Genetic variability, general performance and interrelationships of grain yield and its components of nine inbred lines of maize under Striga infested and non-infested soil

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ABSTRACT

Nine inbred lines of maize were evaluated at the Gezira Research Station (GRS), Agricultural Research Corporation (ARC), Wad Medani, Sudan, under Striga non-infested (normal conditions) and infested (stress conditions) soil for seasons 2008 and 2009. A randomized complete block design with three replicates was used. The objective was to estimate the general performance, genetic variability and interrelationships of grain yield and its components. Data were collected on days to 50% tasseling, plant height, ear height, ear length, 100 kernels weight and grain yield. The traits showed significant differences under normal conditions with the exception of ear height in 2008 and grain yield in 2009. Under stress conditions and in 2008, the traits showed no significant differences except for days to tasseling but in 2009, the traits showed significant differences in plant height, ear length and 100 kernel weight. Over seasons, the mean across conditions in grain yield ranged between 425-1181 kg/ha in 2008 and 575-1320 kg/ha in 2009. Line TZSTR148 showed the highest grain yield (1181 kg/ha) as well as early flowering and short plants in 2008, while Line TZSTR133 showed the highest grain yield (1320 kg/ha), early flowering and short plants in 2009. In both seasons under normal and stress conditions, grain yield was highly significantly and positively correlated with plant height, ear height and ear length. Lines TZSTR133 and TZSTR138 were early maturing, short and high yielders and hence were suggested as parents to develop high yielding hybrids after studying their combining ability under conditions of low rainfall environments.
However, lines TZSTR148 and 1368STR (tall, late maturing, high yielders) are suggested to develop hybrids for high rainfall zones.

INTRODUCTION

Maize ranks second among the world's cereal crops, after wheat in production. However, among the developing economies, maize ranks first in Latin America and Africa but third after rice and wheat in Asia. Maize is the fourth cereal crop in Sudan, after sorghum, millet and wheat, but recently gained more importance as a forage and industrial crop than other cereal crops (Ali, 2004). Maize is a promising cereal crop in Sudan with a potential usefulness for people and animals (Salih *et al.*, 2008). It is grown along the River Nile banks, at Toker Delta, and as a traditional rainfed crop in the Blue Nile State and Nuba mountains. The most important rainfed production areas are southern Gedarif and Blue Nile States. In Sudan, maize is grown on 80000 ha with an annual production of 60000 tones with an average yield of 750 kg/ha (AOAD, 2008). Large investments in maize production in Sudan are now led by individual investors who used maize grains mainly for poultry production (Salih *et al.*, 2008). This necessitates research intervention technologies for maize husbandry and breeding.

A major objective of maize breeding is to develop hybrids that are high yielders and adapted to a wide range of environmental conditions, however, inbred lines development is the main prerequisite for production of hybrid varieties. The evaluation of inbred lines to be used in crosses is an important task in hybrid breeding programs. Through conventional breeding, the International Institute of Tropical Agriculture (IITA) in Nigeria has made a significant progress in developing maize germplasm tolerant to different biotic and abiotic factors. This germplasm includes inbred lines and population developed through different breeding programs. The germplasm available as inbred lines can be used to develop maize hybrids. Hybrid maize varieties commonly have higher yields than landraces and open pollinated varieties (OPVs) and may also have superior levels of disease and /or insect resistance.

In Sudan, maize is grown as improved, open pollinated varieties (OPVs) and landraces for commercial production. These have low grain yield compared to hybrid varieties. The evaluation of inbred lines to be used in crosses is an important task in hybrid breeding programs. The present study included maize inbred lines introductions from the International Institute of Tropical Agriculture (IITA) in Nigeria, to be evaluated for performance under normal and stress condition (Striga infested, low nitrogen and continuously cultivated land) in Gezira Research Station, to contribute in hybrid maize varieties production in Sudan. The objectives of this study were to evaluate the performance of selected inbred lines for yield potential under normal and stress conditions and also to estimate the extent of genetic variability and association of certain characters with grain yield to identify those which can be used as selection criteria for high yielding grain yield.

MATERIALS AND METHODS

This study was conducted under normal (non-stress) and stress (Striga infested, low nitrogen and continuously cultivated) conditions during seasons 2008 and 2009, at the Gezira Research Station (GRS), of the Agricultural Research Corporation (ARC), Wad Medani, Sudan. The genetic material used in this study consisted of 9 inbred lines of maize introduced from the International Institute of Tropical Agriculture (IITA) in Nigeria with the following code number TZSTR133, TZSTR136, TZSTR137, TZSTR138, TZSTR145, TZSTR147, TZSTR148, TZSTR149 and 1368STR.

