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Agronomic Performance, Genotype X Environment Interactions and Stability Analysis of Grain Sorghum (*Sorghum bicolor* L. Moench)

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Abstract: This research was undertaken to evaluate the performance of parental lines and their crosses under different environments for yielding ability and some traits and determine the most stable lines and hybrids. Testing newly developed genotypes under several environments is important for evaluating stability of performance and range of adaptation. Twenty five F_1 and their 10 parents of sorghum were evaluated at two locations (Assiut and Qena governorates) under early and late sowing dates in both 2007 and 2008 summer seasons. Year effects were significant for the studied traits. Location and date effects had the largest impact on the studied traits. The interaction effects of genotype with each of locations and dates were highly significant for all studied traits whereas genotype x year interaction effect was highly significant for days to blooming, plant height and grain yield. Genotype x year x date interaction effect was highly significant for plant height, 1000-grain weight and grain yield. However, genotype x year x location x date interaction effect was highly significant only for plant height and grain yield. Most of hybrids were significantly earlier, taller, heavier grain weight and higher grain yield compared to their parents and checks. Stability analysis for grain yield demonstrated that most of F_1 hybrids had higher yields than their parents, but the parents were relatively more stable. Four genotypes (three crosses; (A-73 x R-272), (A-604 x R-92010) and (A-613 x R-210) and one parent (R-273)) were the best stable genotypes. These genotypes gave higher yields compared to the average overall genotypes (hybrids and parents, respectively). These genotypes are considered as promising cultivars and it may be suitable for growing in a wide range of environments.

Key words: Grain sorghum, *Sorghum bicolor*, genotype, parents, hybrids, adaptation

INTRODUCTION

Grain sorghum (*Sorghum bicolor* L. Moench) ranks fourth in important as a cereal crop after wheat, rice and maize. The cultivated area of grain sorghum is 150 thousand hectare. Sorghum is grown in Upper Egypt from Giza to Aswan but most of the area (89 thousand hectare) is concentrated in Assiut and Sohag governorates and about 37 thousand hectare in Fayoum governorate (Anonymous, 2008). It is adapted to stress conditions; hot weather, drought, salinity and low soil fertility. Therefore, great governorates efforts are devoted to increase the cultivated area in Upper Egypt by reclaiming desert land (Hovny *et al.*, 2000).

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In Egypt maize and sorghum are similar in uses, sorghum flour is mixed with wheat flour for bread making, and stalks are used for fodder or fuel. At present, grain sorghum is a minor component of livestock feeds. Local demands for cereal, including grain sorghum are progressively increasing due to dramatic increase of population and the wide gap between production and consumption (Ali, 2000).

Newly genotypes generally need to be tested at many locations and for several years before being recommended for a given zone. To achieve this goal, multi-environments trials form the core of varietal testing programs locations. Several studies have investigated the effect of years and/or locations on agronomic traits on grain sorghum genotypes (El-Attar *et al.*, 1986; Nayeem and Bapat, 1989; Bakheit, 1990; Ahmed, 1993; Narkhede *et al.*, 1997; Ali, 2000; Hovny *et al.*, 2005). The differences among genotypes in agronomic traits are likely due to the different weather patterns and soil type from year to year and from location to another. Studies have indicated that temperature plays a vital role in the duration of plant growth stages, especially during pollination and grain filling. Studies conducted with genotypes under extreme temperature conditions have indicated that grains from sorghum plants exposed to low daily temperatures, resulting reduced grain yield (Francis *et al.*, 1984; Lothrop *et al.*, 1985).

El-Menshawy (1996), Mahmoud (1997), Amir (1999), Ali (2000) and Hovny *et al.* (2005) reported that most of hybrids were earlier, taller, higher grain yield and heavier in grain weight than their better parent under different environments.

Nachit *et al.* (1992) stated that the differential genotypic responses to variable environmental conditions especially when associated with changes in genotypic ranking, limit the identification of superior, stable hybrids. Francis *et al.* (1984) found that hybrids and populations were relatively more stable in late than in early sowings. The stable populations in late sowings did not produce yield higher than the average yield of all genotypes. Hybrids were more stable than populations in early sowings but the reverse was true in late sowings.

This research was undertaken to (1) evaluate the performance of parental lines and their crosses under different environments for yielding ability and some traits and (2) determine the most stable lines and hybrids.

