Performance, genetic variations and interrelationships in different traits of sorghum (*Sorghum bicolor* L. Moench) genotypes

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ABSTRACT

Eighteen sorghum genotypes were evaluated over three consecutive seasons (2009,2010,and 2011) at three locations (Rahad Research farm of the Agricultural Research Corporation (ARC), Sudan, Gedarif Research Station farm North Gedarif and South Gedarif region). Both experiments conducted in North and South Gedarif were rainfed, while that conducted at Rahad station was irrigated. A randomized complete block design with four 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% flowering, plant height, number of heads/m^2, head length (cm), head width (cm),1000 seed weight (g) and grain yield (kg/ha). The study found that there were highly significant differences among genotypes in all the characters studied except head width in season 2011.The early maturing genotypes were Milo (59-64 days), Gesheish (60-67 days) , AG-8 (59-65 days) and Butana (62-68 days), an indication that these genotypes would fit quite well in short rainy seasons of North Gedarif environment. The late maturing genotypes were Tabat (68-83days),Wad Ahmed (69-83 days), Faki Mustahi (68-88 days) and Tetron (73-88 days) which were suitable to be grown under Rahad and South Gedarif environments**.** The highest grain yields (kg/ha) were exhibited by the genotypes Butana (735 kg/ha), Wad Ahmed (2572 kg/ha), and Mugod (2545 kg/ha). Grain yield was positively and highly significantly correlated with head width (0.65**) and number of heads/m^2 (0.46**) .Accordingly, the simple linear correlation and path coefficient analysis indicated that head width and number of heads/m^2 could be used as potential selection criteria in breeding programs for developing high yielding sorghum genotypes.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the major cereal crops of the semi-arid tropics. It is the fifth most important cereal crop of the world. Major producers of sorghum in the world are USA, India, Nigeria, China, Mexico, Sudan and Argentina. Twenty one percent of the world sorghum area is in India. In the Sudan, sorghum is the most widely produced and consumed cereal crop. It is utilized in various forms as stable food for humans, feed for animals and contributes about 70% of total grain produced in the country. It ranks first in total area cultivated as well as total tonnage produced. However, the areas as well as production vary year after year due to many biotic, abiotic, technical and policy factors. The area is reported to be 4-8 million hectares with an average of 5.5 million/ha, about 90% of it is under rain; while total grain production varies between 3-4.5 million tonnes with an average of 0.6 tonnes/ha. Of the abiotic factors limiting sorghum productivity, rainfall stands out as the most important factor. The climatic change seriously affected the traditional sorghum growing areas of northern Gedarif, Gezira, Sennar, White Nile States as well as northern parts of Kordofan and Darfur States. This area is estimated to be > 50% of the total sorghum production area. (Elzein *et al*, 2008).

In these dry areas (250 mm– 400 mm), farmers used to grow their own local sorghums, which are low yielders and suffer drought stress at almost all stages of crop growth. The outcome is either low yield or straw and chaff. In fact, sorghum is loosing ground in these important areas. The improved, medium maturing, high yielding varieties and hybrids such as Feterita , Wad Ahmed , Hageen Dura-1 and Tabat require 550 mm– 650 mm which is not available and accordingly these varieties/hybrids, were not recommended for these low rainfall regions. (Osman and Mahmoud, 1992). The short maturing varieties released earlier by ARC, such as Umbenien 7, 11, 22, feterita Maatuog, *etc*, were out of cultivation due to their poor grain quality, small seed, pigmented seed coat and hence low market value.

Progress in plant breeding depends on the extent of genetic variability present in a population that permits effective selection procedures, based on locally adapted land races (Swarp and Chaugale,1962). Therefore, the first step in any plant breeding program is the study of genetic variability, which cannot easily be measured. The ultimate objective of most sorghum breeding programs is to improve yield which is genetically a complex character, that requires a reasonable level of genetic diversity (Sprague, 1966).

Correlation studies are important in breeding programs, as they give information on direction and magnitude of association between different traits. This could be utilized to select for one character indirectly by selection for another one (Sharaan and Ghallab,1997). One of the objectives of the sorghum breeding program in Agricultural Research Corporation (ARC) of the Sudan is to increase productivity and sustainability of sorghum production in irrigated and low rainfall regions of the country and thereby making better use of natural resources.

