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Genetic variability, heritability and character association of grain yield and its components among selected genotypes of maize (*Zea mays* L.), Gezira State, Sudan

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ABSTRACT

In the Sudan, the low yield of maize was mainly due to the use of low yielding land races and open-pollinated varieties. Hence, the current study was conducted to measure the extent of genotypic and phenotypic variability, genotypic performance, heritability, genotype x season interaction, and the magnitude of association among seed yield and its components of 10 maize genotypes. The experiment was carried out during the summer of 2017 and the winter of 2017/18, using a randomized complete block design with three replicates, at the University of Gezira Farm, Wad Medani, Sudan. The characters measured were days to 50% tasseling and silking, plant and ear height, number of kernels per row and per ear, ear diameter, cob length, 100-kernels weight and grain yield. High significant phenotypic variability was detected for all the measured characters. Seasonal differences were also significant. High broad sense heritability estimates were recorded for 50% tasseling and silking and plant height while the rest of the characters showed moderate estimates. The study confirmed the fact that maize is a summer crop in central Sudan. In summer, the highest seed yield genotype was HSD 5158 (2609 kg/ha) and in winter was HSD 3538 (2285 kg/ha). Days to 50% tasseling and silking and plant height were significantly and positively correlated with yield and so recommended as selection criteria for seed yield improvement. It is recommended to grow genotypes HSD 5158 in summer and HSD 3538 in winter as well as genotypes VMH 4040, VMH 4102 and HSD 5007 in both seasons. Testing of these genotypes under different locations and seasons is suggested.

INTRODUCTION

Maize (*Zea mays* L.) is used as human food, feed for livestock, for fermentation and industrial purposes. Every part of the plant has an economic value. The grain, the leaves and stalks, the tassel and even the cob are used to produce hundreds of food and non-food products (Watson, 1988).

Maize yield in Africa is low (1.2 to 2.5 t/ha) compared to 6.2 t/ha for developed countries. This was due to low plant density and low levels of purchased inputs used, especially fertilizers (Dowswell *et al.,* 1996; Romain, 2001). Maize is the fourth cereal crop in the Sudan, after sorghum, wheat and millet. In the Sudan, maize is of less importance than sorghum and pearl millet, but recently its importance rises as a forage and industrial crop. In the Sudan, the low yield of maize was due to the use of land races and open-pollinated cultivars which were characterized by having low yield, i.e. 1 to 2 t/ha. In addition, the land preparation was not proper. If high yield is to be obtained, adequate plant population is necessary, due to the fact that maize is a non- tillering crop (Romain, 2001).

A major objective of maize breeders is to develop hybrids that are high yielders and adapted to a wide range of environmental conditions. The International Institute of Tropical Agriculture (IITA) in Nigeria has made 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. These inbred lines can be used to develop maize hybrids. The present study consisted of maize inbred lines from IITA in Nigeria, to be evaluated for performance *per se* to contribute in hybrid maize production in the Sudan.

The objectives of this study were to evaluate the performance *per se* of selected inbred lines of maize for yield potential, estimate the extent of genetic variability as well as the association of certain characters with grain yield.

MATERIALS AND METHODS

This study was conducted during two seasons (summer 2017 and winter 2017/18), at the University of Gezira Farm, Wad Medani, Sudan, latitude 14° 06´ N, long. 33° 38´ and altitude 407 masl. The area is characterized by hot semi- arid climate. The soil of the experimental site is typically Sulemi soil series, dark brown, deep cracking clays with very low permeability when moist, pH ranges from 7.9 -8.4, low organic matter content (0.06%) and nitrogen content (0.02%). The soil is in non-saline and non-sodic soils (Soil Survey Staff, 1999).

Treatments consisted of ten maize genotypes (Hudeiba1, Hudeiba2, Hybrid VMH2000, VMH2015, VMH4040 and VMH4102 and advanced inbred lines HSD3538, HSD5007, HSD5158 and HSD5514). The experiments were arranged in a randomized complete block design with 3 replicates.