MATERIALS AND METHODS

The basic material consisted of 10 grain sorghum lines introduced from ICRISAT; 5 cytoplasmic male sterile lines (A-lines; A-73, A-93, A-604, A-613 and A-614) and 5 restorers (R-lines; R-210, R-272, R-273, R-295 and R-92010). These parents were sown for hybridization on three different dates 1st, 15th and 30th June Qena Agric. Res. Farm, South Valley Univ. during the two summer seasons of 2006 and 2007 to avoid differences in flowering time and to increase hybrid seed. Each genotype was sown in three rows, 6 m long, 75 cm apart and 20 cm between plants within a row. Twenty five hybrid seeds were obtained.

The 25 hybrids comprising their 10 parents (five B-lines and five R-lines) and two checks (Shandaweel-1 hybrid and Dorado variety) were tested in field trials at two locations (Assiut Univ. Exper. Farm and South Valley Univ. Exper. Farm at Qena). In each location, the materials were sown at early (15th June) and late (15th July) planting dates in 2007 and 2008 summer seasons. Some physical and chemical properties of a representative soil sample of the experimental sites are presented in Table 1. Minimum and maximum daily temperatures during the growing season were obtained from the metrological station. at each location (Table 2). The total growing degree days GDD (Table 3), (base = 10°C) was calculated according to Saeed and Francis (1984) as follows:

Table 1: Some physical and chemical properties of a representative soil sample of the experimental sites

	Value*	
Soil property	Assiut	Qena
Sand (%)	23	74
Silt (%)	27	16.6
Clay (%)	50	9.4
Soil texture	Clay	Sandy loam
PH (1:1 Soil: Water suspension)	7.9	8.12
Organic matter (%)	1.61	0.35
Total N (%)	0.07	0.04
Available P (ppm)	11.25	9.4
K^+	0.35	0.19
Calcium carbonate (%)	2.5	13.6

*Each value represents the mean of two seasons

Table 2: Monthly high, low and mean temperatures for the 2007 and 2008 growing seasons in Qena and Assiut

		Qena						Assiut					
	Year	2007			2008			2007			2008		
Month	Day	Max.	Min.	Average	Max.	Min.	Average	Max.	Min.	Average	Max.	Min.	Average
June	16-30	40.83	26.82	33.83	40.99	25.83	33.41	39.50	22.98	31.24	39.71	22.84	31.28
July	1-15	40.13	25.64	32.89	40.82	26.34	33.58	38.24	22.33	30.29	36.76	25.95	31.36
	16-31	41.71	26.36	34.04	39.76	25.85	32.81	39.95	22.68	31.32	33.3	22.99	28.15
Average		40.92	26.00	33.46	40.29	26.10	33.20	39.10	22.51	30.80	30.80	24.47	29.75
August	1-15	41.47	25.83	33.65	39.69	25.34	32.52	37.23	22.09	29.66	38.67	22.33	30.50
	16-31	40.70	25.83	33.27	41.22	26.46	33.84	39.18	22.46	30.82	35.49	23.04	29.27
Average		41.09	25.83	33.46	40.46	25.90	33.18	38.21	22.28	30.24	37.08	22.69	29.88
Sept.	1-15	38.23	24.09	31.16	39.47	25.16	32.32	35.84	21.31	28.58	31.96	22.07	27.95
	16-30	35.97	21.30	28.64	38.85	24.07	31.46	33.64	19.19	26.42	34.69	19.59	26.71
Average		37.10	22.69	29.90	39.16	24.61	31.89	34.74	20.25	27.50	33.33	20.83	27.29
Oct.	1-15	36.53	21.93	29.23	35.50	20.84	28.17	36.4	18.33	27.37	33.25	17.52	26.57
	16-31	31.84	17.94	24.89	35.49	20.79	28.14	33.09	16.70	24.90	30.23	15.56	24.10
Average		34.19	19.94	27.07	35.50	20.82	28.16	34.74	20.25	27.50	31.74	16.54	27.29
Nov.	1-15	26.74	13.41	20.08	31.55	16.66	24.11	29.49	11.85	20.67	29.45	15.17	21.33
	16-31	24.93	11.03	17.98	26.41	10.27	18.34	26.32	9.56	17.94	26.28	12.16	18.45
Average		25.84	12.22	19.03	28.98	13.47	21.23	27.91	10.71	19.31	27.87	13.67	19.89

Table 3: Dates of planting and total growing degree days (GDD) in Qena and Assiut where grain sorghum trials were conducted