The present study consists of eighteen sorghum genotypes to be evaluated under different environments (rainfed and irrigation conditions) to contribute to sorghum improvement in the Sudan. The objectives of this study were to evaluate the performance for yield potential, the extent of genetic variability, interrelationships in nine different growing environments of sorghum in the Sudan.

MATERIALS AND METHODS

Location

The experiments were conducted over three consecutive seasons (2009, 2010, and 2011) at three locations,*viz*. Rahad Research Farm, North and South Gedarif regions of the Gedarif Research Station farm.The three locations lied within the central clay plain of the Sudan characterized by heavy, alkaline clay soil, with a pH of around 8.5 and poor in nitrogen and organic matter.

Plant material

Eighteen accessions of sorghum collected from Gedarif and from the gene bank (Wad Medani) were used in this study. Five of these accessions (Wad-Ahmed, Tabat, Butana, Bashayer and Arffagadamak-8). were released varieties and 13 local land races preferred by farmers Korakollo, Mugod, Saffra, Wad-Bako, Tetron, Faki-Mustahi, Farhoda, Gadambalia bloom, Ajeb-seido, Arafah, Gesheish,Wad-fahal and Milo.

Cultural practices

The standard cultural practices adopted for sorghum production at ARC were followed. Land was prepared by disc ploughing, disc- harrowing, leveling and ridging in irrigated site and by wide level disc in rain-fed sites. Treatments were laid out in a randomized complete block design with four replicates in the different locations and seasons.

Sowing was done in the first week of July under irrigation and the first to the third week of July under rainfed conditions depending on the onset of rainfall. Under irrigation, the entries were sown in five rows, 5 m long on ridges; 0.8 m apart at 0.3 m intra - row spacing and thinned to two seedlings per hill. Under rain fed conditions, they were also sown in five rows 5 m long, on flat; 0.8 m apart at 0.2 m intra row spacing and thinned to two seedlings per hill. Urea at the rates of 80 kg and 40 kg /fed was applied under irrigation and rain-fed sites, respectively, as recommended by the ARC. The crop was irrigated every two weeks or whenever necessary and irrigation was withheld three weeks before harvest.

In irrigated and rainfed experiments, assessments were made in the central three rows of the plot discarding one row or more on each side. The data were collected on days to 50% flowering, plant height, number of heads/m^2, head length (cm),head width (cm),1000 seed weight (g) and grain yield (kg/ha).

Statistical analysis

Analysis of variance was performed for each season; location and combined to test for significant differences among genotypes. Means for seasons were used to compute simple linear correlation coefficients between all possible combinations. The path coefficients procedure was used in order to partition correlation coefficients between grain yield and its components which is divided into direct and indirect effects.

RESULTS AND DISCUSSION

Mean performance

Days to 50%flowering

This trait is used as an earliness index. Across locations, it showed significant differences among genotypes under the three locations (Table 1).The highest general mean was observed at season 2010 while the lowest general mean was obtained in season 2011. The range for days to 50% flowering was 59 (Milo) to 83 (Wad Ahmed) in 2009, from 60 (Gesheish) to 88 days (Faki Mustahi and Tetron) in 2010, and from 59 (AG-8) to 74 days (Tetron) in 2011.

Identifying early and medium maturing genotypes is important for choosing genotypes to suit the different growing environments (irrigation and rainfed). Hence, from these findings, the early maturing genotypes were Milo, Gesheish , AG-8 and Butana, an indication that these lines would fit quite well in short rainy seasons, i.e suitable for North Gedarif environment, while the late maturing ones were Tabat, Wad Ahmed, Faki Mustahi and Tetron which were suitable to grow under Rahad and South Gedarif environments (Table 1). These findings were in agreement with those of Abdalla *et al*. (2009), who reported that lines AG-8 and AG-15 were 18 days and 14 days earlier than Wad-Ahmed. Elzein *et al*. (2008) found a wide range of variability in days to 50% flowering

Plant height (cm)

