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Genotypic and Differential Responses of Growth and Yield of some Maize (*Zea mays* L.) Genotypes to Drought Stress

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Abstract

Fiften genotypes of maize (*Zea mays* L.) were evaluated at two locations in Sudan (Khartoum and Wad Medani) during the season 2003/04, to estimate the genetic variability and performance for yield and some vegetative characters under drought at vegetative and reproductive growth stages. Three water treatments were applied, namely; well-watering, drought during vegetative stage only, and drought during reproductive stage only. Phenotypic and genotypic variances, genotypic coefficient of variation, heritability, genetic advance and phenotypic correlation between yield and some vegetative traits were estimated. Significant differences among genotypes were found for most of the traits studied, except days to 95% anthesis, stem diameter (45 days), leaf area index (30 and 60 days), and number of leaves/plant (45 days). The genotypes showed differential yield response to drought stress. High yield (kg/ha) was exhibited by genotype PR-2 when drought stress was during vegetative stage, and by genotype Z-2 when it was during reproductive stage. However, the genotype M-45 exhibited considerable high yield when it exposed to drought at both vegetative and reproductive stage. The effect of drought on genotypes was significant for days to 25% silking, plant height and grain yield (kg/ha) at Wad Medani. High genotypic coefficient of variation, heritability and genetic advance were exhibited by plant height. Grain yield (kg/ha) was significantly and positively correlated with plant height, stem diameter (45 days), leaf area index and number of leaves/plant (60 days), however, significant and negative association with days to 50% and 95% silking was observed. It could be concluded that, genotypes have differential yield response to drought and accordingly the genotype M-45 could be used for further improvement of drought tolerance in maize. Based on their positive association with yield, the characters plant height, stem diameter and number of leaves/plant would be the best selection criteria for maize improvement.

Introduction

Maize is the third most important food crop worldwide (Frova *et al*, 1999). It is used in many ways than any other cereal. Therefore it is considered as a multi-purpose crop and has been put to a wider range of uses such human food, animal and poultry feed and for hundreds of industrial purposes. Maize grows over a wider geographical and environmental range than any other cereals. It is grown at latitudes varying from the equator to slightly north and south of latitude 50 ^{0}, from sea level to over 3000 meters elevation, under heavy rainfall and semi-arid conditions, cool and very hot climates. In Sudan, maize is normally grown as a rain fed crop in Kordfan, Darfur and Southern States or in small-irrigated areas in Northern States (Ahmed and Elhag, 1999). Recently, there has been an increased interest in maize production in the Sudan (Nour *et al*, 1997). Maize is more sensitive to drought. It is exposed to more hazards and it is a higher risk crop in general (Misovic, 1985). Drought is an important climatic phenomenon, which after soil infertility, ranks as the second most severe limitation to maize production (Sallah *et al*., 2002). The effect of water stress on crop growth and yield depends upon the degree, duration of stress and the developmental stage at which the stress occurs (Chapman *et al.*, 1997). Ribaut et al., (1997) reported that maize is susceptible to drought at flowering stage than any other crop. Baenziger *et al*., (2000) reported that drought leads to reduced leaf, silk, stem, root and grain development. Mangombe *et al*., (1996) found that varieties of maize exposed to unpredictable drought stress during the growing season produced low grain yield. Improvement of productivity of maize cultivars under drought conditions becomes one of the objectives of breeding programmes in maize. During the last 50 years, considerable effort has been devoted to improving yield performance through breeding and understanding the mechanisms involved in drought tolerance (Ribaut *et al.*, 1997). The main objectives of this study are: 1) to estimate the effect of drought stress on yield and vegetative traits of maize genotypes. 2) to determine the genetic variability and stability of maize genotypes under different drought stresses. 3) to estimate the association between yield and vegetative characters under normal and stress conditions.

