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Genetic Variation of Flowering Trait in Maize (Zea mays L.) under Drought Stress at Vegetative and Reproductive Stages

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Abstract
A study was conducted under water stress in vegetative and reproductive growth stages at two locations (Shambat and Medani) in Sudan during the season (2003/2004). Genotypic and phenotypic variability, genetic advance and heritability in a broad sense were estimated in a split-plot layout within randomized complete block design with three replications. Fifteen genotypes of maize were used for the study. Phenotypic correlation coefficient between grain yield and 25%, 50% and 95% of flowering trait anthesis and silking were evaluated. All flowering stages were found significant differences among the genotypes, except days to 95% anthesis. Significant differences among water treatments were observed for days to 25% silking at Medani. High heritability, genotypic coefficient of variation and genetic advance were exhibited by days to 25% silking. Grain yield was significantly and negatively associated with days to (50% and 95%) silking. Based on the results drought stress at vegetative and reproductive stages of maize results in a drastic reduction in grain yield, and flowering character would be the important selection, creation for maize improvement under drought stress.
Keywords: Maize (Zea mays L.), Genetic variability, heritability, correlation, flowering, drought.

INTRODUCTION

Maize is susceptible to drought at flowering stage than any other cereal crops (Mangombe et al., 1996, Ribaut et al., 1997). It is particularly sensitive to drought stress in the pre-flowering and post-flowering stages (Gowda et al., 2009). The effect of water stress on crop growth and yield depends upon the duration, degree of stress and the developmental stage at which the stress occurs (Sullivan and Eastin, 1974; Chapman et al., 1997). The risk of drought is highest at both the start and end of the growing stages. Grant et al., (1989) found that the extreme sensitivity seems confined to the period 2 to 22 days after silking with a peak at 7 days and almost complete barrenness can occur if maize is stressed during the period from just before tassel emergence to the beginning of grain filling. Schussler and Westgate (1995) revealed that pollen and fragile stigmatic tissue are exposed to dry and otherwise hostile atmosphere for pollination to occur. Pollination may be successful in water stressed crops, only to be followed by abortion of the grains a few days later (Dowswell et al., 1996; Gowda et al., 2009). Westgate and Boyer (1986) reported that moisture stress during flowering lengthens the interval between anthesis and silking and decreases the number of silks that are viable for pollen germination to fertilize the embryo. While, drought or shading immediately after flowering has their primary effect on the number of aborting kernels (Schussler and Westgate, 1991). Bănziger et al., (2000) reported that drought leads to reduced silk and grain development. Rõtter (1993), found that localized yield losses can reach 100% where rainfall was below 500 mm in sandy soil when the stress coincided with flowering.Dowswell et al., (1996) reported that research to determine the stage of growth that is sensitive to water stress revealed that maize is most susceptible to moisture stress during tasseling. Ribaut et al. (1996) found that selection for reduced anthesis silking interval in tropical open-pollinated varieties has been shown to be correlated with improved yield under drought stress. Bolaños and Edmeades (1996); Zaidi et al. (2004) revealed that when photosynthesis per plant at flowering is reduced by drought stress, silk growth is delayed and leading to an easily measured increase in the anthesis silking interval. The tolerance of maize grain yield to drought stress is largely determined by events that occur at or shortly after flowering (Lafitte and Edmeades, 1995). Sari-Gorla et al., (1999), Sallah et al., (2002) concluded that breeding for drought tolerance during flowering and /or post-flowering has the best chance of affecting maize production, provided those types of drought stress are relevant in the target environment. Heisey and Edmeades (1999) reported that exhaustive attention has been focused on the flowering and grain filling stages of crop development.

The genetic variances were larger under stress conditions (Ceccarelli et al., 1992; Hohls, 2001). Ribaut et al., (1996) demonstrated that the genetic variance of anthesis silking interval (ASI) increased as a function of the stress intensity. Ribaut et al., (1996) found that the broad-sense heritabilities of male flowering, female flowering and anthesis silking interval (ASI) in maize were high under stress conditions, being 82% and 78%, respectively. Sari-Gorla et al., (1999) estimated the genetic correlation between grain yield and anthesis silking interval (ASI) and found that under well-watered conditions the correlation was weak, but increased under severe stress. However, the silk delay is correlated with low grain yield (Ribaut et al., 1997). Sallah et al., (2002) found that effects due to environment (E), genotype (G) and GxE interaction were highly significant ($p<0.01$) for days to 50% silking emergence. The study objectives were to estimate the genetic variability for flowering trait under drought during different growth stages, to determine the correlations between yield and flowering trait under normal and stress conditions.