	Qena			Assiut		
	Total growing degree days (GDD)		Date of grain maturity	Total growing degree days (GDD)		Date of grain maturity
Planting date	2007	2008		2007	2008	
15th June	2703.5	2762.2	15th October	2382.0	2468.1	15th October
15th July	2607.9	2621.4	15th November	2312.3	2331.1	15th November

GDD = [(Maximum + Minimum temperature)/2-10 (Zero vegetation point)]

Genotypes were arranged in a randomized complete block design with three replications in each environment. Single row plot of 6 m length, 60 cm apart and 20 cm between hills within a row was used. After full emergence, three weeks after planting, seedlings were thinned to two plants per hill; 168700 plants ha^{-1}. All culture practices were applied as recommended for grain sorghum production.

The traits recorded for each plot were days to 50% blooming (when anthers dehiscing half-way down the panicle of 50% plants), plant height; cm, 1000-grain weight; g and grain yield of 3 m in middle portion of the plot (converted to Mg ha^{-1} at 15% moisture content).

Statistical Analysis

The combined analysis of variance was done according to (Gomez and Gomez, 1984) after carrying out homogeneity test. Phenotypic stability parameters; regression coefficients (b_i) and mean square deviations from regression (S^2d_i) were calculated for grain yield and for each genotype using the model described by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The planting dates at the two locations used to evaluate performance of the F_1 hybrids and their parents in this study provided a range of variation in seasonal climate (Table 2, 3). Seasonal climate, edaphic and planting dates are three important cultivation environmental factors influencing crop performance, in general. In terms of genetic effect, environment often causes instability in non additive genetic effect as also obtained by Pathak and Sanghi (1992) and Can *et al.* (1997).

The combined analysis of variance indicated that year and location effects were significant ($p<0.01$) for all the studied traits; days to 50% blooming, plant height, 1000-grain weight and grain yield (Table 4), reflecting the differences in climatic and edaphic factors prevailing at the two locations. Mean squares indicated that the effect of locations was more important than that of years for all traits. Planting Dates (PD) show significant ($p<0.01$) differences for all traits as it would be expected for optimum and late sowing dates. Highly significant differences among genotypes and their partitions; parents, crosses, females and males for all traits, which showed the presence of genetic variability in this material. Male x female interaction also showed highly significant differences for all traits, indicating specific

Table 4: Combined analysis of variance for days to 50% blooming, plant height, 1000- grain weight and grain yield Mg ha^{-1} of 25 F_1,s and their 10 parents over all environments

		Mean squares			
SOV	df	Days to 50% blooming	Plant height	1000-grain weight	Grain yield Mg ha^{-1}
Years (Y)	1	2540.55**	57973.68**	376.48**	116.99**
Locations (L)	1	7345.63**	642447.33**	1541.03**	352.91**
Y x L	1	17.88	5037.42**	2.01	0.13
Ea	8	30.44	364.10	7.36	0.58
Dates (D)	1	15886.86**	299384.04**	5077.51**	1133.23**
Y x D	1	38.13	3.41	3.31	0.06
L x D	1	62.72*	22250.03**	5.12	0.01
Y x L x D	1	28.83	287.19	2.40	1.87
Eb	8	8.38	81.00	6.89	0.57
Genotypes (G)	34	7847.36**	39473.69**	1014.34**	86.94**
Crosses (C)	24	165.76**	4622.13**	195.48**	14.40**
Males (M)	4	116.53**	12478.48**	787.68**	21.35**
Females (F)	4	418.74**	7605.04**	72.11**	13.94**
M x F	16	114.82**	1912.31**	78.27**	12.78**
Parents (P)	9	233.63**	9414.46**	68.47**	5.07**
P vs C	1	260729.20**	1146444.41**	29179.70**	2564.70**
G×Y	34	13.87**	397.62**	3.81	0.92**
G×L	34	37.37**	3929.52**	11.21**	2.51**
G×Y×L	34	4.68	298.69**	2.99	0.60
G×D	34	61.83**	1331.01**	17.24**	3.42**
G×Y×D	34	11.04*	160.59**	3.95	0.45
G×L×D	34	7.84	911.43**	9.44**	0.92**
G×Y×L×D	34	7.51	133.62**	3.57	0.80**
Ec	544	6.69	75.74	4.35	0.45

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

combining ability. Moreover, the relative of mean squares due to parents vs crosses was high and significant ($p>0.01$) for all studied traits, emphasizing great heterotic effects for these traits. These results are in agreement with these reported by Patel *et al.* (1987), Mahmoud (1997), Amir (1999), Ali (2000) and Hovny *et al.* (2005).

