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RESPONSE OF MAIZE (*Zea mays* L.) GENOTYPES GROWTH CHARACTERS UNDER DROUGHT AND HEAT STRESS CONDITIONS EVALUATED IN SUDAN SAVANNA, NIGERIA

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ABSTRACT

Drought stress and heat stress are two major limiting factors affecting maize productivity in the tropical regions. High temperatures and changes in rainfall pattern can cause significant decline in maize yields under rain fed conditions with Africa being one of the worst affected areas. Heat tolerance can be accomplished through genetic management approach. The aim of the research is to assess the extent of variation in tolerance to drought stress and heat tolerant stress and their performance on growth and yield characters. The trials were conducted on genetic analysis of Maize (*Zea mays* L.) inbred lines under combined (drought and heat stress) conditions. The parental materials comprises eight inbred lines that were crossed in a partial diallel pattern; thereafter, the checks, parents and resultant F_1 generations were evaluated at two locations, Kano University of Science and Technology and farmers field at Dambatta local government area Kano state during 2021 dry seasons. The experiment was laid out in a randomized complete block design and replicated three times. The results indicated the crossing of P4 X P9 and P3 X P4 to produce significantly to produce significantly better growth attributes like plant height ear height, plant aspect and grain yield. These parental lines might be used in maize breeding programs in Nigeria as sources of drought and or heat tolerance.

Keywords: Drought, Growth, Heat and Maize

1. INTRODUCTION

Maize (*Zea mays* L.) is a major crop for both human consumption and animal feed in Nigeria. Drought stress (DS) and heat stress (HTS) are two major limiting factors affecting maize productivity in the tropical lowlands, where erratic rains and increased temperatures are becoming of frequent occurrence (Sultan *et al.*, 2016). It is likely that high temperatures will occur more often and will last longer and extreme precipitations events will become more intense and frequent in many regions (IPCC, 2016). High temperatures and changes in rainfall pattern can cause significant decline in maize yields under rainfed conditions in the tropical region with Africa being one of the worst affected areas (Cairns, *et al.*, 2013).

An increase in temperature over 30˚C reduces grain yield by 1% under optimal rain-fed condition and by 1.7% under DS (IPCC, 2007) and up to 40% under combined drought and heat stress (Lobel *et al.*, 2011). With the current changes in climatic conditions, it is projected that by 2030 drought and higher temperatures may render 40% of the current maize growing areas in Africa unsuitable for varieties available today (Neate *et al.*, 2018). Unless strong adaptation measures are taken, these changes are expected to reduce yields of maize and other food crops by 10% to 20%, causing marked decline in human welfare (Pye-Smith *et al.*, 2011). Adaptation to climate change may involve the use of crop varieties that are endowed with tolerance to higher temperatures and drought, and resistance to emerging pests and diseases (Bolanos *et al.*, 1993). Approaches that improve the performance of maize genotypes under combined drought and heat stress (DSHTS) are therefore essential to sustain productivity and to avoid widespread famine in Africa.

(i) Assess the extent of variation in tolerance to DSHTS from among the maize inbred lines
(ii) Examine the response patterns of the maize inbred line to DSHTS

2. METHODOLOGY

The parental materials comprises of eight inbred lines of drought and heat tolerant and drought and heat susceptible maize, they were crossed in a complete diallel pattern; the genotypes were be made in all possible combinations. Evaluation for the eighty one entries was done using (9x9) lattice design with three replications in each location. The experiment was conducted at Kano University of Science and Technology (KUST) research farm, latitude11.59^{1} N longitudes 8.76^{1} E in the Sudan savannah agro ecological zone of Nigeria. The other location is Farmers field at Dambatta, Kano state, latitudes 11.39^{1} N, longitude 8.27^{1} E, and Elevation 500 m. The hot and