MATERIALS AND METHODS

Study site and experimental design:

The experiments were conducted during the 2003/04 season at two locations the Demonstration Farm of the Faculty of Agriculture, University of Khartoum, at Shambat (latitude 15°40``N., longitude 32°32``E. and 380m above sea level). The soil of Shambat is fine montmorillonitic clay (56%) characterized by low permeability, low nitrogen content (0.08%) and high pH (7-8). The second location Gezira Research Station Farm, at Wad Medani (latitude 14°24``N., longitude 33°29``E. and 407m above sea level). The soil is characterized by heavy cracking clay (58%), pH of 8.3, low organic matter (0.6%) and nitrogen content (0.02%). Means of monthly temperatures (C°), relative humidity (%) and rainfall distribution (mm) for the two locations, Shambat and Medani, during the 2003/04 season (Table 1). Fifteen genotypes of maize were used for the study, obtained from the national program, Agricultural Research Corporation, Sudan. These genotypes were G-1, G-2, G-3, G-4, V-1, Z-2, M-45, PR-1, PR-2, D-2, D-3, D-6, D-7, E-7 and C-12. The experiment is designed a split-plot layout within randomized complete block design with three replications. The main plots were three levels of irrigation; normal, water stress during the vegetative stage and water stress during the reproductive stage, and subplots included 15 genotypes of maize. Control: watering every 14 days throughout the growing season. Water stress during vegetative stage: irrigation was every 21 days till the end of vegetative growth, and then followed by well watering every 14 days till harvest. Water stress during reproductive stage: irrigation was every 14 days till the end of flowering, and then irrigating every 21 days till harvest. All the cultural practices were applied according to the recommendations.

Table 1. Means of monthly temperatures (C°), relative humidity (%) and rainfall distribution (mm) for the two locations, Shambat and Medani, during the 2003/04 season.

Month	Temperature(Cº)		Relative humidity (%)			Rainfall (mm)	
	Shambat	Medani	Shambat	Medani		Shambat	Medani
June	33.95	NA	33	NA		6.0	
July	31.25	29.65	65	74.8		40.3	91.8
August	30.55	28.00	73	83.5		74.4	147.1
September	31.80	28.60	61	76.3		120.0	51.0
October	31.40	NA	39	NA		43.4	11.8
Mean	31.8	28.8	54.2	78.2	Total	284.1	301.7

NA = not available.

Data collection:

Data were recorded on days to following 25%, 50%, and 95% anthesis (days from sowing to a time when 25%, 50%, and 95% of the plants start to shed pollen, respectively), days of following 25%, 50% and 95% silking (days from sowing to a time when 25%, 50%, and 95% of the plants start to silks 2-3cm long, respectively), Grain yield (kg/ha) was estimated from the grain yield per subplot.

Statistical analysis:

Analysis of variance (ANOVA) was carried out for each character using the computer system PLABSTAT version (2N of 1997/09 /15). Based on the analysis of variance, phenotypic and genotypic variances, genetic advance, genotypic coefficient of variation, heritability, and phenotypic correlation between grain yield and flowering traits were estimated. Means for each location and two locations were used to compute simple linear correlation coefficients.

RESULTS

Phenotypic Variability

The genotypes showed highly significant differences ($P \leq 0.01$) at Medani and significant differences ($P \leq 0.05$) at Shambat for the 25% anthesis, while highly significant differences ($P \leq 0.01$) at Shambat and significant differences ($P \leq 0.05$) at Medani for the 25% and 95% silking were observed (Table 2). The genotypes showed highly significant differences ($P \leq 0.01$) at Shambat and non-significant at Medani for days to 50% flowering (Table 2).

Table 2. Mean squares from the analysis of variance due to Treatments (T), Genotypes (G) and their Interactions (G x T) for flowering character of 15 maize genotypes, evaluated over three water treatments at two locations (Shambat and Medani) during the 2003/04 season.