Genotypes x year interaction effects were highly significant for all traits except 1000-grain weight (Table 4). Genotype x location and genotype x planting date interaction effects were significant ($p<0.01$) for all traits, indicating that these traits differed between locations and planting dates among genotypes (Table 4). Interaction of genotypes with locations and planting dates was more important than that with years for all studied traits. Therefore, testing at more locations or dates at given locations should be done rather than testing in more years. Several workers stated that genotype x location and genotype x location x year interactions was more important than genotype x year interaction for sorghum yields (Obilana and El-Rouby, 1980; Saeed *et al*., 1984; Ali, 2000). Moreover, genotypes x years x locations x dates interaction was highly significant for plant height and grain yield, this indicates that it is essential to evaluate genotypes for such traits under different environments.

Environmental conditions at Assiut were good for sorghum production in both seasons compared to Qena as observed in Table 1 and 2. Early planting was better during growth, pollination and grain filling compared to late planting.

The data presented in Table 5, revealed that early planting registered earlier blooming, taller plant height, heavier 1000-grain weight and higher grain yield than late planting date in both locations in the two years. This suggests that both of temperature and edaphic factors could be playing a significant role in different plant growth stages. Also, Assiut was higher than Qena for all the studied traits over years.

The overall mean of crosses (Table 5) indicates that the crosses were earlier at Assiut compared to Qena location at early and late plantings. Furthermore, Assiut was better than Qena location in plant height, 1000-grain weight and grain yield Mg ha^{-1} in both of planting dates. Likewise, the crosses mean of days to 50% blooming and plant height was highly significant earlier and taller than the two cheks; Shandaweel 1 and Dorado. Respects to 1000-grain weight, the crosses mean (25.5 g) was highly significant heavier than Shandaweel 1, but not from Dorado. However, 10 crosses showed highly significant heavier grain weight than Dorado (24.6 g). The overall mean of crosses for grain yield (7.55 Mg ha^{-1}) was significantly higher than for the best check Shandaweel 1 (7.1 Mg ha^{-1}), and ten crosses highly significant outyielded the best check (Table 5).

Comparisons of F_1 hybrids with each of their parents and the two commercially checks (Shandaweel-1 hybrid and Dorado variety) exhibited that most of hybrids were significantly earlier blooming, taller plants, heavier 1000-grain weight and higher grain yield than both their parents and checks for all studied traits overall environments (Table 5). These data supports the results obtained by Borgonovi (1985), Tadesse and Debelo (1995), El-Menshawy (1996), Mahmoud (1997), Amir (1999), Ali (2000) and Hovny *et al.* (2005).

Stability Analysis

The joint regression analysis of variance showed highly significant yield differences among F1 hybrids as well as their parents (Table 6). The relative yield performance of crosses and their parents varied from environment to another as was indicated by significant hybrids x environments and parents x environments interactions.

Table 5: Average performance of 25 F1, s and their 10 parents at the two locations and two sowing dates over years for days to 50% blooming, plant height, 1000-grain weight and grain yield