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dry weather occur between February and June in both locations. The soil type is Regosols, with mainly sandy to clay loam texture, pH of 5.9 (Gabasawa *et al*, 2014). The temperature during the dry season ranges from 33 to 45 ˚C. Maize seeds was planted in mid-February at both locations and it flower in mid-April, the hottest period. Two maize seed were planted per hole and later be thinned to one at a spacing of 0.25x0.75m, while the seed bed size was 2.5 x 2.5m (6.25m^2) and a discard of 0.5m was provided to avoid water spillage. A gravity irrigation system was used to supply sufficient water through furrows to the crop every four days during the first 45 days after planting. Thereafter, irrigation was withdrawn in mid-April when mean day temperature were expected to be ranged from 36 to 45 ˚C and night temperature varied from 27 to 30 ˚C, inducing the combined effects of drought and heat stress that coincided with flowering stage. Irrigation was resumed after 21 days and it was applied only once a week to allow for grain filling of the crop until physiological maturity. Meteorological data were provided during the trial period using an automated weather station at Gaya and Danbatta in Kano State. Soil temperature and soil moisture content were determined accordingly for the two locations at regular intervals.

3. RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Plant height (m)

The result on plant height of maize inbred genotypes is presented in Table 1. There is significant differences on plant height among the genotypes with P3 X P6 and P5 X P7 producing the tallest plant, though they were statistically at par with majority of the genotypes except P3XP7 and all the parents plant where P2 had the shortest plant.

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Table 1: Performance of Maize Genotyped on Growth Characteristics under Drought and Heat Stress Conditions Evaluated in Sudan Savannah During 20121/2022 Dry Season.