Sowing date was in the second week of June for the summer season and third week of November for winter season. All cultural practices were followed as recommended by ARC.

Analysis of variance was carried out, using Genstat ed 12.1 for each season separately. Then, the combined analysis of variance for seasons was conducted. The estimates of genetic parameters, phenotypic and genotypic coefficient of variation, genetic advance as a percentage of the mean, heritability in broad sense as well as the simple correlation coefficients were also estimated.

RESULTS AND DISCUSSION

Phenotypic variability

The current study indicated a wide range of genetic variability for all the measured characters in both seasons, as shown by their significant mean squares (Table 1). This depicted potential genetic variability and diversity in the material under consideration and improvement through conventional plant breeding methods would be possible. Similar results were reported by Setimela (1996) and Karrar *et al*. (2013).

Seasonal differences were highly significant (P=0.001) while that of seasons x genotype were significant for all the traits studied with the exception of days to 50% silking (Table 1). This is an indication of character instability over seasons and need further studies over seasons and locations. In the Sudan, autumn is a short, hot rainy season while winter is a relatively dry, cool season. Falconer (1989) and Setimela (1996) found that the inconsistent performance of genotypes across environments is caused by differential responses to changes in the environment.

Table 1. Mean squares for seasons, genotypes and their interaction of some characters of ten maize genotypes, in seasons 2017 and 2017/18.

Characters	Season (S)	Genotype (G)	G x S
Days to 50% tasseling	5504.167***	17.898***	9.59***
Days to 50% silking	6695.745***	8.854***	2.92 NS
Plant height (cm)	5580.92 ***	232.96***	117.5*
Ear height (cm)	2584.98***	53.98**	113.8***
Number of kernels /row	15.1101 ***	1.554**	2.047***
Ear diameter (cm)	1.79428 ***	0.22045***	0.119**
Cob length (cm)	134.729***	7.434 ***	1.29*
Number of kernels/ ear	12430.21***	280.33***	310.93***
100 kernels weight (g)	382.338***	25.847***	23.9***
Grain yield (kg/ha)	3263490***	595223***	29.64***

*, ** and*** Significant at $P \leq 0.05$, 0.01 and 0.001, respectively.

Heritability and genetic advance

As expected, the values of genotypic coefficient of variation (GCV) were smaller compared to those of phenotypic coefficient of variation (PCV) for all the characters and in both seasons (Table 2). Seasonal variation in GCV and PCV is very small. According to the scale suggested by Sivasubramanian and Menon (1973), most of the measured traits showed high PCV, (more than 20%) and moderate GCV values (10-20%). Characters like 50% tasseling, cob length, kernels per ear and 100- grain weight showed high GCV and PCV, in both seasons (Table 2). These characters showed high genetic and environmental variation that could make selection for improvement possible.

The current study gave high broad-sense heritability estimates (>60%) for 50% tasseling, 50% silking and plant height, then moderate heritability estimates (30-60%) for ear height, kernels per row, ear diameter, cob length and kernels per ear and finally low h^2_B for yield (0-30%) according to the rating of Robinson *et al*. (1949). Variations in seasons showed no effects on h^2_B estimates.

The low h^2_B estimate for yield is expected since yield is a quantitative, complex character controlled by multi genes or minor genes of small effects. Characters that showed high h^2_B estimates, 50% flowering, 50% silking and plant height, were almost qualitative characters because plants can easily be classified as late, early, short and tall. Hence these characters are controlled by major genes and could easily be used as selection criteria for grain yield improvement if positively correlated. Characters that showed high genetic advance, as percentage of the mean (GA%) were 50% silking, 50% tasseling, ear diameter, kernel per ear and grain yield according to Johanson *et al*. (1955) classification. These characters also showed relatively high and moderate GCV and h^2_B which qualify them to be used as selection criteria for grain yield improvement. Such findings were in accordance with those of Viola *et al*. (2003), Ihasan *et al*. (2005) and Elali Elkhalf *et al*. (2007).