Characters		Shambat			Medani		
		T	G	G x T	T	G	G x T
		d. f = 2	d. f =14	d. f =28	d. f =2	d. f =14	d. f =28
Days to 25%	A	2.32^{ns}	9.10*	4.51^{ns}	10.70^{ns}	7.21**	5.00*
flowering	S	2.10^{ns}	10.01**	2.31^{ns}	29.60*	4.88*	3.12^{ns}
Days to 50%	A	1.61^{ns}	10.87**	3.93^{ns}	18.10^{ns}	4.55^{ns}	4.45^{ns}
flowering	S	1.45^{ns}	10.17**	4.25^{ns}	15.62^{ns}	4.04^{ns}	5.16^{ns}
Days to 95%	A	18.87^{ns}	6.22^{ns}	6.37^{ns}	16.01^{ns}	8.26^{ns}	7.95^{ns}
flowering	S	27.12^{ns}	8.19^{ns}	7.91^{ns}	9.49^{ns}	21.98*	25.13**

A and S = anthesis and silking flowering, respectively.

The combined analysis showed highly significant differences among the genotypes for the 25% anthesis, while non-significant due to genotypes x locations interaction. Significant variation due to genotype x locations interaction for the 25% silking was observed (Table 3). The highly significant differences among the genotypes and non-significant variation due to genotypes x locations interaction for the 50% anthesis, while non-significant among genotypes and variation due to genotypes x locations interaction for the 50% silking were observed (Table 3). Non-significant differences among the genotypes and variation due to genotypes x locations interaction for days to 95% flowering was found (Table 3).

Table 3. Mean squares from combined analysis due to Locations (L), Treatments (T), Genotypes (G) and their Interactions for flowering character in 15 maize genotypes evaluated over three water treatments at two locations (Shambat and Medani) during the 2003/04 season.

Characters		L	T	T x L	G	G x T	G x L
		d. f = 1	d. f = 2	d. f = 2	d. f = 14	d. f = 28	d. f = 14
Days to 25%	A	1677.51**	8.63^{ns}	4.38^{ns}	13.10**	5.46^{ns}	3.21^{ns}
flowering	S	1276.18**	23.11^{ns}	8.58^{ns}	9.42^{ns}	3.44^{ns}	5.46*
Days to 50%	A	2953.51**	9.10^{ns}	10.63^{ns}	12.23**	4.48^{ns}	3.10^{ns}
flowering	S	2094.46**	5.71^{ns}	11.36^{ns}	8.55^{ns}	5.50^{ns}	5.67^{ns}
Days to 95%	A	3513.61**	17.49^{ns}	17.38^{ns}	8.49^{ns}	7.86^{ns}	6.00^{ns}
flowering	S	4192.95**	16.51^{ns}	20.10^{ns}	17.19^{ns}	17.28^{ns}	13.00^{ns}

A and S = anthesis and silking flowering, respectively.

The overall means of the 25% anthesis were 43 days at Shambat, 48 days in Medani and 46 days for the average of both locations. Moreover, the 25% silking was 47days at Shambat, 51 days in Medani and 49 days for the average of both locations (Table 4). The overall means of the 50% anthesis were 46 days at Shambat, 52 days in Medani and 49 days for the average of both locations. On the other hand, the 50% silking were 49 days at Shambat, 55 days in Medani and 52 days for the average of both locations (Table 4). The overall means of the 95% anthesis were 49 days at Shambat, 57 days at Medani and 53 days for the average of both locations. Furthermore, the 95% silking were 50 days at Shambat, 61days at Medani and 57 days for the average of both locations (Table 4).

Table 4. Means of flowering for 15 genotypes of maize evaluated under three water treatments at Shambat, Medani and over two locations during the 2003/04 season.

