



Yield Performance and Adaptation of Four Sorghum (*sorghum bicolor* (L.) Moench) Hybrids Evaluated under Sudan Environmental Conditions

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Abstract

Sorghum plays a significant role for the small holder farmers of Sudan. It is the many sources of food and income for majority of Sudanese but yields are low and crop management lacking leading to smallholder food and income insecurity. An experiment was carried out during seasons 2017 and 2018 at four locations; tow under irrigated condition and tow under rain fed conditions. The irrigated sites were; Wad Medani, and Suki, and the rainfed sites were Gadarif and Damazin. The hybrids tested were Express, Ahmos, ISIS and MH-1, while, HD-1, HD-2 ,W.Ahmed and Tabat were used as checks. The objective of this study was to evaluate the grain yield performance, stability and adaptability of these hybrids under diverse environmental conditions. The design used was a randomized complete block design (RCBD) with four replications. Sowing was done at the first week of July under irrigated conditions and at the first to the third week of July under rain fed conditions depending on the effective onset of rainfall. All Other cultural practices were carried as recommended by the Agricultural Research Corporation (ARC). The data collected were grain yield, Stover yield, days to 50% flowering, plant height, panicle length and 1000 grain weight. Combined analysis of variance showed significant differences for grain yield. AMMI ANOVA showed highly significant ($P \leq 0.01$) differences between environments (E), Genotypes (G) and their interactions (GEI). The partitioning of GE interaction through AMMI model analysis revealed that, the two terms (PCA1 and PCA2) were significant and explained that 83.7% of the total GE sum of squares. According to the AMMI estimates per environments; the Express hybrid was found to be the best and was selected 7 times in eight environments also , had PCA values close to zero (near to origin).meaning that it was adapted, high grain yield compared to all checks (3.5 t/h). Express hybrid performed consistently well across the diverse environments indicating good stability and adaptation ,Also showed agronomic traits (days to 50% flowering, plant height, panicle length,1000 grain weight and Stover yield) better and comparable to all checks. Across different environmental conditions, Express hybrid had higher grain yield (3.5 t/h) compared to all checks and over all mean grain yield, also selected seven times out of eight environments indicating its wide adaptation This hybrid are therefore recommended for commercial production in the Sudan.

Keywords: Yield Performance, Sorghum Adaptation, Hybrids Evaluated Environmental Conditions.

Introduction

Sorghum (*Sorghum bicolor* (L) Moench) is an important food and feed crop. As an energy supplier for the world's population, it ranks sixth, and it is fifth in importance among cereals. It was first domesticated in the region of North East Africa. The region of Eastern Sudan and Ethiopia is considered a center of probable origin (Doggett and Prasada Rao, 1995). Doggett (1988) reported that, the greatest genetic diversity of cultivated and wild sorghum is present in East Africa. Worldwide, it is grown over 42 countries (Belum VS Reddy *et al.* 2004) Developing countries growing 90% of the world sorghum area and producing 70% of the total sorghum production. Semi-arid tropical Asia and semi-arid tropical Sub-Saharan Africa grow about 60% of the world area (ICRISAT and FAO, 1996) .In the Sudan sorghum, is the main staple food especially in rural areas of the country, and is used in different forms. The national average yield in the Sudan was (250 kg/fed) which is very low compared to that obtained at research stations. This is due to the use of low yielding poor seed quality cultivars and poor crop management. In the Sudan, sorghum is the most important cereal crop for both production and consumption. It is the main staple food specially in rural areas of the country, and is used in different forms. However, productivity per



