

Yield potential of landraces of maize in Sudan and the avenues for their genetic improvement*

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ABSTRACT

The study was conducted for two years (1998-1999), during the rainy season, at the Gezira Research Station (GRS) of the Agricultural Research Corporation (ARC) of the Sudan, to identify some yield components for improving the yield levels and to determine the genetic factors influencing the yield parameters of six landraces of maize and their 15 single crosses produced by a 6 x 6 half diallel arrangement. The analysis of variance mean squares depicted significant ($P \leq 0.01$) differences for most of the traits studied in both years, indicating high phenotypic variability. The best crosses giving grain yield above parental average were Hegeri x Red, Sennar x Red and Hegeri x Ahmar Mahali with a range of 4098-4710 kg ha⁻¹ and 3014-3348 kg ha⁻¹ in both cropping seasons, respectively. The best yielding parents were Ring-8 (4870 and 3192 kg ha⁻¹) and Red (4658 and 3348 kg ha⁻¹) (In 1998 and 1999, respectively). Strong, positive association exists between grain yield and days to 50% anthesis and silking, ear length, 100-seed weight and grain per ear ranging from $r = 0.54^{**}$ (days to 50% silking) to $r = 0.76^{**}$ (ear length). Days to 50% anthesis and silking, plant and ear heights, 100-seed weight and ear length showed relatively high heritability estimates ranging between 21.91% - 65.33%. The analysis of variance mean squares due to GCA and SCA were significant ($P \leq 0.01$) for most of the traits. The GCA: SCA ratio indicated that days to 50% anthesis, plant height, ear length, grain per ear and grain yield were controlled by additive genetic effects while days to 50% silking, ear height, ear per plant and 100-seed weight were largely influenced by non-additive genetic effects.

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Ring-8 was the best general combiner for most traits while Sennar and Hegeri showed high GCA for 50% silking and anthesis, ear length, plant and ear heights. The results suggested landraces Ring-8, Higeri and Red for improvement through recurrent selection while the cross Hegeri x Ahmar Mahali for development of hybrid varieties.

INTRODUCTION

Maize (*Zea mays* L) is an alien crop of recent introduction in Sudan. Its landraces are grown on small scales at different locations under rain, flood and irrigated conditions. to exploit the genetic variability of these landraces in developing high yielding cultivars adapted to the local conditions. Misovic (1964) evaluated six landraces and two introduced open-pollinated varieties of maize at Gezira Research Station (GRS). His findings showed that the landrace, Hegeri, long dent, was the top high yielder (2.43 t ha¹) Imam (1974) made selections among landraces of maize collected from different agro-ecological zones of Sudan and released two open pollinated pollinated varieties, No. 113 and Bafrewa, originally collected from the Nuba mountains and Rosieris area, respectively. Idris (1996) found high phenotypic variability for a large number of parameters landraces of maize collected from different parts of the Blue Nile region and he emphasized the importance of populations for breeding programs.

Grain yield is usually the primary trait targeted for improvement, however, the design of effective procedures to increase yield is dependent upon knowledge not only of inheritance of yield and its components, but also of the strength and stability of the genetic relationship among these traits (Nienhuis and Singh, 1986). Estimates of genetic variation and combining ability in diallel analysis would be useful in determining procedures for improvement of the landraces because plant breeding is based upon attempts to select plants that incorporate features desirable in offspring (Lee et al., 1967). Therefore, a better understanding of genetic effects, heritability and correlation components would provide avenues for future breeding efforts to improve yield levels of the landraces.

Guei and Wassom (1992) reported high heritability estimates for days to 50% anthesis and number of ears per plant, and high genotypic and phenotypic correlations between yield and these traits. Nyuetta and Cross (1997) reported that maize genotypes with high leaf number tend to produce longer leaves and ears; leaf length correlated positively with ear length and

grain yield. Ear length is a good indicator of biomass allocation into the ear, and the existence of threshold for silk emergence (Otiegui and Melon, 1997). Vedia and Claire (1995) demonstrated the importance of ear length as a selection index for yield improvement. The genetic gain reached 5.75% per cycle. Singh and Asnan (1979) found significant differences among maize genotypes for yield and its components, in a set of diallel analysis, fifty percent of the genotypes were good general combiners for grain yield, 100-grain weight, kernel rows per ear, ear length and diameter. Tulu and Ramachandrapa (1998) found significant GCA for earliness, lower ear placement and plant height in the high yielding cultivar Abo-Bako. The current study was designed to furnish information on the inheritance of yield components that are strongly associated with yield and the estimates of genetic effects controlling them in order to choose appropriate breeding procedures for improving yielding capabilities of six maize landraces in the Sudan.