The experiments were laid out in a randomized complete block design with three replicates. Each entry was represented by a plot of 3 rows, each row was 4.0 m long with spacing of 0.25x0.80 m between holes and rows, respectively, giving a total plot area of 2.4 m^2.The land was prepared by disk plowing, harrowing and then ridging. Sowing date was the second week of July. Seeds were sown along the ridges at the rate of 2-3 seeds per hole and then thinned to one plant per hill after three weeks from sowing. Nitrogen was applied at the rate of 43 kg N\ha in a split dose after thinning and before flowering. Irrigation was applied at intervals of 10 days to supplement the rains during mid- July, August and September. Hand weeding was done to keep the plot free from weeds.

At physiological maturity, when the leaves and husks of the plants started to turn yellow, each plot was harvested separately. Data werecollected on days to 50% tasseling, plant height, ear height, ear length, 100 kernels weight and grain yield

Statistical analysis

The analysis of variance was carried out for each season separately, and then the data from the two environments were pooled for combined analysis. Varietal means over trials were used to estimate the simple linear correlation coefficients in each season separately, among grain yield and its components.

RESULTS AND DISCUSSION

Genotype x environment interaction

The effects of season, condition (stress *vs* non-stress) and genotype on most of the traits measured were significant as shown by their mean square values (Table 1). This showed that the 9 inbred lines used in the study were quite variable. The first and second degree interaction effects of the three factors (season, condition and genotype) were non-significant in most cases (Table 1). Such findings exhibited very clearly that the traits measured varied from season to season, under stress and non- stress conditions and with the different genotypes. The non-significant interaction effects showed that these genotypes were stable in spite of the differing environmental conditions of both seasons. The inconsistent performance of genotypes across environments is caused by differential responses to changes in the environment (Falconer, 1989; Setimela, 1996; Hols, 2001).

General performance

Days to 50% tasseling

This trait showed significant differences caused by genotypes under both seasons and under the two stress conditions (Table 2) .All the genotypes reached days to 50% tasseling in more than 60 days with general means of 64 days in 2008 and less than that in 2009, with the general mean of 57 days. The late tasseling genotypes were 1368STR and TZSTR147 while the early ones were TZSTR145 and TZSTR149.Stressed genotypes, in this study, tasseled a bit later compared to those under normal conditions. Stressed plants seemed rather weak.

Table 1. Mean squares of season, condition, genotype and interactions of six traits of maize evaluated at two conditions (normal and stress) during 2008 and 2009 seasons at the Gezira Research Station, Wad Medani, Sudan.

Traits / SOV	DT	PH	EH	EL	KW	GY
Season (S)	514***	3446***	1482***	0.33	184***	1492992**
Condition(C)	223*	16654***	4266***	23.62***	14*	15205014***
Genotype(G)	76*	668**	145**	23.47***	31***	315615*
SXC	235*	55	34	0.03	80***	1165689*
SXG	73	202	67	1.72	3.74	214983
CXG	53	283	60	1.95	14*	98563
SXCXG	31	48	59	2.51	4.15	75464

DT: days to tasseling; PH: plant height (cm); EH: ear height (cm); EL: ear length (cm); KW: 100 kernels weight (g); GYD: grain yield (kg/ha).
*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

Plant height

Genotypes differed significantly in plant height under normal and stress conditions and in both seasons (Table 3). The plant height, under normal conditions, was above 100 cm while under stress condition, it was below 90 cm. Plants were tall in 2009 compared to that in 2008, because plants were subjected to shortage of irrigation water in 2008. The highest plant height values were shown by the lines 1368STR137 (120 cm), TZSTR137 (120 cm) and TZSTR145 (110 cm), while the lowest values were depicted by TZSTR148 (79 cm) and TZSTR133 (92 cm). It seems that tall plants are late tasselers, e.g. line 1368STR is the tallest and late tasseling genotype. Tall, late maturing lines are not suitable for growth under sub- Saharan environmental conditions because of drought and high wind velocity that leads to lodging (Shah *et al*., 2000).

Table 2. Means for days to 50% tasseling (DT) of the maize inbred lines evaluated under normal and stress conditions, in seasons 2008 and 2009.