	Days to 50% blooming					Plant height (cm)				
	Qena		Assiut			Qena		Assiut		
Parameters	June 15	July 15	June 15	July 15	Mean	June 15	July 15	June 15	July 15	Mean
A-Crosses										
A-73 x R-210	70.9	80.2	63.7	72.2	71.7	155.9	115.0	223.3	135.0	157.3
A-73 x R-272	70.0	82.3	66.0	75.0	73.3	167.5	120.9	252.5	161.7	175.6
A-73 x R-273	73.5	82.2	64.7	74.8	73.8	158.4	148.4	245.0	172.5	181.0
A-73 x R-295	68.5	78.2	59.7	66.5	68.2	188.4	85.8	237.5	125.9	159.4
A-73 x R-92010	71.9	82.0	61.9	70.4	71.6	171.4	105.0	201.7	130.0	152.1
A-93 x R-210	78.5	86.2	69.4	76.2	77.5	180.0	120.9	269.2	158.6	182.1
A-93 x R-272	73.3	84.2	69.7	75.4	75.7	181.7	117.9	240.9	130.9	167.9
A-93 x R-273	72.4	84.2	67.0	74.0	74.4	199.2	139.2	265.9	174.2	194.6
A-93 x R-295	70.3	80.9	64.4	71.5	71.8	172.5	110.8	201.7	133.4	154.6
A-93 x R-92010	69.7	83.9	65.4	78.2	74.3	157.5	113.4	217.5	135.9	156.0
A-604 x R-210	71.2	86.2	64.2	75.8	74.3	172.5	120.0	206.7	137.5	159.2
A-604 x R-272	72.7	85.7	64.0	77.0	74.8	155.9	132.5	196.7	156.7	160.4
A-604 x R-273	76.5	85.0	72.2	79.9	78.4	193.4	131.7	213.4	166.7	176.3
A-604 x R-295	72.2	84.5	69.0	81.4	76.8	155.9	95.0	195.9	125.9	143.1
A-604 x R-92010	73.7	85.5	70.7	79.9	77.4	143.4	136.7	197.5	172.5	162.5
A-613 x R-210	70.4	82.2	65.4	75.3	73.3	160.0	99.2	197.5	128.4	146.3
A-613 x R-272	78.2	84.9	68.8	77.7	77.4	185.9	125.9	219.2	165.0	174.0
A-613 x R-273	71.5	79.7	65.0	73.7	72.5	162.5	121.7	202.5	155.8	160.6
A-613 x R-295	70.7	86.2	68.9	78.2	76.0	172.5	108.4	200.0	126.7	151.9
A-613 x R-92010	75.9	83.7	68.7	77.4	76.4	163.4	94.2	210.5	116.7	146.3
A-614 x R-210	70.5	83.9	64.8	76.5	73.9	157.5	119.0	200.0	170.0	161.7
A-614 x R-272	79.5	87.0	74.2	81.9	80.6	155.0	124.2	177.5	170.9	156.9
A-614 x R-273	71.5	80.7	70.4	74.9	74.3	146.7	136.7	174.2	163.9	155.4
A-614 x R-295	76.8	81.7	69.3	79.2	76.8	151.7	96.7	197.5	115.0	140.2
A-614 x R-92010	75.5	80.5	72.3	77.3	76.4	125.9	117.5	169.2	141.7	138.5
Average of all crosses	73.0	83.2	67.2	76.0	74.9	165.4	117.4	212.5	146.8	160.6
B-Female parents										
A-73	78.5	86.2	72.3	78.9	79.0	132.5	99.2	157.5	114.2	125.8
A-93	69.8	80.5	65.0	75.5	72.7	126.7	105.0	208.4	120.0	140.0
A-604	76.0	80.4	70.7	76.2	75.8	118.4	85.0	176.7	101.7	120.4
A-613	77.4	84.7	73.4	81.0	79.1	140.8	76.7	175.0	99.2	122.9
A-614	78.5	87.0	72.8	81.0	79.8	131.7	85.0	208.4	111.7	134.2
Average of all females	76.0	83.7	70.8	78.5	77.3	130.0	90.2	185.2	109.3	128.7
C-Male parents										
R-210	75.8	84.0	73.0	78.7	77.9	174.2	123.3	196.7	155.9	162.5
R-272	74.0	78.9	69.0	74.5	74.1	170.9	115.0	213.4	145.9	161.3
R-273	75.5	85.2	70.2	79.5	77.6	150.0	126.7	210.8	162.5	162.5
R-295	83.5	88.0	78.5	84.0	83.5	155.8	122.5	262.5	150.0	172.7
R-92010	73.0	83.0	69.0	77.2	75.5	174.2	114.2	215.9	145.9	162.5
Average of all males	76.4	83.8	71.9	78.8	77.7	165.0	120.3	219.8	152.0	164.3
D-Checks										
Shandaweel 1	79.3	86.0	77.4	83.0	81.4	135.0	122.5	148.4	134.2	135.0
Dorado	82.5	87.5	78.9	83.9	83.2	112.5	101.7	125.9	111.7	112.9
Average of the checks	80.9	86.8	78.1	83.4	82.3	123.8	112.1	137.1	122.9	124.0
LSD 0.05					1.5					5.0
LSD 0.01					2.0					6.6