MATERIALS AND METHODS

The study was conducted for two years (July- November 1998 and (1999 at GRS (140° 24 N, 33° 29 E and 407 masl), wad Medani, Sudan. The soil is characterized by heavy cracking clay (58%), pH of 8.3 low organic matter (0.6%) and nitrogen content (0.02%). The entries were six landraces of maize and their 15 single crosses produced by a 6x6 half a diallel arrangement sown in a randomized complete block design with four replications. The parents were Sennar (flint, yellow seeds), Ahmar Baladi (semiflint, seeds with different colours), Hegeri (semident, yellow seeds), Red (dark red seeds), Ahmar Mahali (semident, white seeds) and Ring-8 (dent, yellow seeds). Their seeds were collected from the Blue Nile area with the exception of Ring-8 which was introduced from Mexico.

Each genotype was planted in a single ridge of 4.0m long, spaced 0.8m apart and 0.2m between hills, giving a plant population of 62,500 plants per hectare. Sowing was done on July 4 and 19 in 1998 and 1999, respectively, at a rate of three seeds per hole. Re-sowing was practiced before the second irrigation. The seedlings were to one plant per hill three weeks after sowing. A compound fertilizer was applied at the rates of 42.5 kg N and 40 kg P₂O₅ per ha at 1 week of sowing. An additional 42.5 kg N per ha was applied as top dress four weeks later. The crop was irrigated at intervals of 12-15 days to supplement the rains. The trial was kept weed free manually.

Days to 50% anthesis and silking were recorded as number of days from sowing to the date when 5000 of the plants within a plot shed pollen and exerted silks, respectively. Plant and ear heights (cm) were recorded as average of five plants, measured from ground surface to the tip of the tassel and from the surface of the ground to the exertion base of the ear. Average ear length (cm) of five randomly selected plants were measured from the base to the tip of the ear. Number of ears per plant was determined by dividing the total number of harvested ears by the total number of harvested plants. Grains per ear was recorded as an average of five ears threshed and gains the counted. Hundred seed weight was recorded as weight (g) of 100 grains taken at random from the bulk of five threshed ears. Grain yield per plot was converted to grain yield in kg/ha according to the following formula:

$$\text{Grain yield (kg/ha)} = \frac{\text{grain weight/plot} \times 10000}{\text{actual plot area}}$$

Statistical analysis of variance was carried out for each seasons separately. Simple linear correlation coefficients of yield components with grain yield and their heritability estimates were computed using the entries means over the two seasons. Combining ability analysis was performed according to Griffing's (1956), GCA and SCA effects were determined for each of the landraces and their hybrid combinations, respectively.

RESULTS AND DISCUSSION

The analysis of variance mean squares revealed significant differences among varieties and their crosses for most of the traits measured in the two crop seasons (Table 1). Such variability could be exploited through selection for developing new lines possessing improved agronomic traits. Landraces with high phenotypic variability are superior source materials, since uniform populations narrow down the genetic basis of breeding maize (Singh and Asnan, 1979; Geric *et al*, 1989; Idris, 1996).