Development of short, medium genotypes is important for any plant breeding program, because these genotypes will be suitable for mechanical harvesting and for resistance to lodging. Across locations, plant height showed significant differences among genotypes under the three locations (Table 1)**.** The highest general means were observed in season 2010**,** while the lowest general mean**s** were observed in season 2011. The range for plant height was 112 cm (Tabat) to 189 cm (Wad Baku) in 2009, from 137cm (Butana) to 216 cm (Tetron) in 2010 and from 97 cm (Bashaiyer and AG-8) to 139 cm (Tetron) in 2011.Thus, in this study, the short genotypes were Tabat, Butana , Bashaiyer and AG-8, while the tall genotypes were Wad Baku and Tetron (Table 1). From these results, tall genotypes such as Wad Baku and Tetron are not appropriate for drought areas such as North Gedarif , because they were susceptible to drought, while Butana and Bashayier were suitable to grow under North Gedarif conditions. These findings were in agreement with Elasha *et al* (2011) , who found significant

differences (P< 0.01) between the entries in their plant height. Also Bushara (1999) , recorded highly significant differences in plant height among
hybrids of grain sorghum, in the Sudan.

Table 1. Means of days to 50% flowering and plant height (cm) for 18 sorghum genotypes grown at North Gedarif (NG),South Gedarif (SG),and Rahad (RH),seasons 2009,2010, 2011.

** Significant at 0.01 of probability level.

Number of heads /m²

This character is an indicator for high grain yield. Good crop establishment will result in increasing number of heads/m² which lead to an increase in grain yield. Across locations, this trait showed highly significant differences among the genotypes in the three locations (Table 2)**.** The highest general mean was observed in season 2010**,** while the lowest

general mean was observed in season 2011. The range for this trait was from 6 (Wad Fahal, Mugod, Tabat) to 11 (Wad Ahmed) in season 2009, from 8 (Wad Fahal) to 13 (Wad Baku) in season 2010, from 5 (Arafa and Faki Mustahi) to 9 (Korakollo) in season 2011 (Table 2). In this study, the highest numbers of heads/m² were obtained by the genotypes Wad Ahmed, Wad Baku, and Korakollo, while the lowest number of heads/m² were obtained by the genotypes Wad Fahal, Tabat and Arafa. This is because Wad Fahal and Arafa are late in maturity and some plants failed to produce heads due to moisture stress.

	Days to 50% flowering				Plant height (cm)			
Genotypes	2009	2010	2011	Mean	2009	2010	2011	Mean
Korakollo	70	67	66	67.7	171	162	110	147.6
Mugod	74	77	69	73.3	153	179	119	150.3
Safra	64	65	68	65.6	177	187	119	161.0
Wad Baku	60	69	73	67.3	189	209	119	172.3
Tetron	73	88	74	78.3	181	216	139	178.6
Faki Mustahi	68	88	68	74.6	177	185	128	163.3
Farhoda	80	83	73	78.7	175	187	123	161.6
Gadambaliabloom	71	66	69	68.7	168	154	110	144.0
Ajeb seido	69	71	73	71.0	143	155	110	136.0
Arafa	82	83	73	79.3	171	176	114	153.6
AG-8	60	65	59	61.3	125	144	97	122.0
Butana	62	68	68	66.o	119	137	104	120.0
Bashayier	72	74	67	71.0	118	141	97	118.6
Tabat	83	84	68	78.3	112	142	98	117.3
Wad ahmed	83	82	69	78.0	116	147	108	123.6
Gesheish	65	60	67	64.0	143	159	105	135.6
Wad Fahal	73	80	70	74.0	182	151	108	147.0
Milo	59	63	64	62.0	134	149	112	131.6
Mean	70	74	69	71.0	153	166	112	143.7
CV%	6.8	2.8	6.5	5.3	6.8	21.7	10.6	13.1
SE±	1.39	0.60	1.36	1.12	2.9	10.36	4.48	5.91
	**	**	**		**	**	**	

Head length (cm)

Highly significant differences among genotypes were observed for this trait under the three locations (Table 2). Across locations, the highest general mean(19 cm) was observed in season 2010**,** while the lowest general mean (14 cm) was observed in season 2011. The range for this trait was from 13 cm (Mugod, Farhoda and Wad Baku) to 24 cm (Faki Mustahi) in season 2009, from 12 cm (Mugod) to 27 cm (Tetron) in season 2010, from 12 cm (Safra and Farhoda) to 18 cm (Tabat) in season 2011. In this study, the longest heads were obtained by the genotypes Faki Mustahi ,Tetron, and Tabat ,while the shortest heads were obtained by the genotypes Mugod and Safra (Table 2).This result agreed with that reported by Elasha *et al* (2011),who found that during both seasons at the irrigated and the rainfed sites, there were significant differences (P< 0.01) between the entries in their panicle length.