unit area is low due to the fact that, most of the crop (90%) is produced under low, medium to high rainfall (FAO, 1995). The national average yield in the Sudan is about (250 kg/fed) which is equivalent 18% of that obtained at the research stations (Ishag and ajeeb, 1987) and this was attributed to the use of low yielding cultivars as well as poor cultural practices. During the last 15 years, plant breeders in the Agricultural Research Corporation have successfully developed high yielding open pollinated cultivars such as FW Ahmed, Ingaz (Osman and Mahmud 1992) and Tabat (Osman *et al.* 1996). In addition, many other cultivars suitable for both irrigated and rain fed sectors, also developed Butana and Bashayer (Ibrahim *et al* 2007), and AG-8 (Abdalla *et al* 2009). Recently plant breeders in the ARC were releasing hybrids such as DIA-07666, PAC-501 and E-1 (Elasha *et al.* 2011) as well as hybrids such as Gezira, Suki and Gedarif (Mohammed *et al.* 2016, Elasha *et al.* 2016). These hybrids were suitable for irrigated conditions and high rain fall areas of the Sudan.

Materials and Methods

Multi-environmental trials were carried during seasons 2017 and 2018 at four locations, two under irrigated conditions and two under rain fed conditions. The irrigated sites were; Wad Medani, and Suki, and the rain-fed sites were; Gadarif, and Damazin. The hybrids tested under both irrigation and rain fed were Express, Ahmos, ISIS and MH-1, while, HD-1, HD-2, W.Ahmed and Tabat which was used as checks. Land was prepared by disc ploughing, disc harrowing, leveling and ridging at the irrigated site, and by disc harrowing and ridging at the rain-fed sites. The design used at each site and season was a randomized complete block with four replications. Sowing was carried at the first week of July under irrigation and at the first to the third week of July under rain fed conditions depending on the onset of rainfall. Under irrigation, the hybrids were sown to five rows, 5 m length on ridges; 0.8 m apart at 0.3 m intra row spacing and thinned to three seedlings per hill. Under rain fed conditions, they were also sown to five rows 5 m in length, on flat; 0.8 m apart at 0.2 m intra row spacing and thinned to two seedlings per hill. In each season, urea at a rate of 80 kg and 40 kg /fed was applied under irrigation and rain fed sites respectively. Thinning was carried at two to three weeks after emergence at each site during each season. Other cultural practices such as irrigation, weeding etc. were carried as recommended by the Agricultural Research Corporation. The net harvested area at each site and season was three rows x 4 m length x 0.8 m for grain yield and 1 m length x 0.8 m x 3 rows for Stover. The data recorded at each site and seasons were; days to 50% flowering, panicle length, plant height; grain yield, Stover yield and 1000 grain mass. Chemical analysis and organoleptic tests were carried for the most promising hybrids. Samples of selected hybrids were subjected to analysis to perform physical and proximate chemical characteristics.

Results and Discussion

Morphological traits:

Days to 50% flowering

From the combined analysis of variance of the two seasons 2017 and 2018, there were highly significant differences ($P \leq 0.01$) between the tested genotypes in their days to 50% flowering (Tables 1a and 1b). At the irrigated sites, days to 50% flowering ranged between (66-72) days with a grand mean of 69 days; Express hybrid was found to be earlier (66 days) compared to all checks, while Tabat and W.Ahmed were found to be late (72) days (Table 1a). At the rain-fed sites, this trait also showed highly significant differences between the hybrids ($P \leq 0.01$) in their days to 50% flowering and the data were presented at (Table 1b). Days to 50% flowering ranged between (59-73 days) with a grand mean of 67 days, Express hybrid was found to be



early compared to all checks. From these results. Express hybrid was found to be earlier in both irrigated and rain -fed areas.

Table (1a) Mean of days to 50% flowering of sorghum hybrids evaluated over four environments during season 2017/18

*, **,*** significant at 0.05, 0.01 and 0.001 probability level, respectively

NS: not significant

Table (1b) Means of days to 50% flowering of sorghum hybrids evaluated over four

site location	Irrigated environmental conditions				Mean
	Medani	Medani	Suki	Suki	
genotypes	2017	2018	2017	2018	
1- Express	65	65	76	59	66
2- Tabat	69	71	72	67	70
3- Ahmos	70	71	79	60	70
4- HD-2	64	70	70	65	67
5-HD-1	70	72	69	61	68
6-ISIS	64	71	72	73	70
7- MH-1	70	71	73	74	72
8- W.Ahmed	69	70	80	68	72
Mean	68	70	74	66	69
CV%	6	2.6	9.2	2.2	6
SE±	2.9NS	1.27**	3.42Ns	1.032**	1.46**

Environments during season 2017/18.