Table 1. Analysis of variance mean squares for nine yield components of maize at Gezira Research Station (1998 and 1999)

Character	Mean square		c.v(%) .	
	1998			
Days to 50% tassel	10.30**	13.38**	2.40	3.80
Days to 50% silking	2.38**	10.38**	2.50	2.90
Plant height	377.26**	362.20**	4.40	6.50
Ear height	309.70**	273.72**	8.00	10.80
Ear length	4.93**	4.99**	8.60	10.80
Ear per plant	0.04	0.03	14.00	19.20
Grains per ear	874.00	6939.00	21.90	16.10
100-seed weight	0024.61**	9.18	10.30	12.00
Grain yield	1527330**	452404**	21.10	39.90

**Significant at the 0.01 probability level

Days to 50% anthesis for all entries ranged between 43-56 days while for 50% silking between 47-60 days, in both seasons. The early maturing parent was Ahmar Balady while the early maturing crosses were Ahmar Balady x Hegeri, Sennar x Ahmar Balady and Ahmar Balady x Ring-8 with Ahmar Balady as a common parent. They all matured in 87 days, in both seasons. The early maturing Ahmar Balady was the shortest (170 cm) while the late maturing (91 days) Ring-8 was the tallest (242 cm). The best crosses giving grain yield above parental average (data not shown) over the two crop seasons, were (Hegeri x Red, Sennar x Red and Hegeri x Ahmar Mahali) with a range of 4098-4710 kg ha⁻¹ and 3014-3348 kg ha⁻¹ in 1998 and 1999, respectively. The best yielding parents were Ring-8 (4870 and 3192 kg ha⁻¹) and Red (4658 and 3348 kg ha⁻¹) in 1998 and 1999, respectively. The crosses are expected to out-yield their parents but this is not fully expressed in this study and it is quite difficult to explain. The grain yield of 1998 was higher than that of 1999 for all entries. This was attributed to water logging in 1999.

The analysis of simple linear correlation coefficient means of entries over the two seasons, showed that gr area was significantly and positively correlated with measured traits (Table 2). However, grain yield was strongly, highly and positively correlated with days to 50% anthesis and silking ear length, grain per ear and 100-seed weight ranging from $r = 0.54^{**}$ (days to 50% anthesis and silking) to $r = 0.76^{**}$ (ear length)

Table 2. Simple linear correlation coefficients among var pai nine characters in maize at GRS.

character	1	2	3	4	5	6	7	8	9
1.Days to 50% anthesis		0.93**	0.59**	0.65**	0.33	0.08	0.52*	0.00	0.58**
Days to 50% silking			0.55**	0.59**	0.33	0.02	0.42	-0.03	0.54**
Plant height				0.95**	0.42	0.385	0.66**	0.09	0.50*
Ear height					0.31	0.38	0.65**	-0.11	0.46*
Ear length						0.40	0.54**	0.46*	0.76**
Ear per plant							0.14	-0.05	0.27
Grains per ear								0.17	0.55**
100-seed weight									0.55**
Grain yield									

Significant at the 0.05 and 0.01 probability levels, respectively

The broad and narrow sense heritability estimates for most of measured parameters were relatively high compared to that of grain yield ha⁻¹ (23.31% and 12.88% for broad and narrow sense heritability estimates, respectively) (Table 3). The traits that showed relatively high heritability estimates were: days to 50% anthesis (65.33% and 46.87%), days to 50% silking (63.00% and 37.97%) plant height (44.03% and 23.870%), ear height (51.64% and 46.68%) and 100-seed weight (43.28% and 29.24%).

For a trait to be useful in yield improvement, it must show strong relationship with grain yield and should be genetically heritable. Our results indicated that days to 50% anthesis and silking, ear and plant heights, 100-seed weight, and ear length fulfilled these requirements and could be used as selection criteria for high grain yield in the Sudanese landraces used in the current study. These results are in line with those of Uhr and Goodman (1995); Samanci (1996); and Sughrouse and Hallauer (1997).

Table 3. Broad (h^2_B) and narrow (h^2_N) sense heritability estimates of nine yield components of maize at GRS.

character	H2B(%)	H2N(%)
Days to 50% anthesis	63.33	46.87
Days to 50% silking	63.00	37.97
Plant height	44.03	23.87
Ear height	51.64	46.68
Ear length	27.43	21.91
Ear per plant	10.68	6.66
Grains per ear	8.48	4.27
100-seed weight	43.28	29.24
Grain yield	23.31	12.88

The analysis of variance mean squares due to GCA as well as that due to SCA were significant for most of the traits (Table 4). The ratio of GCA : SCA for days to 50% anthesis, plant height, ear length, grain per ear, and grain yield were almost one or more than one indicating that the inheritance of these characteristics was due to GCA effects and largely controlled by additive genetic effects. Progeny selection using these traits would be effective in yield improvement of the current landraces. However, the ratio of GCA : SCA for days to %50silking, ear height, ear per plant and 100-seed weight were less than one suggesting that inheritance of these traits was mainly due to SCA effects and largely controlled by non-additive genetic effects. The use of these parameters as selection criteria in hybridization programs may be rewarding.