	1000-grain weight g					Grain yield Mg ha^{-1}				
	Qena		Assiut			Qena		Assiut		
Parameters	June 15	July 15	June 15	July 15	Mean	June 15	July 15	June 15	July 15	Mean
A-Crosses										
A-73 x R-210	23.4	19.5	29.6	20.7	23.3	7.9	5.0	9.4	6.8	7.28
A-73 x R-272	24.3	19.6	28.2	26.0	24.5	9.5	6.3	10.5	8.6	8.70
A-73 x R-273	24.1	20.0	29.1	20.3	23.3	8.9	7.2	10.0	7.7	8.47
A-73 x R-295	27.7	23.3	31.3	26.0	27.1	7.9	5.1	9.2	6.9	7.27
A-73 x R-92010	25.7	23.8	33.5	27.0	27.5	8.3	4.8	10.2	6.5	7.45

Table 5: Continued

	1000-grain weight g					Grain yield Mg ha^{-1}				
	Qena		Assiut			Qena		Assiut		
Parameters	June 15	July 15	June 15	July 15	Mean	June 15	July 15	June 15	July 15	Mean
A-Crosses										
A-93 x R-210	21.1	17.7	21.5	18.3	19.7	8.8	5.9	10.2	7.8	8.18
A-93 x R-272	27.4	21.1	25.6	22.4	24.1	8.8	6.2	10.2	6.6	7.96
A-93 x R-273	24.2	22.3	27.4	23.1	24.2	9.7	6.6	10.1	7.2	8.39
A-93 x R-295	26.8	21.9	30.9	25.0	26.1	8.4	6.0	9.2	7.2	7.70
A-93 x R-92010	31.4	23.8	34.6	29.3	29.7	7.7	5.2	9.2	7.0	7.26
A-604 x R-210	27.9	24.3	29.6	25.5	26.8	8.0	6.3	9.5	7.4	7.82
A-604 x R-272	27.9	25.8	30.6	26.1	27.6	9.3	7.2	10.5	8.4	8.86
A-604 x R-273	22.7	20.2	25.9	21.2	22.5	7.9	4.9	9.7	7.1	7.40
A-604 x R-295	30.0	24.7	34.1	27.6	29.0	6.4	4.4	7.0	5.4	5.83
A-604 x R-92010	29.6	22.9	31.3	28.5	28.0	8.4	5.3	9.0	7.8	7.62
A-613 x R-210	23.4	20.5	28.1	21.0	23.2	9.7	6.5	10.2	8.4	8.69
A-613 x R-272	22.2	20.0	27.0	20.5	22.4	7.4	5.1	8.2	5.6	6.55
A-613 x R-273	27.0	20.3	29.4	24.4	25.2	6.8	5.4	8.2	6.2	6.64
A-613 x R-295	31.3	23.1	33.7	26.8	28.7	6.4	4.4	7.5	5.4	5.95
A-613 x R-92010	31.0	24.2	31.6	29.1	28.9	7.3	6.3	9.1	6.8	7.36
A-614 x R-210	26.5	19.2	29.0	22.6	24.3	7.0	4.1	10.3	8.0	7.35
A-614 x R-272	24.4	18.4	27.2	21.2	22.8	8.4	5.2	9.9	6.8	7.56
A-614 x R-273	22.3	18.9	26.2	21.4	22.2	7.9	5.5	8.5	6.8	7.20
A-614 x R-295	28.3	22.3	29.8	25.7	26.5	7.9	5.8	9.4	7.3	7.59
A-614 x R-92010	32.2	26.3	34.7	30.8	31.0	7.8	5.7	10.9	6.7	7.78
Average of all crosses	26.5	21.7	29.6	24.4	25.5	8.1	5.6	9.5	7.1	7.55
B-Female parents										
A-73	24.3	19.8	28.6	23.5	24.0	7.4	5.1	8.4	6.3	6.60
A-93	25.8	17.1	27.3	22.6	23.0	5.7	3.9	7.6	5.9	5.77
A-604	23.3	19.7	27.2	22.2	23.1	6.5	4.8	7.3	5.8	6.11
A-613	24.5	17.7	28.2	21.5	22.9	7.4	4.7	8.9	6.1	6.79
A-614	24.4	21.2	25.7	22.0	23.4	7.3	6.0	8.4	7.1	7.08
Average of all females	24.4	19.1	27.4	22.3	23.3	6.8	4.9	8.1	6.2	6.47
C-Male parents										
R-210	22.9	17.5	24.4	18.3	20.7	7.0	4.4	8.1	5.6	6.26
R-272	20.0	15.8	22.8	19.0	19.4	7.1	5.4	9.5	6.4	7.11
R-273	23.3	18.5	27.4	20.5	22.4	7.7	5.7	9.0	6.1	7.13
R-295	23.9	18.4	25.4	19.3	21.7	7.1	4.4	7.9	6.0	6.39
R-92010	27.3	21.6	28.8	24.1	25.4	7.6	4.9	8.5	5.7	6.68
Average of all males	23.5	18.3	25.7	20.2	21.9	7.3	5.0	8.6	6.0	6.72
D-Checks										
Shandaweel 1	22.1	18.8	26.3	21.5	22.1	7.7	5.6	9.0	6.1	7.10
Dorado	23.3	20.5	29.2	25.6	24.6	7.1	4.4	7.9	6.2	6.40
Average of the checks	22.7	19.6	27.7	23.5	23.4	7.4	5.0	8.5	6.1	6.75
LSD 0.05					1.2					0.38
LSD 0.01					1.6					0.50