Materials and methods

Two field experiments were used to achieve the objectives of this study. The experiments were conducted during the year 2003/04 at two locations in Sudan. The first one was the Demonstration Farm of the Faculty of Agriculture, University of Khartoum, at Shambat (Latitude: 15^0 40" N., Longitude: 32^0 32" E., and 380 meters above sea level). The second was Gezira Research Station Farm, at Medani (Latitude: 14^0 24" N., Longitude: 33^0 29" E., and 407 meters above sea level). Fifteen genotypes of maize were used for this study. These consisted of six open-pollinated varieties and six land races from CIMMYT, and two varieties one from Egypt and the other was local variety. Drought stress was induced by applying the following watering regimes: 1) control, which was watering every 14 days throughout the growing season (D1). 2) Water stress during vegetative stage, which achieved by watering every 21 days till the end of vegetative growth, then followed by well watering every 14 days till harvest (D2). 3) Water stress during reproductive stage, which achieved by watering every 14 days till the end of flowering, and then watering every 21 days till harvest (D3). The design used was split plot design with three replications. The water regimes were assigned randomly as main plots, and the genotypes were grown randomly as subplots, each genotype was sown on two ridges, each of 3 meters length. All the cultural practices were done according to the recommendations. Ten randomly selected plants from each subplot at the two locations were taken for data assessment. Different plant characters were measured, which included grain yield (Kg/ha) at harvest. The traits plant height, stem diameter, leaf area index, and number of leaves/plant were measured three times during the growth of the crop (30, 45, 60 days). Anthesis and silking were recorded in days from sowing when there was 25%, 50% and 95% anthesis and silking. Drought tolerance was measured as the ratio of yield under stress (YD2 & YD3) to grain yield under non-stress (YD1) conditions. Analysis of variance was carried out for each character according to Gomez and Gomez (1984) for split plot design. Based on the analysis of variance, phenotypic and genotypic variances, genotypic coefficient of variation, heritability, genetic advance and phenotypic correlation between yield and some vegetative traits were estimated.

Results

The combined analysis revealed that grain yield (kg/ha) was reduced due to the effect of drought, however, the reduction was non-significant. The reduction was more pronounced when the drought occurred at the reproductive stage, D3 (Table 1). Most of the vegetative traits were not affected significantly by drought, e. g., number of leaves/plant was not affected by the drought (Table 1). The highest phenotypic coefficient of variation was exhibited for grain yield (kg/ha) and the lowest was for 95% anthesis., and the highest value of heritability was estimated for plant height and the lowest value was for 95% anthesis (Table 1).

Table 1: Means of yield (kg/ha) and some vegetative traits for 15 genotypes of maize (*Zea mays* L.) under three levels (D1, D2 and D3) of drought, and estimates of phenotypic coefficient of variation (PCV) and heritability (h^2), averaged over two locations (Shambat and Medani) of Sudan, during the season 2003/04

Traits	Drought treatments			mean	LSD (5%)	PCV (%)	h^2 (%)
	D1	D2	D3				
Grain yield (kg/ha)	4310	3374	3060	3581	1390	26.1	40
95% Anthesis (day)	54	53	53	53	3	4.4	26
95% Silking (day)	57	57	56	57	3	5.3	29
Plant height (cm)$^{\Psi}$	180	174	184	180	22	8.9	56
Stem diameter (mm) $^{\Psi}$	20	19	19	19	1	9.4	36
Leaf area index$^{\Psi}$	2.83	2.68	2.99	2.83	0.46	16.1	27
No. of leaves/plant$^{\Psi}$	11	11	11	11	1	9.7	41

$^{\Psi}$ the values given for these traits were measured at 60 days from sowing.

The performance of genotypes was variable according to the incidence of drought (Figure 1). The highest (4915 kg/ha) grain yield under non-stress (D1) conditions was obtained by genotype PR-1, while the lowest (3784 kg/ha) was produced by genotype G-3. When drought was induced during vegetative stage (D2), the highest (4166 kg/ha) grain yield was recorded for genotype M-45 and the lowest (2706 kg/ha) for the genotype PR-1 (Figure 1). When drought occurred during reproductive stage (D3), the highest (3556 kg/ha) grain yield was achieved by genotype Z-2, and the lowest (2737 kg/ha) by the genotype D-3.