Entry	Season 2008			Season 2009		
	Normal	Stress	Across	Normal	Stress	Across
TZSTR133	65.0	67.6	66.3	50.0	60.3	55.2
TZSTR136	63.2	66.0	64.5	53.0	60.2	56.6
TZSTR137	63.3	65.2	64.3	56.0	63.3	59.7
TZSTR138	63.0	65.0	64.0	55.3	64.3	60.5
TZSTR145	61.3	63.1	62.4	57.0	54.1	48.2
TZSTR147	64.7	67.0	66.0	58.0	61.0	60.0
TZSTR148	62.0	65.1	63.3	55.7	60.7	58.2
TZSTR149	61.2	63.0	62.2	54.0	58.5	56.7
1368STR	66.0	68.0	67.1	57.2	64.0	60.3
Mean	63.4	65.6	64.2	55.0	59.3	57.2
SE±	0.43	0.94	0.50	1.3	1.2	0.94
Sig. level	**	*	***	*	NS	**

Ns, *, **, *** not significant, significant at P= 0.05, 0.01 and 0.001, respectively.

Ear height

The differences in ear height, in 2008, due to genotypes, were not significant under both conditions but in 2009, it was significant under normal conditions (Table 4). The stress conditions depressed ear height by 38% and 43% in 2008 and 2009, respectively. The largest ear height values were shown by the lines TZSTR137 (57 cm), TZSTR145 (54 cm) and TZSTR138 (51 cm), while the smallest values were shown by TZSTR148 (37 cm). As explained for the other traits, 2009 values were larger than those of 2008 due to shortage of irrigation water in 2008.

Table 3. Means of maize inbred lines according to plant height (PH) measured in cm, under normal and stress conditions (Seasons 2008 and 2009).

Entry	Season 2008			Season 2009		
	Normal	Stress	Across	Normal	Stress	Across
TZSTR133	93.0	81.4	87.0	104.3	82.0	92.0
TZSTR136	101.3	69.0	85.0	112.0	76.0	94.0
TZSTR137	110.0	67.2	94.3	145.3	92.0	120.1
TZSTR138	105.0	74.1	89.0	127.5	90.2	109.0
TZSTR145	111.0	93.0	104.0	128.0	93.0	110.4
TZSTR147	103.0	68.1	85.1	123.0	88.2	106.0
TZSTR148	90.3	79.0	83.0	87.0	75.1	79.0
TZSTR149	104.0	82.0	95.0	111.3	95.0	99.3
1368STR	120.3	83.1	102.0	141.3	98.4	119.8
Mean	104.1	79.9	94.8	119.6	87.8	105.4
SE±	4.5	7.2	5.2	7.3	4.6	4.8
Sig. level	**	NS	*	**	*	***

Ns, *, **, ***, not significant, significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

Table 4. Means of maize inbred lines according to ear height (EH) measured in cm, under normal and stress conditions (seasons 2008 and 2009).

Entry	Season 2008			Season 2009		
	Normal	Stress	Across	Normal	Stress	Across
TZSTR133	40.3	36.0	38.0	57.0	38.0	47.0
TZSTR136	47.3	34.0	40.0	62.0	40.3	50.9
TZSTR137	49.0	26.0	41.0	70.0	44.0	57.1
TZSTR138	51.0	33.0	42.0	60.0	41.9	51.2
TZSTR145	55.0	43.0	50.1	65.3	42.4	54.0
TZSTR147	43.7	27.1	35.2	49.0	37.0	42.8
TZSTR148	46.0	35.0	40.4	42.0	33.4	37.3
TZSTR149	44.2	30.4	38.4	47.3	49.5	42.6
1368STR	44.0	32.1	37.2	64.3	37.3	51.0
Mean	47.0	34.0	42.0	57.0	40.0	49.0
SE±	4.20	3.96	3.0	3.91	3.79	3.03
Sig. level	NS	NS	*	**	*	***

Ns, *, **, not significant, significant at the 0.05 and 0.01 probability levels, respectively.

Ear length

Ear length across seasons and conditions varied between 9 to 10 cm (Table 5). The genotypic variation in ear length was highly significant in both seasons and under both conditions. The reduction in this trait due to stress was around 11%. Lines TZSTR145 and 1368STR gave the largest ear length values (13 and 10 cm, respectively) while the smallest values were given by lines TZSTR136 (7.5 cm) and TZSTR138 (8 cm). This character was not affected by variation in seasons and differences were mainly genetical. Ear length is a good indication of biomass allocation into the ear and hybrid maize with the long ears gave high yields (Tracy, 1990; Otegui and Melon, 1997).

Table 5. Means of maize inbred lines according to ear length (EL) measured in cm, under normal and stress conditions (seasons 2008 and 2009).