GENOTYPES	PH (cm)	EH (cm)	EPP	PASPECT	EARESPECT	LDS	GRAIN YIELD (kg ha^{1})
P2xP4	17.09a-h	11.59abc	2.99	1.41cd	1.74abc	1.580bc	5.465a-f
TZEI 16	17.22a-g	11.58abc	2.99	1.41cd	1.59abc	1.896abc	5.017a-g
P1xP5	16.72a-i	11.40bcd	2.80	1.59a-d	1.59abc	2.064ab	5.166a-g
P1xP9	17.27a-d	11.00cde	2.95	1.41cd	1.59abc	1.896abc	4.345gh
P3xP9	17.17a-h	11.71abc	1.45	1.31d	1.59abc	2.073ab	5.073a-g
P7xP8	16.59a-i	11.02cde	2.81	1.41cd	1.59abc	2.64a-e	5.343a-f
P5xP8	17.46a	12.36ab	2.92	1.31d	1.41c	2.66a-d	5.745a-d
P1xP6	17.19a-h	11.46bc	1.44	1.31d	1.60abc	2.51a-h	5.357a-f
P4xP9	16.69a-i	10.99cde	3.05	1.74abc	1.41c	2.86a	5.917a
P5xP9	17.35ab	12.67a	3.02	1.31d	1.50bc	2.37c-h	5.193a-g
P3xP8	17.08a-h	11.40bcd	1.40	1.41cd	1.87ab	2.54a-g	5.162a-g
TZEI 25	17.09a-h	10.98cde	2.93	1.31d	1.98a	2.64a-e	5.582a-e
P1xP3	16.49a-j	11.30b-e	2.59	1.41cd	1.59abc	2.47a-h	4.857c-g
P1xP2	16.88a-h	11.70abc	1.51	1.41cd	1.50bc	2.56a-f	4.913b-g
P3xP4	16.94a-h	11.68abc	1.47	1.48bcd	1.58abc	2.78abc	5.953a
TZEI 13	17.04a-h	11.44bcd	2.87	1.32d	1.42c	2.49a-h	5.501a-e
P4xP5	16.80a-i	11.31b-e	1.49	1.54bcd	1.59abc	2.63a-e	5.383a-f
P6xP8	16.16e-j	11.33b-e	2.71	1.31d	1.50bc	2.54a-g	5.168a-g
P2xP9	17.07a-h	11.58abc	1.52	1.31d	1.41c	2.46a-h	4.898b-g
P1xP8	16.84a-i	11.56abc	2.77	1.50bcd	1.50bc	2.14gh	4.473fgh
P4xP8	1730a-d	11.74abc	2.76	1.31d	1.57abc	2.35d-h	4.792d-g
P3xP6	16.94a-h	11.72abc	1.47	1.59a-d	1.59abc	2.55a-g	5.186a-g
TZEI 125	16.87a-h	11.19b-e	2.96	1.41cd	1.50bc	2.49a-h	5.177a-g
P1xP4	16.46a-j	10.94cde	2.59	1.50bcd	1.50bc	2.36d-h	4.905b-g
P6xP9	17.11a-h	11.20b-e	2.58	1.75abc	1.68abc	2.40b-h	4959a-g
P5xP6	16.71a-i	11.36b-e	2.84	1.31d	1.50bc	2.59a-e	5.136a-g
P6xP7	17.31a-d	11.75abc	2.89	1.57a-d	1.60bc	2.17fgh	4.708efg
P4xP6	16.83a-i	11.20b-e	2.96	1.41cd	1.66abc	2.67a-d	5.460a-f
P4xP7	16.76a-i	11.31b-e	2.04	1.50bcd	1.50bc	2.75abc	5.889ab
P3	16.19d-j	10.92cde	2.55	1.50bcd	1.69abc	2.40b-h	3.528hi
P5xP7	17.47a	11.92abc	3.26	1.41cd	1.50bc	2.49a-h	4.860c-g
P7xP9	17.42ab	11.61abc	3.01	1.41cd	1.67abc	2.44b-h	4.741efg
P8xP9	17.11a-h	11.74abc	2.97	1.84ab	1.59abc	2.37d-h	4.871c-g
P2xP5	16.43a-j	10.85cde	2.83	1.41cd	1.86ab	2.42b-h	4.912b-g
P2xP6	16.65a-i	11.30b-e	2.67	1.74abc	1.50bc	2.64a-e	5094a-g
P3xP7	16.14f-j	11.29b-e	1.43	1.41cd	1.50bc	2.63a-e	5.520a-e
P2xP3	1674a-i	11.07cde	2.87	1.31d	1.59abc	2.60a-e	5.602a-e
P3xP5	16.54a-i	11.00cde	1.52	1.22d	1.39c	2.69a-d	5.800abc
P1	15.720ij	10.28de	2.85	1.31d	1.50bc	2.45a-h	3.631hi
P8	16.235c-i	11.15cde	3.02	1.95a	1.59abc	2.79ab	3.537hi
P2xP7	1682a-i	11.44bcd	2.85	1.31d	1.41c	2.72a-d	5.660a-e
P1xP7	16.88a-h	11.47bc	1.48	1.31d	1.57abc	2.73a-d	5.596a-e
P2xP8	16.65a-i	11.57abc	1.46	1.49bcd	1.41c	2.58a-e	5.408a-f
P9	16.71a-i	10.92cde	2.74	1.31d	1.69abc	2.38b-h	3.241i
P2	15.377j	10.21e	1.49	1.84ab	1.69abc	2.46a-h	3.552hi
P7	16.07hij	10.74cde	1.52	1.31d	1.59abc	2.24e-h	3.190i
P6	16.24c-j	10.98cde	1.42	1.41cd	1.50bc	2.51a-h	3.613hi
P4	16.13g-i	10.90cde	2.65	1.41cd	1.50bc	2.37e-h	3.619hi
P5	16.30d-j	11.24b-e	2.98	1.32d	1.59abc	2.46a-h	3.678hi
SE±	1.412	1.469	2.355	0.478	0.523	0.512	1.242

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3.1.2 Ear height (cm)

Result on ear height of maize genotypes is presented in Table 1. There was significant difference on ear height among the genotypes where P5 X P9 produced the tallest plant and it was followed by P5 X P8, though they were statistically at par with some few others and P2 had the shortest ear height.