The genotypes responded differentially to drought stress for grain yield (kg/ha) as well as for the other vegetative traits. The highest value of drought tolerance (YD2/YD1=0.99) was exhibited by genotype PR-2 when drought occurred at the vegetative stage (D2), while the most sensitive (YD2/YD1=0.55) genotype to drought at this stage was PR-1 (Figure 2). When drought occurred at the reproductive stage (D3), the most tolerant (YD3/YD1=0.87) genotype was G-3, and the most sensitive (YD3/YD1=0.56) one was PR-1.

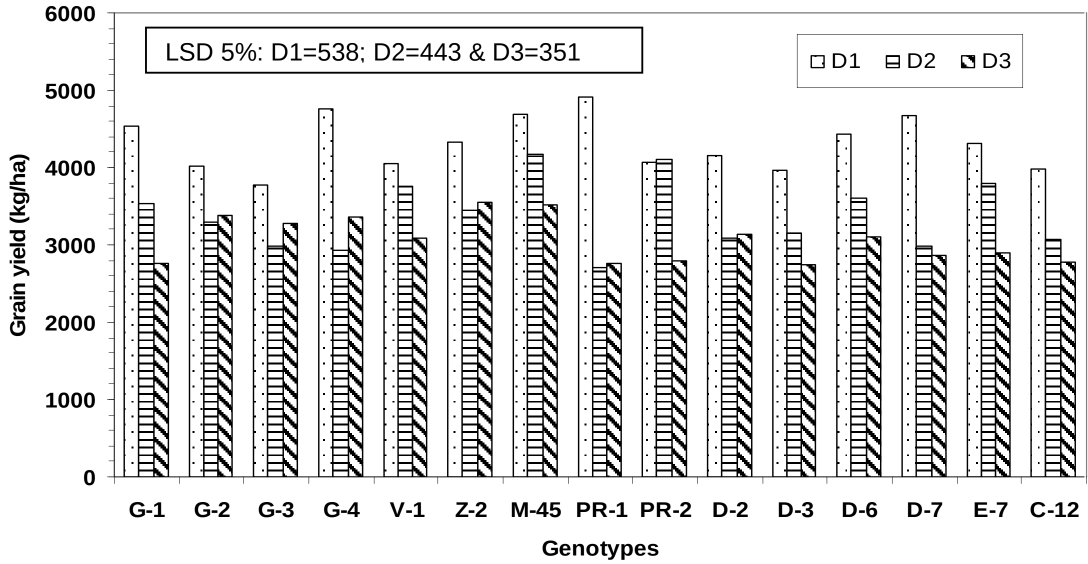

Figure 1: The performance of 15 genotypes of maize under three levels (D1, D2 & D3) of drought, averaged over two locations (Shambat and Medani) of Sudan, during the season 2003/04.