Entry	Season 2008			Season 2009		
	Normal	Stress	Across	Normal	Stress	Across
TZSTR133	7.9	7.9	7.9	8.7	8.0	8.0
TZSTR136	8.8	7.8	8.5	8.2	6.7	7.5
TZSTR137	8.7	8.0	8.7	9.1	7.1	8.1
TZSTR138	11.0	9.1	10.3	11.4	8.7	10.0
TZSTR145	13.0	11.0	12.0	12.3	13.3	12.8
TZSTR147	9.0	8.3	9.0	9.3	8.6	9.0
TZSTR148	10.8	9.3	10.4	10.1	9.3	9.7
TZSTR149	10.0	8.6	9.4	8.3	10.0	8.2
1368STR	10.9	9.4	10.5	12.2	8.5	10.4
Mean	10.1	9.0	10.0	10	9.1	9.5
SE±	0.33	1.24	0.41	0.72	0.56	0.56
Sig. level	***	Ns	***	**	**	***

Ns, *, **, ***, not significant, significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

100-kernels weight

Contrary to other parameters measured, kernels were heavier (13 g) in 2008, across conditions, than that in 2009 (10 g) (Table 6). This is different to explain since assimilates were expected to be translocated to seeds more under favorable environmental conditions than under drought conditions. The effects of genotypes on this parameter were significant. The heaviest seeds were given by the lines TZSTR133 (13g) and TZSTR136 (11g), while the lightest seeds were exhibited by the lines TZSTR148 (6 g) and TZSTR137 (7.5 g).It is worth mentioning that line TZSTR133 is an early tasseler, short and gave the heaviest seeds.

Table 6. Means of maize inbred lines according to 100 kernel weight (KW) measured in g, under normal and stress conditions (seasons 2008 and 2009).

Entry	Season 2008			Season 2009		
	Normal	Stress	Across	Normal	Stress	Across
TZSTR133	15.0	15.0	15.0	15.2	10.2	13.0
TZSTR136	16.0	14.5	14.8	14.0	8.6	11.3
TZSTR137	11.2	13.3	12.0	10.1	5.0	7.5
TZSTR138	10.0	13.1	11.3	11.0	6.2	9.0
TZSTR145	14.6	15.1	14.7	12.1	10.3	11.2
TZSTR147	13.0	12.5	13.0	11.6	9.0	10.3
TZSTR148	11.0	13.0	11.2	7.3	6.0	6.4
TZSTR149	12.1	16.0	14.0	9.4	14.6	9.6
1368STR	9.8	13.2	11.0	10.6	5.5	8.1
Mean	12.3	14.1	13.0	11.2	8.3	9.8
SE±	0.95	2.27	0.92	0.96	1.46	0.92
Sig. level	**	Ns	*	**	*	***

Ns, *, **, ***, not significant, significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

Grain yield

Grain yield was high (1001 kg/ha) in 2009 compared to that of 2008 (707 kg/ha) (Table 7) due to shortage of irrigation water in 2008. The grain yield of the lines was greatly reduced when grown under stress condition, by 300% and 400% in 2008 and 2009, respectively. The highest grain yielding lines were TZSTR133 (1320 kg/ha), TZSTR138 (1136 kg/ha), TZSTR148 (1019 kg/ha) and 1368STR (978 kg/ha), while the lowest grain yielders were TZSTR137 (662 kg/ha) and TZSTR149 (575 kg/ha).

Table 7. Means of maize inbred lines according to grain yield (GY) measured in kg/ha, under normal and stress conditions (seasons 2008 and 2009).

Entry	Season 2008			Season 2009		
	Normal	Stress	Across	Normal	Stress	Across
TZSTR133	771	144	457	2176	524	1320
TZSTR136	784	142	539	1536	67.1	852
TZSTR137	356	190	425	1348	124	662
TZSTR138	1572	302	1089	2010	215	1136
TZSTR145	867	155	587	1264	456	860
TZSTR147	809	164	563	1260	364	812
TZSTR148	1595	462	1181	1619	357	1019
TZSTR149	946	386	742	1180	221	575
1368STR	944	319	784	1754	201	978
Mean	961	252	707	1546	292	1001
SE±	220	168.6	159	113.9	170	208
Sig. level	*	Ns	*	Ns	Ns	Ns

Ns, *, not significant and significant at the 0.05 probability levels, respectively.