3.1.3 Plant aspect

Result on plant aspect of maize genotypes is presented in Table 1. There is a significant differences on Plant aspect among the genotypes where P8 producing the highest score P8 X P9 and it was followed by P5 X P8 and P8 though they were statistically at par with considerable number of the genotypes. The least plant aspect score was recorded by P3 XP5.

3.1.4 Ear aspect

Result on ear aspect score of maize genotypes is presented in Table 1. There is a significant difference on ear aspect among the genotypes where TZIE I25 produced the highest score and it was followed by P2 X P5 and P3 X P8 though they were statistically at par with considerable number of the genotypes. The least plant aspect score was recorded by P3 XP5.

3.1.5 Leaf death score

Result on Leaf death score of maize genotypes is presented in Table 1. There is significant differences on Leaf death score among the genotypes with P3 X P6, P2 and P7 recording the highest number of leaf death score. The result however, had shown statistical similarity with most of the genotypes except P2 X P4, P4 X P9, P4 X P5, P6 X P7, P4 X P6 and TZEI 13 which recorded the least score among them.

3.1.6 Gain yield (kg ha^{1})

Result on one grain yield of maize inbred genotypes is presented in Table 1. There is significant differences on the grain yield among the genotypes with P3 X P4 and P4 X P9 producing the highest grain yield and they were followed by P4 X P7, the result had indicated the parent plant to produced statistically lower grain yield while P7 and P9 recorded the lowest figure.

3.2 DISCUSSION

The extent of vegetative growth is dependent on the severity of drought and heat stress and the maize genotypes under study. In this study, combined drought and heat stress reduced some growth characters to a greater extent and this is in conformity with previous findings that demonstrated more stunted growth from combined effects of drought and heat stress than drought stress alone (Lobell *et al*., 2011). However the parental line (P5) cross with other lines like P5 X P9, P5 X P7 prove to have better performance on growth and other components and can therefore be utilizes in producing genotypes that may adopt under combined drought and heat stress for better growth and its components.

The wide variation in grain yield decrease and some growth components under drought stress could be attributed to varying levels of drought tolerance in the experimental inbred lines, the crop growth stage at which drought stress occurred, and the severity and duration of the drought stress (Cairns and Prasanna, 2018). The genotypes identified in the present study may carry some adaptive traits for drought tolerance and some or all of their parental lines might be used in maize breeding programs in Nigeria as sources of drought an or heat tolerance.

Combined drought and heat stress adversely affected grain yield and days to flowering of most hybrids more than drought, possibly due to its adverse effects on pollen production, or ovule fertility, leading to premature embryo abortion and reduced grain weight (Saini and Westgate, 1999). Air temperature above 35 °C suppresses maize ovary fertilization and the grain filling process, which is directly associated with the final grain yield. Heat stress decreases the time for tasselling and pollen shedding and enhances the anthesis-silking interval to reduce the viability and amount of pollens (Zandalinas, 2018). Our results corroborate earlier findings of Edmeades, *et al*. (1999) that, the effect of DSHTS was higher in maize at the reproductive stage than at the vegetative stage. Previous studies on maize by Trachsel, *et al*. (2016) showed that, tolerance to DSHTS is genetically distinct from tolerance to individual drought and heat stresses. However, results from this study indicated strong relationship between the two, that breeding for DS, to some extent, has spill-over effect under DSHTS, with many of the best DT lines selected under DS showing appreciable grain yields under DSHTS.

4. CONCLUSIONS

In conclusion, our study revealed that the combined effects of drought and heat stress has adverse effect on most of the lines tested for growth and yield, while only few of them prove to perform better and this can be the basis of selecting them for further improvement. Large variations were observed in grain yield and other agronomic traits among the inbred lines under DSHTS condition. There is the possibility of the existence of common genetic factors controlling these traits and may be used to enhance productivity under the two stresses.

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