Site location	Rain fed environmental conditions				Mean
	Gadaref	Gadaref	Damazin	Damazin	
genotypes	2017	2018	2017	2018	
Express	61	57	59	61	59
Tabat	69	67	69	60	69
Ahmos	64	66	69	69	67
HD-2	66	66	67	68	67
HD-1	60	63	63	60	64
ISIS	68	60	60	66	66
MH-1	69	67	69	69	68
W.Ahmed	67	66	60	69	68
Mean	67.7	66	66	67	67
CV%	2.9	1.0	2.4	2.3	2.3
SE±	0.966**	0.703**	1.14**	1.117**	0.555**

*, **,*** significant at 0.05, 0.01 and 0.001 probability level, respectively

NS : not significant

Plant height (cm)

At the irrigated sites, there were highly significant differences among the tested genotypes for plant height , data were presented in (Table 2a). Same results were reported by Elasha and Mohammed (2021) The plant height for genotypes was ranged between (120.3-160.5 cm) for Express and HD-1 , Express was found to be short compared to all checks. Development of medium and short plant height hybrids is very important for plant breeders because they are suitable for combine harvesting and with stand lodging. At the rain fed sites, also there were highly significant differences between the tested genotypes for this trait ($P \leq 0.01$) and data were presented in (Table2b). Plant height ranged between (114.8-165.1 cm) for Express hybrid and for hybrid HD-2 , with grand mean of (145.7). From this study it can be



concluded that, the Express hybrid found was to be shorter compared to the all checks (Table 2b).

Table 2a. Means of plant height (cm) of sorghum hybrids evaluated over four environments season 2017/18.

site location	Irrigated environmental conditions				Mean
	Medani	Medani	Suki	Suki	
genotypes	2017	2018	2017	2018	
1- Express	116.9	116.5	120	128	120.3
2- Tabat	134.3	137.5	134	156	140.4
3- Ahmos	161.5	169.5	157.3	127.5	153.9
4- HD-2	160.9	206.3	134.7	137.5	159.9
5-HD-1	170	148.3	178.7	144.8	160.5
6-ISIS	126.4	148	120.7	164.5	140
7- MH-1	128.3	107.5	143.5	159.8	134.8
8- W.Ahmed	144.5	147	136.5	173	150.3
Mean	142.9	147.6	140.7	148.9	145
CV%	17.2	2.8	3.6	10.6	10.3
SE±	17.37*	2.9**	3.621**	11.21**	10.34***

*, **, ***
signifi

cant at 0.05, 0.01 and 0.001 probability level, respectively

NS: Not significant

Table 2b. Means of plant height (cm) of sorghum hybrids evaluated over four environments during season 2017/18.

site location	Rain fed environmental conditions				Mean
	Gadaref	Gadaref	Damazini	Damazini	
genotypes	2017	2018	2017	2018	
1- Express	123.8	126.5	105.8	103	114.8
2- Tabat	145.2	143.2	138.2	141.2	142
3- Ahmos	139.2	135.9	165.2	165	151.4
4- HD-2	143	144.1	181.5	177.5	161.5
5-HD-1	151.8	148.2	137	140	144.2
6-ISIS	146.8	145.8	183.2	186.2	165.5
7- MH-1	148	147	139.5	144.8	144.8
8- W.Ahmed	131.5	130.3	151	152.5	141.3
Mean	141.2	140	150.1	151.3	145.7
CV%	17.3	18.1	4.2	4.4	12.5
SE±	17.26NS	17.81Ns	4.46**	4.71**	12.88**