Table 2. Means of number of heads/m² and head length (cm) for 18 Sorghum genotypes grown at North Gedarif (NG),South Gedarif (SG),and
Rahad (RH), season 2009, 2010, 2011.

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	No. of heads/m²				Head length (cm)			
Genotypes	2009	2010	2011	Mean	2009	2010	2011	Mean
Korakollo	8	11	9	9	17	18	15	16
Mugod	6	11	7	8	13	12	14	13
Safra	8	11	7	8	17	14	12	14
Wad Baku	8	13	8	9	13	14	14	13
Tetron	7	10	6	8	17	27	17	20
Faki Mustahi	10	9	5	8	24	26	17	22
Farhoda	7	10	6	8	13	13	12	12
Gadambaliabloom	9	11	6	8	16	17	13	15
Ajeb seido	9	11	8	9	15	19	13	15
Arafa	8	9	5	7	20	19	15	18
AG-8	10	10	7	9	15	18	14	15
Butana	9	10	7	9	23	24	15	20
Bashayier	7	11	7	8	22	20	14	18
Tabat	6	9	7	7	20	22	18	20
Wad ahmed	11	11	8	10	17	18	15	16
Gesheish	7	11	8	8	19	17	14	16
Wad Fahal	6	8	7	7	21	20	14	18
Milo	9	11	7	9	16	17	13	15
Mean	8	10	7	8	18	19	14	17
CV%	29.6	23.9	8.5	20.6	12.4	22.0	14.6	16.6
SE±	0.67	0.72	0.71	6.7	0.62	1.18	0.80	0.86
	**	**	**		**	**	**	

Significant at 0.01 of probability level.

Head width (cm)

Across locations, this trait showed highly significant differences among genotypes except for season 2011. The highest general mean (5cm) was observed in season 2010, while the lowest general mean (3cm) was observed in season 2011(Table 3). The range for head width varied from 3 cm (Faki Mustahi) to 4 cm (Wad Fahal), from 4 cm (Faki Mustahi) to 6cm (Butana and Gesheish), from 3cm (Bashaiyer) to 4cm (Mugod) in seasons 2009, 2010 , and 2011, respectively (Table 3). From this study, genotype Mugod had the largest head width coupled with the longest head length. This means that tall, late maturing genotypes are not suitable for drought areas such as North Gedarif but suitable for South Gedarif and Rahad environments.

1000 seed weight (g)

Across locations, highly significant differences among genotypes were observed for this trait.The highest general mean (31g) was observed in season 2010,while the lowest general mean (25 g) was obtained in seasons 2009 and 2011(Table 3). The range for 1000 -seed weight (g) varied from 18 g (Butana) to 36 g (Mugod), from 25g (Tetron and Wad Ahmed) to 42g (Wad Fahal) , from 21g (Wad Ahmed) to 31g (Wad Fahal) in season 2009, 2010, and 2011, respectively. Hence, in this study, the highest 1000 seed weight was obtained by the genotypes Mugod and Wad-fahal,while the lowest 1000 seed weight (g) was exhibited by the genotypes Butana , Tetron and Wad Ahmed

(Table 3). These findings agreed with those reported by Geremew (1993), who recorded a wide range of variability in 1000 seed weight. From these findings genotypes Mugod and Wad Fahal had large seed sizNorthGedarif (NG),South Gedarif (SG),and Rahad (RH), seasons 2009,2010 , 2011.

*,** significant at 0.01 probabili

Genotypes	Head width (cm)				Seed weight (g)			
	2009	2010	2011	Mean	2009	2010	2011	Mean
Korakollo	3	5	4	4	25	30	25	26.6
Mugod	4	5	4	4	36	39	26	33.6
Safra	3	6	3	4	25	31	27	27.6
Wad Baku	4	5	3	4	27	31	27	28.3
Tetron	3	5	4	4	27	25	22	24.6
Faki Mustahi	3	4	4	3	25	39	27	30.3
Farhoda	3	5	4	4	25	35	24	28.0
Gadambaliabloo m	4	5	3	4	27	33	25	28.3
Ajeb seido	3	5	3	3	20	27	22	23.0
Arafa	4	5	3	4	28	28	24	26.6
AG-8	3	5	4	4	26	30	25	27.0
Butana	3	6	3	4	18	23	22	2.0
Bashayier	3	5	3	3	23	27	25	25.0
Tabat	3	5	3	3	20	27	25	24.0
Wad ahmed	3	5	4	4	22	25	21	22.6
Gesheish	3	5	3	3	26	30	26	27.3
Wad Fahal	4	6	4	4	29	42	31	34.0
Milo	4	5	3	4	24	31	25	26.6
Mean	3.34	5	3	3.78	25	31	25	27.0
CV %	21.9	2.6	4.3	9.6	13.5	16.3	4.2	18.0
SE±	0.2	.3	0.2	0.2	0.9	1.4	0.8	1.1
	**	**			**	**	**	