Table 2. Estimates of genotypic (GCV%) and phenotypic (PCV%) coefficient of variation, heritability (h^2_B), genetic advance (GA) and genetic advance as percentage of the mean (GA%), in seasons 2017 and 2017/18.

Character	GCV (%)		PCV (%)		H_B (%)		GA		GA (%)	
	2017	2017/18	2017	2017/18	2017	2017/18	2017	2017/18	2017	2017/18
50% tasseling	32	21	38	32	70	70	6.5	10.2	25.3	19.3
50% silking	10	11	36	36	70	52	18.3	2.6	31.2	29.4
Plant height (cm)	15	12	48	38	60	50	4.2	3.7	18.5	10.9
Ear height (cm)	12	13	35	49	48	44	6.0	3.3	8.5	7.2
Kernels/row	27	10	48	48	42	38	4.2	2.5	12.6	8.0
Ear diameter (cm)	21	10	42	51	40	36	4.0	1.5	15.5	41.0
Cob length (cm)	23	21	45	40	40	42	5.3	3.5	10.9	4.5
Kernels/ear	31	25	47	58	42	53	6.1	3.8	16.6	10.2
100 grains weight(g)	23	31	48	43	38	47	12.2	5.6	15.8	8.5

Yield (kg/ha)	20	12	57	55	28	22	36.2	10.3	24.7	21.4

Phenotypic performance

Days to 50% tasseling

The genotypes tasseled earlier in summer (mean of 50 days) than in winter (mean of 67 days) (Table 3), an indication that winter is favourable for the vegetative growth of maize in central Sudan. There were no significant differences in the winter season (Table 3). Genotypes were earlier in summer than in winter.

Days to 50 % silking

Silking followed the trend of tasseling, i.e. early (54-56 days) in summer and late (74-77 days) in winter (Table 3), making it very difficult to group the genotypes into early and late classes.

Plant height

Seasonal variation in plant height were very clear (Table 3), summer plants were taller (127.3-141 cm) compared to those grown in winter (106-123 cm). This may be attributed to the conducive effect of the summer rains. The tallest genotypes, in both seasons, were HSD3538 followed by HSD5007 while the shortest was VMH2015. The height of the different genotypes varied significantly in winter as shown in (Table 3).

Table 3. Mean of 50% tasseling, days to 50% silking and plant height (cm) in 2017 and 2017/18 seasons at the University of Gezira Farm.

Genotype	Days to 50% tasseling		Days to 50% silking		Plant height	
	Summer 2017	Winter 2017/18	Summer 2017	Winter 2017/18	Summer 2017	Winter 2017/18
Hudeiba1	47.50	66.75	54.00	75.25	137.25	111.50
Hudeiba-2	50.00	69.00	56.00	75.50	141.25	106.75
VMH2000	51.00	67.25	55.25	75.00	132.00	108.50
VMH2015	49.00	65.00	53.50	74.00	131.25	106.25
VMH4040	50.75	67.00	55.75	75.00	127.25	114.50
VMH4102	49.50	64.50	54.00	75.00	135.25	113.50
HSD3538	49.50	71.00	54.00	74.50	141.00	123.75
HSD5007	47.80	66.57	53.50	74.50	137.75	116.75
HSD5158	46.50	67.00	54.00	74.50	138.50	107.50
HSD5514	51.25	68.75	56.50	76.75	134.75	107.75
Mean	47.90	67.10	53.30	82.20	137.80	121.80
SE±	1.37	0.86	0.97	0.71	3.56	2.30
Sig. level	NS	**	NS	NS	NS	**
CV%	6.78	3.13	4.35	3.32	6.44	5.05

** Significant at P= 0.01.
NS = Not significant

Ear height

There were significant differences among genotypes in both seasons; ear height differed with season with high values in summer (50.75-61.00) compared to those of winter (37.50-47.00). Again, the favourable environmental conditions of summer were the reason. Genotype differences of ear height were significant in both seasons (Table 4). The tallest genotype was VMH2015 which showed the longest ear height in the summer suggesting a closer, positive relationship between plant height and ear height.