Table 6: The joint regression analysis of variance for grain yield for F_1 crosses and their parents

	Mean squares			
SOV	df	F_1 crosses	df	Parents
Genotypes	24	4.82**	9	1.85**
Env. + (G x Env.)	175	2.77**	70	2.29**
Env. (linear)	1	425.73**	1	138.90**
G x Env. (linear)	24	0.76**	9	0.55*
Pooled deviation	150	0.27**	60	0.27**
Pooled error	384	0.13	144	0.17

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

However, both F_1 hybrids and their parents showed highly significant differences in deviations from regression. These results suggest that the magnitudes of genotype x environment interactions in this set of materials are largely due to differential nonlinear response of genotypes to varying environments.

Yield stability of genotype is evaluated from estimates of stability parameters; b_i and s^2d_i (Table 7, Fig. 1). Although the grain yield of F_1 hybrids and their parents were influenced by year, location and dates, the fluctuations for a majority of them were considered stable according to Eberhart and Russell analysis. (A-73 x R-272), (A-604 x R-92010) and (A-613 x R-210) could be considered the best stable hybrids. It has a b- values of 1.05, 0.95 and 0.95, respectively and produced yield higher than average of all crosses. This indicates that these hybrids may be suitable for growing in a wide range of environments. R-273 also seemed to be the best stable parent since it has a b-value of 1.03 and produced yield higher than average yield of all parents. These genotypes would be promising cultivars. Bakheit (1990), Ahmed (1993) and Ali (2000) also demonstrated that some genotypes which were superior in grain yield showed average stability. In addition, grain yield was considered consistently better in favorable environments with the cross (A-614 x R-272) and three parents; (A-613, R-272 and R-92010) because of their high b-value (b_i>1.0). This emphasizes that these genotypes are less environmentally sensitive. Similar results were obtained by

Table 7: Genotypes average performance over eight environments and stability parameters of 25 F_1 crosses and 10 parents for grain yield

No.	A-Crosses	$\bar{X}$	b_i	S^2d_i
1	A-73 x R-210	7.28	1.14	-0.0250
2	A-73 x R-272	8.70	1.05	0.0108
3	A-73 x R-273	8.47	0.80	-0.0201
4	A-73 x R-295	7.27	1.05	0.3368*
5	A-73 x R-92010	7.45	1.42**	-0.0147
6	A-93 x R-210	8.18	1.09	0.3047*
7	A-93 x R-272	7.96	1.09	0.3347*
8	A-93 x R-273	8.39	1.09	0.5629**
9	A-93 x R-295	7.70	0.89	-0.0620
10	A-93 x R-92010	7.26	0.96	0.1544
11	A-604 x R-210	7.82	0.82	-0.0897
12	A-604 x R-272	8.86	0.82	0.0175
13	A-604 x R-273	7.40	1.22	-0.0267
14	A-604 x R-295	5.83	0.72*	-0.0003
15	A-604 x R-92010	7.62	0.95	0.1750
16	A-613 x R-210	8.69	0.95	0.0909
17	A-613 x R-272	6.55	0.89	0.0929
18	A-613 x R-273	6.64	0.74*	0.1357
19	A-613 x R-295	5.95	0.86	0.0303
20	A-613 x R-92010	7.36	0.72	0.0631
21	A-614 x R-210	7.35	1.48**	1.1748**
22	A-614 x R-272	7.56	1.23	0.0354
23	A-614 x R-273	7.20	0.78	-0.0407
24	A-614 x R-295	7.59	0.93*	-0.0559
25	A-614 x R-92010	7.78	1.29*	0.3957**
Mean	7.55	-	-	
$LSD_{0.05}$	0.20	-	-	
No.	**B-Parents**	$\bar{X}$	b_i	S^2d_i
1	A-73	6.60	0.93	0.229
2	A-93	5.77	1.02	0.092
3	A-604	6.11	0.76	0.120
4	A-613	6.79	1.20	0.019
5	A-614	7.08	0.60**	0.228
6	R-210	6.26	1.11	-0.096
7	R-272	7.11	1.22	0.111
8	R-273	7.13	1.03	-0.037
9	R-295	6.39	0.97	0.151
10	R-92010	6.68	1.18	0.085
Mean		6.59	-	-
$LSD_{0.05}$		0.23	-	-