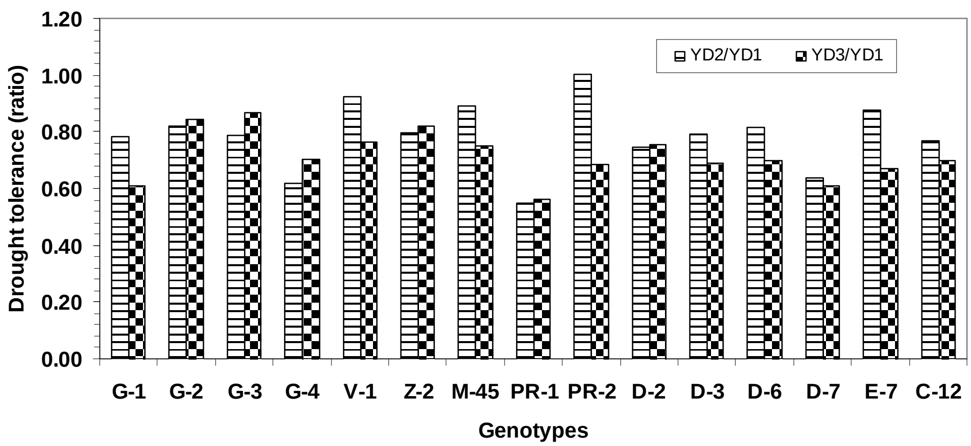

Figure 2: Drought tolerance of 15 genotypes of maize when drought occurred during vegetative (YD2/YD1) and reproductive (YD3/YD1) stages, averaged over two locations (Shambat and Medani) of Sudan, during the season 2003/04.

The grain yield (kg/ha) showed positive and significant association with leaf area index and number of leaves/plant, but positive and non-significant correlation for grain yield with plant height and stem diameter was observed (Table 2). However, negative significant association between grain yield (kg/ha) and days to 95% silking was exhibited. There was positive and significant correlation between stem diameter and plant height, and between leaf area index and number of leaves/plant. Negative but non-significant association for days to 95% silking with leaf area index and number of leaves/plant was observed (Table 2).

Table 2: The phenotypic correlation coefficients between grain yield (GY) and vegetative traits: 95% Anthesis (Anths); 95% Silking (Silk); Plant height (Plht); Stem diameter (Stdm); Leaf area index (Laindx); and No. of leaves/plant (Nlf/pl), for 15 genotypes of maize evaluated in Sudan, during season 2003/04

Traits	GY	Anths	Silk	Plht	Stdm	Laindx
Anths	-0.27					
Silk	-0.55 *	0.67 **				
Plht	0.24	0.19	0.10			
Stdm	0.23	0.30	0.34	0.57 *		
Laindx	0.59 *	-0.11	-0.44	0.23	0.37	
Nlf/pl	0.58 *	-0.30	-0.43	-0.15	0.33	0.61 *

* &** = significant at the probability of 5% and 1% level of significance, respectively.

Discussion

The effect of drought stress resulted in reduction in grain yield and other vegetative traits. However, the effect was non–significant in most of the traits. This result could be attributed to the great variation between locations, where the vegetative stage was shorter in Shambat (50 and 53 for anthesis and silking, respectively) and longer (57 and 61 for anthesis and silking, respectively) in Medani. Also the high relative humidity and low temperature at Medani alleviated drought severity, particularly during the period of flowering. These conclusions are in agreement with that of Mangombe *et al.,* (1996). The reductions in the values of vegetative traits due to effect of drought were also reported by other researchers (Dowswell *et al*., 1996: Baenziger *et al*., 2000). The number of leaves/plant was not affected by drought, which indicates that this character is highly influenced and controlled by genetic factors rather than the environmental factors. In this study, it appears that the grain yield was severely reduced when drought occurred during the reproductive stage. This may be attributed to the fact that there was accelerating leaf senescence at this stage, which resulted in shortening of the seed filling period (De Souza *et al.,* 1997). The high heritability and high coefficient of variation exhibited by plant height indicates that this character is highly genetically controlled and less affected by environment. This finding is in agreement with results of Baenziger *et al.,* (2000).

In this study the genotypes showed a differential grain yield response depending on the incidence of drought, e. g., genotypes M-45 and PR-2 were highly tolerant when drought happened at vegetative stage, and genotypes Z-2 and M-45 when drought occurred at reproductive stage. This differential response could be explained as reported by Veldboom and Lee (1996) to the fact that different sets of alleles and possibly different loci are being expressed under different environmental conditions. This result suggests the possibility of development of promising genotypes when drought occurs early at the vegetative stage or late during reproductive stage. The response of genotypes to drought intensity and time differs according to their genetic structure and adaptability. Wenzel (1999) reported that some genotypes yielded more under moisture stress than under near-ideal moisture conditions.