***, **, *significant at 0.05, 0.01 and 0.001 probability level, respectively

NS: Not significant

Panicle length (cm)

Across irrigated environments, there were highly significant differences among genotypes for this trait (Table 3a). This trait ranged from (24.8 cm) for hybrid ISIS to (29.7 cm) Tabat with a general mean of (27 cm), hybrid Express and Tabat were found had longest panicle length compared to the all checks. At the rain fed sites, this trait showed highly significant differences and ranged from (27.4 cm) for W.Ahmed to (33.4 cm) for HD-1. (Table 3b).



Table 3a. Mean of panicle length (cm) for sorghum hybrids evaluated over four environments during season 2017/18.

site location	Irrigated environmental conditions				Mean
	Medani	Medani	Suki	Suki	
genotypes	2017	2018	2017	2018	
1- Express	29.3	26.5	27.5	34.7	29.5
2- Tabat	27.5	28.7	29	33.7	29.7
3- Ahmos	25.3	27.2	22.7	32.2	26.8
4- HD-2	25.7	24.7	28.7	31.3	27.6
5-HD-1	23.4	24	24.5	32.3	26.1
6-ISIS	23.9	23.5	26.5	25.5	24.8
7- MH-1	24.8	22.2	25.5	27.3	24.9
8- W.Ahmed	24.3	22	24.2	35	26.4
Mean	25.5	24.8	26.1	31.5	27.
CV%	15.2	7.7	6.8	7.5	9.7
SE±	1.94Ns	0.962**	0.886**	1.689**	1.422**

*, **,*** significant at 0.05, 0.01 and 0.001 probability level, respectively

NS : Not significant

Table 3b. Mean of panicle length (cm) for sorghum hybrids evaluated over four environments during season 2017 /18.

site location	Rain fed environmental conditions				Mean
	Gadaref	Gadaref	Damazin	Damazin	
genotypes	2017	2018	2017	2018	
1- Express	28.6	28.8	29	28.5	28.8
2- Tabat	28.5	29	29.7	29.2	29.1
3- Ahmos	28.2	27.4	28.5	26.7	27.7
4- HD-2	28.5	28	36.7	33.5	31.7
5-HD-1	32.2	32.9	35.2	33.3	33.4
6-ISIS	29	29	29.3	28.7	29
7- MH-1	28.5	29.1	29.5	30	29.3
8- W.Ahmed	31	30.7	23.3	24.7	27.4
Mean	29.3	29.4	30.2	29.3	29.6
CV%	10	12.3	5.9	6.9	9.1
SE±	1.47Ns	2.56Ns	1.25**	1.14**	1.48**

***, **, * significant at 0.05, 0.01 and 0.001 probability level, respectively

NS : Not significant

1000 grain weight (g)

1000 grain weight showed highly significant differences between the tested genotypes (Table 4a). This trait ranged between (21.7 -25.1g) for Tabat and Ahmos, with grand mean of 23.5 g, at the irrigated sites, also same results were reported by Shinde *et al* (2010) . While at the rain fed sites, this trait showed no significant differences among the tested genotypes except at Gadaref in the first season (Table 4b). From these results it was concluded that, Express hybrid had lighter seed weight comparable to all checks.



Table 4a. Mean of 1000 grain weight /g of sorghum hybrids evaluated over four environments during season 2017/18.

site location	Irrigated environmental conditions				Mean
	Medani	Medani	Suki	Suki	
genotypes	2017	2018	2017	2018	
1- Express	22.4	24	22.7	22.7	22.9
2- Tabat	23.7	24	23	22.7	23.3
3- Ahmos	25.8	25.5	24	24.5	25.1
4- HD-2	25.5	25.3	24	23.7	24.6
5-HD-1	25.6	23.5	26.5	23.5	24.8
6-ISIS	22.9	23.7	20.2	22.5	22.3
7- MH-1	20.7	22.7	20	23.6	21.7
8- W.Ahmed	23.4	23	24.7	23.3	23.6
Mean	23.8	23.9	23.2	23.3	23.5
CV%	7.6	5.6	10.9	7.1	8.0
SE±	0.906*	0.672Ns	1.261*	0.830Ns	14.97**