The magnitude and direction of GCA effects showed that the landrace Ring-8 was a good combiner for most of the studied traits (data not shown). Sennar showed good GCA for days to 50% silking and anthesis, number of ears plant⁻¹ (proliferous landrace) and grain yield, while Hegeri showed high GCA for 50% silking, ear length and plant and ear height. Parents showing significant GCA for several yield components would be desirable in

developing varieties and inbreds with similar yield potentials that can be expected to occur in improved open pollinated varieties and hybrids (Nevado and Cross, 1990).

Table 4. Combining ability analysis mean squares for nine characters in maize at GRS

Character	DF	Days to 50% anthesis		Days to 50% silking		Plant height		Ear height		Ear length	
		1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Reps	3	2.14	12.79*	18.64**	15.78**	51.18	240.90	35.0	254.47*	10.61**	9.57*
Entries	20	10.30**	13.38**	12.38**	10.11**	377.26**	362.20*	309.7**	273.72**	4.93**	4.99*
GCA	5	4.26**	7.37**	3.98**	4.94**	199.08**	217.53**	148.0**	583.54	1.33*	2.69**
SCA	15	2.01**	2.01*	2.75**	1.72**	59.39**	49.55	53.9**	103.14	1.21**	0.77
Error	60	0.30	1.05	0.40	0.69	22.74	36.33	14.7	16.74	0.49	0.64
GCA: SCA		0.29	0.99	0.19	0.52	0.60	1.71	0.6	0.59	0.15	2.0

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

Table 4 (continued). Combining ability analysis mean squares for nine characters in maize at GRS.

Character	DF	Ear per plant		Grains per ear		100-seed weight		Grain yield	
		1998	1999	1998	1999	1998	1999	1998	1999
Reps	3	0.12**	0.04	14105.0	11925.0*	9.83	7.60	1707367	117384
Entries	20	0.04	0.03	6874.0	6939.0	24.61**	9.18*	1527330	245404
GCA	5	0.00	0.06**	2104.0	5658.0**	7.33**	1.38	247470	2082706
SCA	15	0.01	0.01*	1385.34	425.09	5.76**	2.59*	426619	395924
Error	60	0.01	0.01	1876.79	1023.5	1.52	1.28	172308	227670
GCA: SCA		0.06	0.38	0.06	0.97	0.17	0.01	0.04	1.38

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

The analysis of SCA effects showed that about 34% of the crosses gave reasonably high SCA values for most of the traits measured, in both years (data not shown). Crosses (Red x Ahmar Mahali, Sennar x Ahmar Mahali» Sennar x Ahmar Balady, Hegeri x Ahmar Mahali and Hegeri x Ring-8) showed high SCA effects for most of the measured parameters. When the per se grain yield performance of these best crosses was considered, crosses (Hegeri x Ahmar Mahali, Hegeri x Ring-8 and Sennar x Ahmar Balady) gave high grain yields, while crosses (Sennar x Ahmar Mahali and Red x Ahmar Mahali) gave yields. These results suggest that not all crosses with high SCA effects would necessarily express high per se grain yield performance. The performance of the expected hybrid combination is dependent upon the extent to which favourable genes from one parent

supplement those contributed by the second parent (Hecker, 1968). Though parents Hegeri and Ahmar Mahali tend to show divergent GCA effects in opposite directions but they gave the best hybrid combination with high SCA effects. This indicates the interaction of good specific combiners contributing favourable genes for per se performance. Our results suggest that parents Ring-8, Hegeri and Red would be suitable for varietal improvement through recurrent selection while cross Hegeri x Ahmar Mahali, could be exploited for further improvement through avenues of hybrid production.

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