Serial No.	Genotypes	Shambat						Medani						Combined					
		25%		50%		95%		25%		50%		95%		25%		50%		95%	
		A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S
1	G-1	44	47	47	50	50	54	47	50	52	54	57	62	45	49	49	52	53	58
2	G-2	43	46	46	49	50	52	49	52	53	55	58	60	46	49	49	52	54	56
3	G-3	42	47	45	49	50	53	47	51	52	55	57	60	45	49	48	52	53	57
4	G-4	43	47	45	49	49	52	48	51	52	55	57	61	45	49	49	52	53	57
5	V-113	43	46	45	48	50	53	46	50	53	54	56	60	45	48	49	51	53	57
6	Z-2	43	47	46	51	51	53	47	50	53	55	56	59	45	49	49	53	53	56
7	M-45	44	47	46	49	49	53	48	51	53	55	59	64	46	49	50	52	54	58
8	PR-1	42	45	45	49	49	52	47	51	52	55	57	60	45	48	48	52	53	56
9	PR-2	40	44	44	47	48	51	47	50	52	54	57	60	44	47	48	51	52	56
10	D-2	44	47	47	50	51	53	50	52	54	56	59	63	47	50	51	53	55	58
11	D-3	45	49	49	52	51	54	49	52	54	56	57	61	47	51	51	54	54	57
12	D-6	43	46	46	49	50	53	49	52	53	56	58	63	46	49	50	52	54	58
13	D-7	44	47	46	50	50	53	48	51	52	54	56	60	46	49	49	52	53	56
14	E-7	43	48	46	50	50	54	47	50	51	54	56	60	45	49	49	52	53	57
15	C-12	43	46	46	50	49	52	48	51	52	55	56	58	46	48	49	52	52	55
Mean		43	47	46	49	50	53	48	51	52	55	57	61	46	49	49	52	53	57
LSD 5%		2	2	2	2	2	3	2	1	2	2	2	3	1	2	1	2	2	3
CV %		4.2	3.8	4.6	3.8	4.6	5.3	3.6	2.9	3.4	3.4	4	5.3	4.2	3.4	4.0	3.6	4.3	5.3

A and S = anthesis and silking flowering, respectively.

Genotypic Variability

High genotypic variance relative to phenotypic variance, at Shambat was recorded for days to 25% silking, days to 50% silking and days to 50% anthesis. Whereas in Medani it was recorded for grain yield kg/ha (Table 5). In Medani, slightly high genotypes x treatments interaction variance relative to phenotypic variance was obtained for days to 25% silking, days to 50% anthesis and days to 95% silking. Whereas at Shambat it was recorded for days to 50% silking and grain yield kg/ha (Table 5).

Table 5. Phenotypic (σ^2ph), genotypic (σ^2 g), experimental (σ^2 e) and genotypes x treatments interactions (σ^2gt) variances for flowering character in 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) during the 2003/04 season.

Characters		σ^2 ph		σ^2 g		σ^2 e		σ^2 g t	
		Shambat	Medani	Shambat	Medani	Shambat	Medani	Shambat	Medani
Days to 25%	A	4.85	3.16	0.51	0.25	4.34	2.91	0.06	0.70
flowering	S	4.18	2.43	0.56	0.19	3.32	2.24	-0.34	0.29
Days to 50%	A	5.31	3.24	0.76	0.01	3.55	3.23	-0.21	0.41
flowering	S	4.22	3.26	0.66	-0.12	3.56	3.38	0.23	0.59
Days to 95%	A	5.26	5.35	-0.02	0.03	5.28	5.32	0.37	0.88
flowering	S	7.93	9.82	0.03	-0.35	7.90	10.17	0.003	4.99

A and S = anthesis and silking flowering, respectively.

High heritability, genotypic coefficient of variation and genetic advance were exhibited by days to 25% silking while, lowest values of phenotypic coefficient of variation were (3.1%) at Medani and (4.2%) at Shambat, recorded for days to 25% and 50% silking, respectively (Table 6). The lowest values of genotypic coefficient of variation (0.2%) at Medani was recorded for days to 50% anthesis and (0.3%) at Shambat was recorded for days to 95% silking (Table 6). The lowest values of heritability (4% and 16%) were found for days to (95% and 50%) silking at Shambat and Medani, respectively. The lowest values of expected genetic advance (0.1%) for days to 50% anthesis at Medani (Table 6).

Table 6. Estimates of phenotypic (PCV) and genotypic coefficient of variation (GCV), broad sense heritability (h^2), and expected genetic advance from selection (GA) for flowering character measured on 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani), during the 2003/04 season.

Characters		PCV (%)		(GCV (%)		h^2 (%)		GA (%)	
		Shambat	Medani	Shambat	Medani	Shambat	Medani	Shambat	Medani
Days to 25%	A	5.1	7.3	1.7	1.0	52	60	0.5	0.3
flowering	S	4.4	3.1	2.0	1.0	67	54	0.9	0.3
Days to 50%	A	5.0	3.4	1.9	0.2	58	29	0.7	0.1
flowering	S	4.2	3.8	1.7	#	65	16	0.7	#
Days to 95%	A	4.6	4.1	#	0.3	15	36	#	0.1
flowering	S	5.3	5.2	0.3	#	4	54	0.1	#

A and S = anthesis and silking flowering, respectively.
= the value was not calculated because their variance was negative.