Number of rows per ear

This trait showed significant differences in both seasons. The effect of season on number of kernels per row was not large (Table 4) but the genotypic effect was significant in winter (4-5) and not in summer (13-15). This fact supported the idea that number of kernels per row is a stable character and controlled mainly by genes.

Ear diameter

The value of ear diameter in summer (17.73-23.40 cm) was slightly more than those in winter (13.37- 19.75 cm) (Table 4). This trend was shown by most of the measured characters. The effects of genotypes on the present character were significant in both seasons but clear differentiation among the genotypes is very difficult.

Table 4. Mean of ear height (cm), number of kernels per row and ear diameter of maize in seasons 2017 and 2017/18.

Genotype	Ear height (cm)		Rows/ear		Ear diameter (cm)	
	Summer 2017	Winter 2017/18	Summer 2017	Winter 2017/18	Summer 2017	Winter 2017/18
Hudeiba 1	60.50	41.25	6	4	4.05	3.62
Hudeiba-2	54.25	37.50	5	5	4.15	3.37
VMH2000	52.25	43.25	5	4	3.70	3.65
VMH2015	57.75	45.75	7	4	4.12	3.47
VMH4040	58.00	46.75	7	4	4.02	3.70
VMH4102	54.00	39.75	6	4	4.10	3.52
HSD3538	56.25	47.00	6	4	3.95	3.75
HSD5007	50.75	44.25	7	4	4.05	4.00
HSD5158	58.25	43.25	5	4	3.92	3.95
HSD5514	61.00	43.50	4	4	3.77	3.75
Mean	44.80	51.10	13.5	3.8	3.80	3.90
SE±	2.49	2.21	0.36	0.39	0.06	0.11
Sig. level	NS	NS	NS	*	**	*
CV%	10.85	12.66	6.53	7.94	3.95	7.48

*and** significant at P≤ 0.05 and 0.01, respectively.

Cob length

Seasonal mean cob length was significantly different, (higher in summer) (14 cm) than winter (11 cm) (Table 5). Genotypic mean cob length varied significantly within and across seasons, 12.35-

15.53 cm in summer and 9.95-13.12cm in winter. Genotype VMH2015 gave the longest and shortest cob length in summer and winter, respectively.

Number of kernels per ear

Similar to the results showed by most of the measured characters, summer values of kernels per ear (80), were higher than that of winter (50) (Table 5). Genotypes differed significantly (P=0.01) in number of kernels per row in summer (45-97) as well as in winter (44-57). Genotype Hudeiba-2 showed the highest values while HSD5514 showed the lowest in both seasons.

100 – kernels weight

The trait 100- kernels weight followed the same pattern depicted by the number of kernels per row, i.e. effect of season and genotype were all significant (Table 5). Summer values ranged from 18-23 g while that of winter ranged from 13-20 g. Hudeiba-2 showed the highest number of kernels per row and gave the lowest 100- kernels weight, an indication that weight and number of seeds were negatively correlated.

Table 5. Cob length (cm), number of kernels per ear and 100 kernels weight (g) of maize in seasons 2017 and 2017/18.

Genotype	Cob length		No. of kernels/ear		100 kernels weight		Grain yield (kg/ha)	
	Summer 2017	Winter 2017/18	Summer 2017	Winter 2017/18	Summer 2017	Winter 2017/18	Summer 2017	Winter 2017/18
Hudeiba 1	13.77	10.30	84.42	49.57	21.46	14.25	2187	1894
Hudeiba-2	14.40	10.30	96.80	57.25	20.57	13.37	2148	1972
VMH2000	14.82	10.07	69.95	43.50	17.73	18.87	2031	1797
VMH2015	15.53	9.95	92.00	53.00	23.40	16.62	2105	1773
VMH4040	15.07	11.55	90.60	51.50	20.28	17.75	2457	1992
VMH4102	14.42	10.92	83.17	50.25	21.24	18.62	2344	2125
HSD3538	14.42	10.40	74.00	51.75	21.78	14.75	2168	2285
HSD5007	13.42	13.12	87.20	49.00	22.57	19.75	2478	1925
HSD5158	12.35	11.07	72.30	46.82	21.30	19.25	2609	1783
HSD5514	13.50	10.55	45.57	47.32	18.49	16.50	2218	1368