***, **, *significant at 0.05, 0.01 and 0.001 probability level, respectively

NS : Not significant

Table 4b. Mean of 1000 grain weight /g of sorghum hybrids evaluated over four environments during season 2017/18.

site location	Rain fed environment				Mean
	Gadaref	Gadaref	Damazin	Damazin	
genotypes	2017	2018	2017	2018	
1- Express	25.7	25	26	25.7	25.6
2- Tabat	23.5	22.7	24.7	25.5	24.1
3- Ahmos	22.7	24.1	24.2	26.5	24.4
4- HD-2	23.7	24.5	24.5	26	24.7
5-HD-1	24.5	25.2	23.7	25.5	24.7
6-ISIS	24	24.5	23.3	25.2	24.2
7- MH-1	24	24.5	22	24.2	23.6
8- W.Ahmed	23.7	22.5	21.7	24	23
Mean	24	24.2	23.7	25.3	24.3
CV%	11.4	16.6	5.2	7.0	10.9
SE±	1.36Ns	2.828Ns	0.872**	0.889Ns	1.326Ns

***, **, *significant at 0.05, 0.01 and 0.001 probability level, respectively

NS : Not significant

Stover yield t/ha

Across the irrigated environments, there were significant difference ($P \leq 0.01$) for stover yield and the results were shown in (Table 5a). Stover yield ranged from (6.9 t/ha) for hybrids Express and Ahmos to (8.1 t/ha) for hybrid ISIS and the higher stover yield was obtained by the hybrid ISIS (8.1 t/ha) and the lowest stover yield was recorded by the hybrids Express and Ahmos. From the above results, hybrids had stover yield comparable to the hybrid check HD-2 at the irrigated sites. Across the rain fed sites, this trait showed significant differences among the tested genotypes and ranged from (4.3 t/ha) for hybrid Express to (5.5 t/ha) for hybrids HD-2 and ISIS with a general mean of 5.1 t/ha (Table 5b). Hybrid Express had stover yield comparable to checks Tabat and HD-1 (Table 5b).



Table 5a. Mean of Stover yield (T/ha) of sorghum hybrids evaluated over four environments during season 2017/18.

site location	Irrigated environmental conditions				Mean
	Medani	Medani	Suki	Suki	
genotypes	2017	2018	2017	2018	
1- Express	6	8.5	6.2	7.2	6.9
2- Tabat	6.8	8.5	7	8.1	7.9
3- Ahmos	5.5	7.3	8.2	6.7	6.9
4- HD-2	5.9	8.1	7.6	7.9	7.4
5-HD-1	6	8.4	9.2	7.6	7.8
6-ISIS	5.5	7.8	7.3	11.7	8.1
7- MH-1	6	7.5	9.3	8	7.7
8- W.Ahmed	5.7	7.6	8.3	9.7	7.8
Mean	6	7.9	7.9	8.4	7.6
CV%	13.2	5.6	19.2	17.0	15.0
SE±	0.393Ns	0.222*	0.759Ns	0.714*	0.940*

*, **, *** significant at 0.05, 0.01 and 0.001 probability level, respectively

NS: Not significant

Table 5b. Mean of Stover yield (T/ha) of sorghum hybrids evaluated over four environments during season 2017/18..