Grain yield (kg/ha)

Across locations, this trait showed highly significant differences among the genotypes. The highest general mean (1973 kg/ha) was observed in season 2010, while the lowest general mean (450 kg/ha) was obtained in season 2009 (Table 4).The range for this trait was from 225 kg (Farhoda) to 735 kg (Butana) in season 2009, from 1408 kg (Faki Mustahi) to 2572 kg (Wad Ahmed) in season 2010, from 862 kg (Faki Mustahi) to 2545 kg (Mugod) in season 2011, respectively. Hence, in this study the highest grain
yields (kg/ha) were exhibited by the genotypes Butana, Wad Ahmed, and Mugod. Similar results were reported by Elasha *et al* .(2011);Elzein *et al*, 2008, and Abdalla *et al* (2009). While the lowest grain yields were obtained by the genotypes Farhoda and Faki Mustahi (Table 4).This study indicated that Butana was an early maturing and short genotype which is suitable for North Gedarif conditions ,while medium or tall genotypes that are late maturing, coupled with high grain yield such as Mugod and Wad Ahmed were suitable for growing under irrigation and high rainfall.

Across seasons, grain yield showed highly significant differences (Table 4). The highest general mean (1563 kg/ha) for this trait was obtained at Rahad location, while the lowest general mean (803 kg/ha) was observed at North Gedarif. The range for this trait was from 409 kg (Wad Fahal) to 1129 kg (Arafa), from 916 kg (Faki mustahi) to 2572 kg (Mugod) , and from 1060 kg (Wad Baku) to 2120 kg (Wad Ahmed) for North Gedarif , South Gedarif and Rahad , respectively. Hence, in this study the highest grain yields were exhibited by the genotypes Mugod at South Gedarif and Wad Ahmed in Rahad location ,while the lowest grain yield were obtained by the genotypes Wad Fahal , Faki

Mustahi and Wad Baku at North Gedarif, South Gedarif and Rahad, respectively. This is because all of them are tall and late maturing genotypes and they produce small seeds under drought spell conditions. From this finding, genotype Tetron was late maturing, tall ,with medium seed size and high grain yield, genotype Gesheish was early maturing and has low yield, while genotype Mugod is medium maturing, having medium height with big seed size and high yielding , while Faki Mustahi was a late maturing genotype with a small seed size and has low yield.

Table 4. Means of grain yield (kg/ha) combined over locations and over seasons for 18 Sorghum genotypes grown at North Gedarif (NG), South Gedarif (SG), and Rahad (RH), seasons 2009, 2010, 2011.

**significant at 0.01 probability level.

	Yield (kg/ha)					
	Seasons			Locations		
Genotype	2009	2010	2011	NG	SG	RH
Korakollo	412	1674	1729	721	2004	1090
Mugod	447	1998	2545	679	2572	1738
Safra	363	2087	1753	941	2163	1100
Wad Baku	361	1804	1509	838	1777	1060
Tetron	346	1894	1731	799	1789	1382
Faki Mustahi	355	1408	862	532	916	1178
Farhoda	225	2134	1397	899	1375	1483
Gdambaliabloom	576	2044	1666	789	1799	1698
Ajeb seido	620	2188	977	923	1191	1670
Arafa	434	2059	1400	1129	1080	1684
AG-8	616	1834	1190	885	1156	1510
Butana	735	1963	1302	687	1615	1698
Bashayier	677	2121	1709	1001	1559	1948
Tabat	354	2215	1329	704	1310	1884
Wad Ahmed	391	2572	1450	698	1598	2120
Gesheish	487	1714	1380	726	1659	1196
Wad Fahal	266	1674	1750	409	1207	2073
Milo	450	2121	1287	1101	1231	1526
Mean	450	1973	1498	803	1556	1563
CV%	45.0	20.8	33.6	28.3	27.6	30.6
SE±	24.6 **	49.7 **	61.0 **	27.4 **	52.01 **	1.1 **