Mean	14.60	11.60	81.80	52.80	22.00	16.60	2442	2065
SE±	0.52	0.39	4.96	1.68	0.92	0.80	95	104
Sig. level	*	**	**	**	*	**	**	**
CV%	9.92	8.81	15.28	8.24	1.86	11.71	10	13

* and** Significant at $P \leq 0.05$ and 0.01, respectively.

Grain yield (kg/ha)

As expected from the previous discussion of the other measured characters, summer grain yield (2250 kg/ha) exceeded that of winter (1886 kg/ha) by around 20% (Table 5). The rainy conducive summer conditions for crop growth could be the reason for these seasonal differences. In summer, the range of seed yield was 2031 and 2609 kg/ ha for genotypes VMH2000 and HSD5158 while in winter it was 1368 and 2285 kg/ha for HSD5514 and HSD3538, respectively.

In summer, the highest seed yielding genotypes were HSD5158 (2609 kg /ha), HSD5007 (2478 kg/ha), VMH4040 (2457 kg/ha), VMH4102 (2344 kg/ha) and HSD5514 (2218 kg/ha). In winter, the highest seed yielding genotypes were HSD3538 (2285 kg/ha), VMH4102 (2125 kg/ha), VMH4040 (1992 kg/ha), Hudeiba-2 (1972 kg/ha) and HSD5007 (1925 kg/ha).

It is worth mentioning that genotype HSD5158 was the highest yielder in summer but a low yielder in winter (1783 kg/ha) while genotype HSD3538 was the highest yielder in winter but low yielder in summer. This sort of behavior explained the interaction of genotypes with season. In this study, different genotypes should be recommended for different seasons. Genotypes VMH4040, VMH4102 and HSD5007 could be recommended for growing in both winter and summer seasons since they gave yields higher than the average seasonal seed yield.

Interrelationships

Seed yield was significantly and positively correlated with plant height, ear diameter and cob length (Table 6). It was also reasonably and positively correlated with 50% tasseling and number of kernels per ear but did not reach the significance level at P= 0.05 . It was negatively and non-significantly correlated with ear height and number of kernels per row. These findings are in accordance with those of Yan *et al.* (2000) who reported that grain yield of maize was highly significantly and positively correlated with ear and plant height, ear length and diameter, ear dry weight and number of kernels per row.

Table 6. Simple linear correlation coefficients among 10 pairs of characters in maize, across seasons (combined).

	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	0.391	0.493**	-0.068	0.005	0.495**	0.435*	0.562**	-0.249	0.203
X_2		0.375*	0.571**	0.028	0.354	0.467**	0.018	0.022	0.008
X_3			0.174	0.031	0.511**	0.529**	0.275	-0.137	0.372*
X_4				0.244	0.135	0.057	-0.331	0.039	-0.232
X_5					0.286	0.051	0.051	-0.131	-0.329
X_6						0.536**	0.44*	0.038	0.434*

X_7	0.376*	-0.257	0.402*
X_8		-0.415*	-0.302
X_9			0.124

*and** Significant at P= 0.05 and 0.01, respectively.

X_1= 50% tasseling, X_2 = 50% silking, X_3= plant height, X_4= ear height, X_5 = kernels/row, X_6= ear diameter

X_7= cob length, X_8 = kernels/ear, X_9= 100 seed weight and X_{10}= yield (kg/ha).