site location	Rain fed environmental conditions				Mean
	Gadaref	Gadaref	Damazin	Damazin	
genotypes	2017	2018	2017	2018	
1- Express	4.2	3.4	4.3	5.3	4.3
2- Tabat	3.4	2.9	6.3	6.4	4.8
3- Ahmos	4.5	3.7	6.7	6.5	5.4
4- HD-2	4.2	3.6	7.2	6.9	5.5
5-HD-1	4.2	3.6	5.7	6.2	4.9
6-ISIS	4.2	3.9	7	6.9	5.5
7- MH-1	3.5	2.6	6.5	6.3	4.7
8- W.Ahmed	4.1	3.9	6.9	6.6	5.4
Mean	4	3.5	6.3	6.4	5.1
CV%	22.7	28.2	6.4	5.5	14.2
SE±	0.46Ns	0.49Ns	0.2016**	0.177**	0.35**

*, **, *** significant at 0.05, 0.01 and 0.001 probability level, respectively

NS: Not significant

Grain yield and its stability

Across irrigated sites, there were highly significant differences ($P \leq 0.01$) among hybrids for this trait (Table 6a). same results were reported by Elssidig and Elasha (2015) Grain yield ranged between (4.6 -3,5 t/ha) to (3.5 t/ha), with the grand mean of (4.1 t/ha). The highest mean grain yield were depicted by the hybrid HD-1 (4.6 t/ha), while the lowest grain yield were exhibited by Tabat (3.5 t/ha). The hybrids Express out yielded all other checks Tabat, W.Ahmed and HD-2 in grain yield and comparable to HD-1 (Table 6a). Across the rain- fed sites, the grain yield also showed highly significant differences among the hybrids (Table 6b). Grain yield ranged between (2.8 t/ha) to (2.2 t/ha), with a grand mean of 2.4 t/ha. The highest mean grain yield was recorded by the hybrid HD-2 (2.8 t/ha), while the lowest mean grain yield was exhibited by HD-1, ISIS and W. Ahmed (2.2 t/ha). From the results, it was found that, Express hybrid out yielded the checks W. Ahmed and Tabat and comparable to HD-1 and HD-2 at irrigated and rain fed sites respectively (Table 6b).



Table 6a. Mean of grain yield (t/ha) of sorghum hybrids evaluated over four environments during season 2017/18.

site location	Rain fed and irrigated environmental condition				
genotypes	Medani 2017	Medani 2018	Suki 2017	Suki 2018	Mean
1- Express	4.2	3.6	4.1	5.6	4.4
2- Tabat	4.2	3.9	4	5	4.3
3- Ahmos	4	3.4	4.1	5.2	4.1
4- HD-2	4.1	3.5	3.9	4.8	4.1
5-HD-1	4.2	4	4.5	5.8	4.6
6-ISIS	4	3.8	4.1	4.7	4.2
7- MH-1	3.2	3.1	3.5	4.5	3.5
8- W.Ahmed	3.6	3.1	3.6	4.6	3.7
Mean	3.9	3.5	4	5.1	4.1
CV%	8.1	7.4	18.4	11.7	12.5
SE±	0.1621**	0.132**	0.369Ns	0.297 *	0.2726**

*, **, *** significant at 0.05, 0.01 and 0.001 probability level, respectively

NS: Not significant

The combined analysis of variance according to the AMMI model was presented in (Table 7). Highly significant differences were observed for environments (E), hybrids (G) and their interactions (GEI) $P \leq 0.01$. The results showed that, 89.5 of the variance were due to (E), the GEI accounted for 7.4%, while the genotypes explained only 3.1%. The partitioning of GE interaction through AMMI model analysis revealed that, the two terms (PCA1, PCA2) were significant and explained 53.6%, and 35.1% of variation due to GE interaction sum of squares, respectively (Table 7). Together, they accounted 88.7% of GEI sum of squares and most of the variation was explained by the first two principal components (PCA1 and PCA2). From the bi-plot of the first two principal components axes (PCA1 and PCA2); they explained 83.07% of the total GE sum of squares (Fig.1).

Table 7. AMMI analysis of variance of significant effects of hybrids (G), environments (E) genotype-environments interaction (GE) on grain yield (t/h) and partitioning of GE into AMMI scores.