The positive and significant correlation of grain yield (kg/ha) with leaf area index, number of leaves/plant and plant height was also reported by Nyuetta and Cross (1997). Therefore, selection for these traits will simultaneously improve potential grain yield and accumulate the desirable genes. However, the significant negative association of grain yield with flowering is indicative that delay in flowering is correlated with lowest grain yield. Similar conclusion was reported by Ribaut *et al.,* (1997). Therefore, it could be concluded that there is a differential response of maize genotypes to drought stress which varies with stage at which drought occurs. The genotypes that showed wide range of adaptation and tolerance to drought, such as M-45, could be used for improvement of drought tolerance in maize. Based on their positive association with grain yield, the characters plant height and number of leaves would be the best selection criteria for maize improvement.

References

Ahmed, F. E., and Elhag, H.A. 1999. Effect of watering intervals on yield and yield components of two maize (*Zea mays* L.) cultivars grown in summer and winter. *U. of K. J. Agric Sci.* 7(1): 20-32.

Baenziger, M.; Edmeades, G.O.,; Beck, D., and Bellon, M. 2000. Breeding for drought and nitrogen stress tolerance in maize: From theory to practice. Mexico, D. F: CIMMYT.

Chapman, S.; Crossa, J.; Basford, K.E.; and Kroonenberg, P.M. 1997. Genotype by environment effects and selection for drought tolerance in tropical maize. II. Three mode pattern analysis. *Euphytica*, 95: 11-20.

De Souza, O.I.; Egli, D.B., and Bruenung, W.P. 1997. Water stress during seed filling and leaf senescence in soybean. *Agronomy J. Vol*., 89(5): 807-812.

Dowswell, C.R.; Paliwal, R.L.; and Cantrell, R.P. 1996. Maize in the third world. Westview Press Divsison of Harper Collins Publishers.

Frova, C.; Krajewski, P.; Fronzo, N.D.; Villa, M., and Sari-Gorla. 1999. Genetic analysis for drought tolerance in maize by molecular markers. I. Yield components. *Theo. Appl. Genet.,* 99: 280-288.

Gomez, K.A., and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. 2nd . John Willey and Sons (ed). New York, USA.

Mangombe, N.; Gono, I.T.; and Mushonga, J.N. 1996. Response of sorghum genotypes to drought in Zimbabwe. Page: 99-104, in Drought-tolerance crops for Southern Africa: Proceedings of SADC/ICRISAT Regional Sorghum and Pearl millet workshop, 25-29 Jul. 1994, Gaborone, Botswana (Leuschner, K. and Manthe, C.S; eds.).

Misovic, M.S. 1985. Maize breeding methodologies for environmental stress, pp: 207-227. In: Brandolini, A., and Salamni, F. (1985), Breeding strategies for maize production improvement in the tropics, Florence and Bergam, ITALY:

Nour, A.M.; Nur Eldin, I.; and Dafalla, M. 1997. Crop development and improvement. Annual report of maize research program. Medani- Sudan

Nyuetta, A.S.P.; and Cross, H.Z. 1997. Correlated response in ear and plant traits in maize synthetic selected for R-nj colour expression. *Crop Sci*. 37: 739-744.

Ribaut, J.M.; Jiang, C.; and Gonzalez-de-leon, D.; Edmeades, G.O.; and Hoisington, D.A. 1997. Identification of quantitative trait loci under drought conditions in tropical maize. 2. Yield components and marker-assisted selection strategies. *Theo. Appl. Genet.* 92(7): 905-914.

Sallah, P.Y.K.; Obeng-Antwi, K., and Ewool, M.B. 2002. Potential of elite maize composites for drought tolerance in stress and non-drought stress environments. *African Crop Science Journal*, *vol.* 10 (1): 1-9.

Veldboom, L.R.; and Lee, M. 1996. Genetic mapping of quantitative trait loci in maize in stress and non-stress environments. 1. Grain yield and yield components. *Crop Sci*. 36: 1310-1319.

Wenzel, W.G. 1999. Effect of moisture stress on sorghum yield and its components. South of African Journal of Plant and Soil, 16 (3): 153-157.