Grain yield (kg/ha) was negatively correlated with days to (50% and 95%) silking (r = -0.594 and r = -0.546), respectively in Shambat (Table 7). Likewise, at Medan was negatively correlated with days to (25% and 50%) silking (r = -0.486 and -0.406), respectively (Table 7).

Table 7. Simple linear correlation coefficients between 7 pairs of traits in maize using locations Shambat (above the diagonal) and Medani (below the diagonal) averaged over three water treatments in season 2003/2004.

Traits	GY	DF25%A	DF25%S	DF50%A	DF50%S	DF95%A	DF95%S
GY	1	-0.242	-0.440	-0.307	-0.594*	-0.273	-0.546*
DF25%A	0.080	1	0.836**	0.925**	0.802**	0.810**	0.718**
DF25%S	0.489	-0.100	1	0.803**	0.892**	0.771**	0.902**
DF50%A	0.521*	0.660**	-0.406	1	0.792**	0.809**	0.675**
DF50%S	0.562*	0.703**	0.903**	-0.111	1	0.730**	0.743**
DF95%A	0.595*	0.685**	0.940**	0.928**	-0.486	1	0.671**
DF95%S	0.833**	0.707**	0.887**	0.820**	0.887**	-0.381	1

*, **, *** Significant at 0.05, 0.01 and 0.001 probability levels, respectively. GY: grain yield; DF25%A: Days to 25% anthesis; DF25%S: Days to25% silking; DF50%A: Days to 50% anthesis; DF50%S: Days to 50% silking; DF95%A: Days to 95% anthesis; DF95%S: Days to 95% silking.

DISCUSSION

Genotypes showed highly significant differences (P≤ 0.01) for days to 25% silking, days to 50% flowering (anthesis and silking) and significant differences (P≤ 0.05) was found for days to 25% anthesis, at Shambat. At Medani genotypes showed highly significant differences (P≤ 0.01) for days to 25% anthesis and significant differences (P≤ 0.05) for days to (25 and 95%) silking was found. The combined analysis of variance revealed significant differences among genotypes for days to (25 and 50%) anthesis and days to 25% silking. The length of the vegetative stage was short at Shambat, it was 50 days for anthesis and 53 days for silking. In contrast, it was longer at Medani, 57 days for anthesis and 61 days for silking. High relative humidity and low temperature at Medani alleviated drought severity, especially during the period of pre-flowering and post-flowering, and this may explain the significant difference between locations for most of the flowring trait. The effect of water stress on growth and yield depends upon the degree, the duration and upon the developmental stage at which the stress occurs (Sullivan and Eastin, 1974, Chapman et al., 1997). Days to flowering were affected by stress during vegetative stage at both locations, e.g. it reduced days to 25% silking at Medani. Bãnziger et al. (2000) reported that drought leads to a reduction in the number of silks. Dowswell et al., (1996) found that moisture stress during flowering lengthens the interval between anthesis and silking. Stress applied at the reproductive stage resulted in high reduction in grain yield.

The timing and intensity of stress determine the high reduction in grain yield. This may be due to accelerating leaf senescence and shortening the seed filling period (De Souza et al., 1997). This indicates that soil moisture stress at any stage of growth decreased grain yield substantially. Similar results were observed by Ahmed (2002). Drought stress affects maize grain yield to some degree at almost all growth stages (Grant et al., 1989). The effect of drought on days to flowering at Shambat was more pronounced than that in Medan. This may be due to differences in the monthly temperature and relative humidity during the growing season. Ahmed (2002) reported that heavy losses in yield may occur in maize growing under water-limited conditions and high temperatures. Significant negative correlation was observed between grain yield and days to flowering at both locations. Similar results were reported by Sari-Gorla et al., (1999) and De Souza et al., (1997). The silk delay is correlated with lowest grain yield (Ribaut et al., 1997).

CONCLUSIONS

The negative correlations of the characters days to anthesis and days to silking with grain yield indicate that generally the late maturing genotypes performed better than early maturing genotypes. Drought stress at vegetative and reproductive growth stages of maize results affect the period of pre-flowering and post-flowering consequently a drastic reduction in grain yield. Flowering character can be used as the important morphophysiology selection character for maize adaptation to drought stress.

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