Source	DF	S.S	M.S	F	Efficiency%
Total	255	348.6	1.367		
Treatments	63	287.0	4.556	0.00000	
Genotypes	7	8.9	1.270**	0.00044	3.1
Environments	7	257.0	36.721***	0.00000	89.5
Block	24	8.4	0.351	0.33870	
Interactions	49	21.1	0.430*	0.007882	7.4
IPCA	13	11.3	0.872**	0.00144	53.6
IPCA	11	7.4	0.670*	0.02152	35.1
Residuals	25	2.4	0.095	0.99956	
Error	168	53.2	0.317		

*, ** significant at 0.05 and 0.01 probability level, respectively.

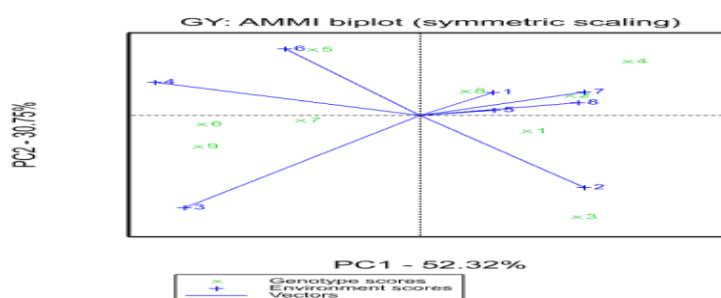
NS: Not significant

From Fig.1 and Table 8. The hybrid Express was found had highest grain yield (3.5 t/h) compared to all checks and greater than the overall mean grain yield (3.3 t/h), was considered stable hybrid. Under diverse environmental conditions.

Table 8. PCA1 And PCA2 scores for yield of nine selected sorghum hybrids evaluated in eight environments.

GenotypeNG	Gm	IPCAG[1]	IPCAG[2]	
G1	1	3.541	-0.08307	-0.46142
G2	2	3.394	0.15471	0.48668
G3	3	3.198	0.35083	0.30810
G4	4	3.445	-0.48983	0.08558
G5	5	3.407	0.79285	-0.42117
G6	6	3.202	0.30634	0.34111
G7	7	3.043	-0.64720	0.30735
G8	8	2.989	-0.38462	-0.64624
G. Mean		3.3		

Fig 1. Bi plot of 8 genotypes and 8 environments for grain yield using genotypic and environmental scores



The best four genotypes selected according to AMMI estimated among all environmental conditions was Express which were selected 7 times in 8 environmental conditions, meaning it was adapted (Table 9). From above results, the stable and adapted hybrid for grain yield was express and had grain yield highest than all checks ,also they showed PCA values close to zero (near to origin).

Table 9. The best four hybrids in each environmental condition for grain yield according to AMMI selections.

Number	Environment	Mean	Score	1	2	3	4
4	E4	5.063	0.5608	G5	G1	G2	G3
3	E3	4.003	0.4674	G5	G1	G2	G3
2	E2	3.572	0.4153	G5	G2	G1	G3
1	E1	3.978	0.3385	G5	G1	G2	G3
7	E7	1.891	-0.3054	G2	G4	G7	G6
8	E8	2.109	-0.3244	G4	G2	G7	G1
5	E5	2.791	-0.5587	G1	G4	G8	G7
6	E6	2.812	-0.5936	G1	G4	G8	G7

Conclusion

Across different environmental conditions, express hybrid had highest grain yield (3.5 t/h) compared to all checks and over all mean grain yield, also selected seven times in eight environmental conditions indicating its wide adaptation. Express hybrid performed consistently well across the diverse environmental conditions indicating its good stability and adaptation and fitting cultivation into both irrigated and rain fed areas. Also showed agronomic traits (days to 505 flowering, plant height, panicle length, 1000 grain weight and Stover yield) comparable to all checks. This hybrid is therefore recommended under both irrigated and rain fed conditions in the Sudan.



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