*, **Significantly different from unity for (b_i) and from zero for (S^2d_i) at 0.05 and 0.01 probability levels, respectively

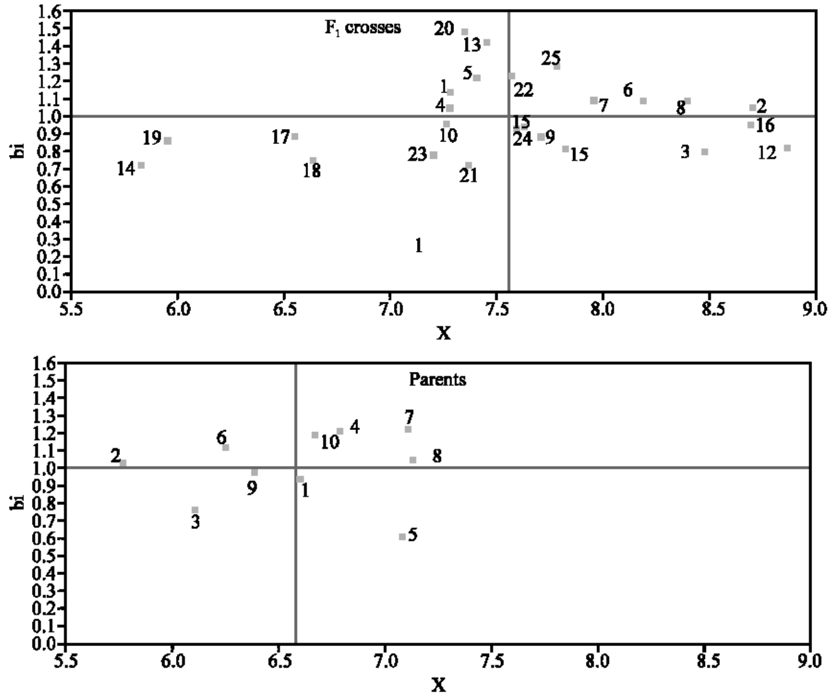

Fig. 1: Distribution of stability parameters for grain yield

Muppidathi *et al.* (1995) and Ali (2000). However, grain yield for the crosses (A-73 x R-273), (A-93 x R-295), (A-604 x R-210) and (A-604 x R-272) and one parent; (A-73) had low b-values, and thus, was considered relatively better in less favorable environments (Table 6, Fig. 1). Meanwhile, grain yield for the crosses no. 4, 6, 7, 8, 21 and 25 had high b-values and thus, were considered unstable. This suggested that these crosses are unstable particularly in low temperature environments.

The results indicated that stability analysis for grain yield demonstrated that most F_1 hybrids had higher yields than their parents, but the parents were relatively more stable.

CONCLUSION

Results from this study showed that among the 25 F_1 crosses and their parents under investigation, genotype x year interaction effect was significant for days to 50% blooming, plant height and grain yield, except 1000-grain weight. Significant genotype x location and genotype x planting date interaction effects was observed for all traits. Significant genotype x year x location x planting date interaction effects was observed for grain yield. This suggests that genotypes need to be tested under several environments before being recommended for given zone. Three crosses; crosses (A-73 x R-272), (A-604 x R-92010) and (A-613 x R-210) and produced yield higher than average of all crosses. These crosses are considered as promising cultivars, it can be tested in large scale and produce the high yielded crosses commercially. Only one parent; (R-273) was the best stable and gave yield higher than average of all parents. This parent can be used in a breeding program for growing in a wide range of environments.

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