Lines TZSTR133 and TZSTR138 were early maturing, short and high yielders and can be suggested for future studies to be used as parents to develop high yielding hybrids after studying their general and specific combining ability. On the other hand, although lines TZSTR148 and 1368STR were high yielders, however, they were late maturing and tall. These two lines can be used to develop hybrids for areas with heavy rainfall like tall grass savannah zones since variation in rainfall and wind velocity had the greatest effect on crop growth and grain yield (Maman *et al*., 2004).

Interrelationships

Under normal and stress conditions, grain yield was positively and in most cases significantly associated with plant height, ear height and length (Table 8). These three characters were positively and significantly interrelated across conditions and seasons. Yield and these three parameters were negatively and significantly correlated with days to tasseling. Kernels weight was weakly correlated with yield and other characters. Other researchers (Devi and Mohamed, 2001; Mohasan *et al*., 2002; Viola *et al*., 2003; Alhussein, 2006) found that grain yield was positively correlated with plant height, ear length and 100 kernels weight.

Table 8. Simple linear correlation coefficients among grain yield and its components of 9 maize inbred lines in normal (upper diagonal) and stress (lower diagonal) conditions grown in seasons 2008 and 2009 (combined).

	DT	PH	EH	EL	KW	GY
DT		-0.31*	-0.53**	0.01	-0.02	-0.60**
PH	-0.26		0.80**	0.42**	0.10	0.38**
EH	-0.41*	0.73**		0.40**	0.25	0.56**
EL	-0.51**	0.52**	0.39*		0.003	0.37**
KW	-0.70**	0.04	-0.02	0.13		0.12
GY	-0.51**	0.36*	0.32	0.46**	0.12	

DT: days to tasseling; PH: plant height; EH: ear height; EL: ear length; KW: 100 kernel weight; GY= grain yield.

*, **, Significant at the 0.05 and 0.01 probability levels, respectively.

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الاختلافات الوراثية والإنتاجية والعلاقات المتداخلة لإنتاج الحبوب ومكوناته لتسع سلالات ذرة شامية في تربة موبوءة وغير موبوءة بالبودة

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الخلاصة

تم تقييم تسع سلالات ذرة شامية ذات تربية داخلية مستقدمة في محطة بحوث الجزيرة، هيئة البحوث الزراعية، واد مدني، السودان، تحت ظروف تربة موبوءة وغير موبوءة بالبودة ، خلال موسمين زراعيين متتالين (2008 و2009). ،استخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات لتنفيذ التجربة بهدف تقدير الأداء العام والاختلافات الوراثية وارتباط الصفات بالإنتاجية ومكوناتها. أخذت بيانات عدد الأيام لظهور 50% من الأزهار المذكرة ، طول النبات، ارتفاع القندول، وزن 100 حبة وإنتاج الحبوب. أظهرت النتائج أن هنالك اختلافاً معنوياً بين السلالات لكل الصفات المدروسة تحت ظروف التربة الغير موبوءة ما عدا ارتفاع القندول في موسم 2008 وإنتاج الحبوب في موسم 2009م. أما تحت ظروف التربة الموبوءة في موسم 2008م كان هنالك اختلافاً غير معنوي بين الصفات الوراثية المدروسة ما عدا عدد الأيام لظهور 50% من الأزهار المذكرة ، بينما أظهرت النتائج في موسم 2009 أن هنالك فروقات معنوية مع طول النبات، طول القندول ووزن الـــ 100 حبة. متوسط إنتاج الحبوب في الحالتين تراوح بين 425 – 1181 كيلوجرام/هكتار في موسم 2008 و 575 -1320 كيلو جران /هكتار في موسم 2009م. حققت السلالة TZSTR 148 (مبكرة وقصيرة) أعلى إنتاجية (1181 كيلوجرام/هكتار) في موسم 2008 ، بينما أظهرت السلالة TZSTR 133 (مبكرة وقصيرة) أعلى إنتاجية (1320 كيلوجرام/هكتار) في موسم 2009م. في كلى الموسمين (2008 و2009) وتحت ظروف التربة الموبوءة وغير الموبوءة أظهرت إنتاجية الحبوب ارتباطاً معنوياً وإيجابياً مع طول النبات ارتفاع وطول القندول. السلالتان TZSTR 133و TZSTR 138(قصيرة ومبكرة النضج) لهما إنتاجية عالية لذا يمكن استخدامها في إنتاج الهجن بعد دراسة مقدرتهما للتآلف تحت ظروف الأمطار الخفيفة. TZSTR 148 و1368STR (طويلة، متأخرة النضج وعالية الإنتاجية) يقترح أن تستخدما في تطوير الهجن في المناطق ذات الأمطار الغزيرة.