Simple linear correlation coefficients

Grain yield was positively , and highly significantly correlated with head width (0.65**), number of heads/m² (0.46**) , and 1000-seed weight (0.32*). It was positively and non-significantly correlated with days to 50% flowering (Table 5). Similar results were reported by Bittinger *et al*. (1981) and Elagib (1999) who found that grain yield was positively correlated with days to 50% flowering and 1000-grain weight. Also, positive association between grain yield and days to 50% flowering was reported by many authors; Liang *et al*. (1969) in sorghum and Umakanth *et al*. (2001) found

that correlation coefficients were moderate to high for days to anthesis, plant height,1000-seed weight, number of plant/m² and number of heads/m². Liang *et al*. (1969) found that 1000-grain weight was significantly correlated with grain yield. Shuklighly significantly correlated with head width (0.59**) and plant height (0.48**) (Table 5), but positively and not significantly correlated with number of heads/m² and days to 50% flowering.1000-seed weight was negatively correlated with number of plants/m² and head length, Significant and positive correlations of 1000-seed weight with plant height were reported by Ezeaku and Mohamed (2006). Hence, in this study, head width, number of heads/m² and 1000-grain weight had strong correlation with grain yield (0.65**), (0.46**), and (0.32*), respectively, while it was negatively correlated with plant height, number of plants/m²,

Table 5. Simple linear correlation coefficients among various pairs of 8 characters of sorghum genotypes combined over three seasons (2009,2010,2011) and three locations (North Gedarif, South Gedarif and Rahad).
Head length, HW: Head width,1000.SW,GY: Grain yield (kg/ha).

	50%F	PH	#P/E	#H/m2	H L	H W	1000SW	GY
50%F	-							
PH	0.30	-						
#P/E	0.03	.348**	-					
#H/m2	-0.01	0.40**	0.18	-				
H L	0.34*	0.28*	0.16	0.18				
H W	0.13	0.43**	-0.27	0.62**	0.23	-		
1000SW	0.22	0.48**	-0.13	0.26	-0.03	0.59**	-	
GY	0.13	-0.04	-0.59*	0.46**	-0.02	0.65**	0.32*	-

Path coefficient analysis

The relatively large, positive and significant simple linear correlation coefficient between grain yield and number of heads/m² was (0.46**) .The positive direct effect of number of heads/m² on grain yield was the highest (0.47) (Table 6). The highest positive direct effect on grain yield was exhibited by head width (0.33). Its indirect effect through number of heads/m² is large while too small through the other characteristics. This suggested the use of this character as a selection criterion for the improvement of grain yield. Its indirect effects on grain yield were negligible through the other traits. The relatively small, negative simple linear correlation between grain yield and head length (-0.02) is explained *via* the negative direct effect of head length on grain yield (-0.12) ,so it is difficult to recommend this character as a selection criterion for yield (Table 6).

Head width was highly significantly and positively correlated with grain yield (o.65**) (Table 6),such strong association is explained *via* the high positively direct effect of head width on grain yield(0.33). Low negative indirect effect were observed *via* plant height, head length, and 1000-seed weight. Also, it had low positive indirect effect on grain yield *via* number of plants/m², number of heads/m² and days to 50% flowering (Table 6).

In this study, correlation and path analysis may measure two different aspects. Hence, the study of correlation alone does not give accurate indications of yield association. For example, in this study correlation between days to 50% flowering and grain yield was very small (0.13). This means that this character had no in influence on grain yield, but the path analysis expressed days to 50% flowering as an important trait influencing yield.

From the present study, the direct effect of the tested traits on grain yield indicated that among yield components head width and number of heads/m² had the highest correlation coefficient with grain yield. These traits also showed a positive direct effect on grain yield and therefore, these characters may be considered as selection criteria for developing high yielding sorghum genotypes.

Table 6. Path coefficient analysis of direct(in bold) and indirect effect of 8 characters on sorghum grain yield of 18 genotypes grown seasons 2009,2010,2011 at North Gedarif, South Gedarif and Rahad.

