laffitte and Edmeades, 1995). This variation is not observed in the genotypes evaluated under non-drought and drought stress treatments. The observed differences in both the hybrids and the open pollinated varieties in yield and yield components may be due to the inherent limitations to yield formation conditioned by the genetic potential of the source and sink of the specific genotype, (Fischer and Palmer, 1983). Yield reduction due to drought stress was less in the hybrid 9134-14 and OPV, SREVIWD. They also had high yields under well-watered conditions. Fredrick *et al.,* (1989), have reported that higher yielding hybrids had yields higher than lower yielding genotypes under optimal and suboptimal soil water availability. The low yield of hybrid 9803-9 (which was among the highest yielding genotypes under well watered condition) and the subsequent yield reduction of 39% (average of the two years) could be partly due to low biomass production, reduced ears per plant, reduced cob length and diameter, reduction in individual kernel weight and reduced translocation of the photosynthate to the grain. Although high maize yield under drought stress have been observed to be associated with a high number of fertile ears per plant (Bolanos *et al.,* 1993, Bolanos and Edmeades 1993), only the reduction in other yield determining traits significantly affected the grain yield of 9803-9 in this study. For other drought susceptible genotypes, the significant reduction in cob length, kernel weight contributed to the yield reduction under drought condition. According to Fredrick *et al.,* (1989), grain yield is normally more strongly correlated with kernel number per ear than with other yield components. This was confirmed only in the OPV in this present study. On the contrary, this study showed that hybrid 9803-9 with high kernel number per ear had the lowest grain yield while the highest yield observed in 9134-14 only had fewer kernels per ear. This confirms the significant ($p<0.05$) correlation that existed only between grain yield and kernel number ($r = 0.37$), cob length ($r = 0.46$) and kernel weight ($r = 0.43$). Reduction in 1000 kernel weight under drought stress condition compared with the well-watered treatments ranged from 18 to 31%. These reductions, though more in drought susceptible genotypes, were smaller than those of grain yield and number of kernels per ear. This is consistent with results of other studies, which indicate that stress drastically reduces kernel number more than weight of individual kernels (Grant *et al.*, 1989).

CONCLUSION

The result of this study shows that drought stress and weed interference reduced the grain yield and the yield components of maize genotypes in the study area. Hybrid 9803-9 was more susceptible to drought and weed stress as indicated by the grain yield. STREVIWD an open pollinated variety and Hybrid 9134-14 were superior in performances in terms of grain yield and shorter anthesis-silking interval. Irrespective of the genotype, maize (hybrid and OPV) was more tolerant of drought in a weed-free environment

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