Tasseling, silking, plant height, ear diameter, cob length and number of kernels per ear were positively and significantly interrelated. These are indictors of earliness.

The association of 100- seed weight with yield and most other characters was weak and negative. It was negatively and significantly correlated with number of kernels per ear. The correlation analysis strongly suggested the use of plant height, ear diameter and cob length as a strong selection criteria for the improvement of maize grain yield since they were highly and moderately inherited, significantly variable with high GA (%) and, furthermore, were strongly, positively and significantly correlated with yield. Such findings were in line with those reported by Venugopal and Rajankanth (2003) and Elali Elkhalf *et al.* (2007).

CONCLUSIONS AND RECOMMEDATIONS

The material under consideration is characterized by high genotypic variability and diversity as well as significant genotype x season interaction which makes improvement through conventional plant breeding methods possible and effective. Characters like 50% tasseling, 50% silking and plant height showed high heritability estimates, high genotypic coefficient of variation and high genetic advance as percentage of the mean. They were positively and significantly correlated with seed yield. This qualified them to be used as selection criteria for seed yield improvement. The study depicted clearly that the summer performance of the crop is far higher than that of winter taking into consideration the infestation of the crop with the stem borer in winter. It is recommended to grow in summer genotypes HSD5158, HSD5007, VMH4040, VMH4102 and HSD5514 while in winter, it is recommended to grow genotypes, HSD3538, VMH4102, VMH4040, Hudeiba-2 and HSD5007.

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التباين الور اثي ودرجة التوريث وإرتباط إنتاج البذور ومكوناته لطرز ور اثية مختارة من الذرة الشامية (*Zea mays* L.)، ولاية الجزيرة، السودان

على أحمد محمد حرسي و أبو الحسن صالح إبراهيم و سليمان حسن سليمان
و عباس محمد سليمان

قسم علوم المحاصيل، كلية العلوم الزراعية، جامعة الجزيرة، واد مدني، السودان.

الخلاصة

يعزى ضعف إنتاجية الذرة الشامية بالسودان لزراعة أصناف مفتوحة التلقيح وسلالات محلية ضعيفة الإنتاج. هدفت هذه الدراسة لقياس التباين الظاهري والوراثي ودرجة التوريث على المدى العريض وتفاعل الطراز الوراثي والموسم وارتباط إنتاج البذور ومكوناته. نفذت التجربة في صيف 2017 وشتاء 18/2017 بتصميم القطاعات العشوائية الكاملة بثلاث مكررات بمزرعة جامعة الجزيرة، واد مدني، السودان. الصفات التي قيست هي : عدد الأيام لظهور 50% من الأزهار المذكرة والمؤنثة وطول النبات وارتفاع القندول وعدد بذور الصف والقندول ومحيط القندول وطول الكوز ووزن مائة حبة وإنتاج البذور. أظهرت النتائج اختلافاً معنوياً بين الطرز الوراثية لكل الصفات وفي الموسمين. تأثير الموسم كان معنوياً. سجلت قيم عالية لدرجة التوريث بالمعنى العريض لصفات 50% إزهار مذكر ومؤنث وطول النبات ولكن الصفات الأخرى أظهرت قيم وسطية. ثبت أن محصول الذرة الشامية في وسط السودان محصول صيفي. الطراز الذي أعطى أعلى إنتاجية صيفاً هو HSD 5158 (2609 كجم/ه) وشتاءً هو HSD 3538 (2285 كجم/ه). ارتبطت صفات الإزهار المؤنث والمذكر وطول النبات ارتباطاً موجباً ومعنوياً بالإنتاجية وعليه يمكن استعمالها كمؤشرات انتخاب لتحسين إنتاجية الحبوب. يوصى بزراعة الطراز HSD 5158 صيفاً والطراز HSD 3538 شتاءً والطرز VMH 4040 و VMH 4102 و HSD 5007 في الموسمين معاً. يوصى بزراعة هذه الطرز المقترحة في مواسم ومواقع متعددة لتأكيد النتائج.