	X1	X2	X3	X4	X5	X6	X7	Rij
X1	**0.23**	-0.07	-0.02	0.01	-0.04	0.04	-0.00	0.14
X2	0.07	**-0.24**	-0.17	0.19	-0.03	0.14	-0.00	-0.04
X3	0.01	-0.08	**-0.50**	0.09	-0.02	-0.09	0.00	-0.59**
X4	-0.00	-0.09	-0.09	**0.47**	-0.02	0.20	-0.00	0.46**
X5	0.08	-0.07	-0.08	0.08	**-0.12**	0.07	0.00	-0.02
X6	0.01	-0.10	0.13	0.29	-0.03	**0.33**	-0.00	0.65**
X7	0.05	-0.11	0.07	0.12	0.00	0.19	**-0.01**	0.32*

*,** Significant at P=0.5 and 0.01 level of probability, respectively. rij= Simple linear correlation coefficient. X1: Days to 50% flowering,X2:Plant height,X3:number of plants at establishment/m2,X4:number of heads/m2,X5: Head length,X6: Head width,X7:1000 SW(g).

CONCLUSION

Based on the results of this study, it could be concluded that a wide range of genetic variability was observed among sorghum genotypes for most of the characters studied**.** The early maturing genotypes were Milo, Gesheish, AG-8 and Butana, an indication that these genotypes would fit quite well in short rainy seasons, which were suitable for North Gedarif environment, while the late maturing ones were Tabat,Wad Ahmed, Faki Mustahi and Tetron which were suitable to grow under Rahad and South Gedarif environments**.** The highest grain yields (kg/ha) were exhibited by the genotypes Butana (735 kg/ha),Wad Ahmed (2572 kg/ha),and Mugod (2545kg/ha). Simple linear correlation and path coefficient analysis indicated that head width and numbers of heads/m^2 could be used as potential selection criteria in breeding programs for developing high yielding sorghum genotypes.

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أداء الانتاجية والاختلافات الوراثية والعلاقة بين الصفات المختلفة لبعض سلالات الذرة الرفيعة
Sorghum bicolor (L.) Moench]**[**

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الخلاصة

تم تقييم ثمانية عشر سلالة من الذرة الرفيعة لثلاثة مواسم متتالية (2009، 2010 و2011) في ثلاثة مواقع هي محطة بحوث الرهد ومحطة بحوث القضارف ،(شمال وجنوب القضارف)، هيئة البحوث الزراعية، السودان واللتان تمت فيهما الزراعة بالأمطار أما محطة بحوث الرهد بالري الأنسيابي. استخدم تصميم القطاعات العشوائية الكاملة بأربعة مكررات وذلك لتقدير أداء انتاجية الحبوب، التباين الوراثي والعلاقة بين الصفات. تم قياس عدد الايام حتي 50% ازهار، طول النبات ، عدد القناديل/متر^2 ، طول القندول ، عرض القندول ، وزن الالف حبة وانتاجية الحبوب. أظهرت النتائج وجود فروق معنوية عالية لمعظم الصفات التي درست ماعدا عرض القندول في موسم 2011م. السلالات المبكرة هي مايلو (59-64 يوم) ،قشيش (60–67 يوم) ، أرفع قدمك -8 (59–65 يوم) وبطانة (62–68 يوم). هذا يوضح ان هذه السلالات يمكن زراعتها في المناطق قليلة الامطار وهي تناسب بيئة شمال القضارف. الاصناف المتأخرة هي طابت (68- 88 يوم)، ود أحمد(69-83 يوم) ، فكي مستحي(68-88 يوم) ، وتترون(73-88 يوم) حيث يمكن زراعتها في بيئات مثل الرهد وجنوب القضارف. السلالات ذات الانتاجية العالية هي بطانة (735 كجم /هكتار) ، ود أحمد (2572 كجم/ هكتار) ومقد (2545 كجم /هكتار). ارتبط انتاج الحبوب ايجابياً ومعنوياً مع عرض القندول (** 0.65) وعدد القناديل/ متر^2 (** 0.46) ، وعليه أوضح معامل تحليل المسار أن عرض القندول وعدد القناديل/ متر^2 يمكن استخدامها كصفات انتخاب في برامج التربية لتطوير سلالات من الذرة الرفيعة عالية الانتاجية.