Gezira J. of agric. sci. 17(2): 276-293 (2019)

Agronomic performance, genetic variability and interrelationships of grain yield and its components of selected maize (*Zea mays* L.) genotypes

Hashim A. Ibrahim[1], Abu Elhassan S. Ibrahim[2] and Khalfala A. Ali[3]

[1] Agricultural Research Corporation, New Halfa, Sudan.
[2] Faculty of Agricultural Sciences, University of Cezira, Wad Medani, Sudan.
[3] Agricultural Research Corporation, Gedarif, Sudan.

ABSTRACT

In Sudan, maize is a promising crop. It has been known and grown for a long time on small scale, under rainfed, flood and irrigated conditions. However, recently, there is increasing interest in maize production for export. In this study, 22 open pollinated genotypes introduced from International Maize and Wheat Improvement Center (CIMMYT) and Intentional Institute of Tropical Agriculture (IITA) plus two local checks (Var113, Hudieba-2) were evaluated over two seasons (2017 and 2018) and four locations, *viz.* New Halfa, Kassala, Gezira and Elsuki Research Station Farms of the Agricultural Research Corporation (ARC) of the Sudan. The objectives of this study were to evaluate these genotypes for grain yield and yield components and identify high yielding and stable genotypes under different environments. Treatments were arranged in a randomized complete block design with three replicates. The characters measured were days to 50% tasseling and silking, plant and ear height, ear length, number of kernel rows/ear and number of kernels per row, ear diameter,100-kernel weight and grain yield. The study revealed significant differences among the 24 maize genotypes for most of the studied traits in each season and location separately and across them paving the road for improvement *via* selection. The simple linear correlation coefficient and path coefficient analysis depicted that the correlation coefficient of most traits with grain yield were significant but suggested ear diameter, ear length, number of kernels per ear and 100 kernel weight as selection criteria for grain yield improvement. Statistical analysis revealed that genotypes TZBREld-3C5, TZBR Eld-4-WC1, BR9922-DMRSR, TZBR Comp1-Y, TZEE-YPOP STR CY, 503SWAB-2, ECAQVE-6 and ECASTRIG- OFF-153 were the highest yielding across environments with a grain yield of over 2500 kg/ha. They were recommended to be grown in the favorable supplementary irrigation conditions of New Halfa, Gezira and Elsuki. The low yielding and stable genotypes of TZBREld-3C5, TZBREld-4-YC1, TZBR Comp1-W, HYDER ABAD97502 (RE) and ECASTRIGOFF-153 were recommended to be grown in the unfavorable rainfed condition of Kassala.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important food crops world-wide, serving as staple food, livestock feed, and industrial raw material (Troyer, 2006). The kernel contains excellent quality of edible oil, carbohydrate, starch, protein, minerals and vitamin A (Amaregouda, 2007). It has greater nutritional value as it contains 72% starch, 10% protein, 4.8% oil, 8.5% fibers, 3.0% sugar and 1.7% ash (Chaudhary, 1983). It can be directly consumed as food at various developmental stages from baby corn to mature grain.

Today, maize is widely grown in most parts of the world, over a wide range of environmental conditions, between latitudes of 58^o North to 40^o South of the equator and on range of precipitation from 400 to 1500 mm and with growing season ranging from three months to about 13 months, temperature ranging from 20 - 31C^o and grows from sea level to over 3000 m above sea-level (Thimothy *et al*., 1988, Dowswell *et al.,* 1996; Golam *et al*., 2011).

Among cereal crops, maize has the highest average yield (4.7 t/ha) and remains third after wheat and rice in total area (177 million ha) and production (967 million tons) in the world (DACNET, 2014). However, among the developing economies, maize ranks first in Latin America and Africa but third after mild rice and wheat in Asia (CIMMYT, 1989; Dowswell *et al*., 1996). The United States, China, the European Union, Brazil and Mexico are the world's largest producers of maize and the United States is the world largest producer and exporter of maize (Meng and Ekboir, 2002).

In Sudan, it is grown as a rainfed crop in Kordofan, Darfur and in small irrigated areas in the Northern States (Ahmed and Elhag, 1999). It is grown mainly as feed crop (both grain and forage) and rarely as food crop.

The genetic variance and genetic gain estimates are of great importance in breeding programs. Therefore, the progress of breeding program is conditioned by the degree and the nature of the genotypic and non-genotypic variation in various characters.

Therefore, the current study involved the evaluation of 24 maize genotypes from CIMMYT (International Maize and Wheat Improvement

Centre, Mexico), ITTA (International Institute of Tropical Agriculture, Nigeria) and Sudan, in order to estimate the performance, extent of genetic variability of grain yield and its components as well as the interrelationships of grain yield components using simple linear correlation and path coefficient analyses.

MATERIALS AND METHODS

The experiment was conducted for two seasons (2017/18 and 2018/19) at four locations, *viz.* New Halfa, Kassala, Gezira and Elsuki Research Stations of the Agricultural Research Corporation (ARC) of the Sudan.

The plant material used in this study consisted of 22 genotypes of maize introduced from the CIMMYT and IITA plus two local checks; Var113 and Hudieba-2 (Table 1).

The experiments were laid out in a randomized complete block design with three replicates. Each entry was represented by a plot of 2 rows. Each row was 5 m long with a spacing of 20x80 cm between holes and rows, respectively, giving a total plot area of 8.0 m^2. The recommended cultural practices of the Agricultural Research Corporation (ARC) of the Sudan were followed in both years to raise a good crop. Sowing date was the second week of July at New Halfa, the third week of July at Gezira and Elsuki, and the first week of August at Kassala. At physiological maturity, when the leaves and husks of the plant started to turn yellow and dry, each plot was harvested separately. Data were collected on days to 50% tasseling, days to 50% silking, plant height, ear height, ear length, ear diameter, number of kernel rows/ear, number of kernels /row and grain yield.

Statistical analysis

The analysis of variance procedure was used to test differences among genotypes in the separate locations, seasons and combined. Varietal means were used to calculate the simple linear correlation coefficients and path analysis at the four locations combined.

Table1. Plant material used in the study [22 open-pollinted genotypes of maize plus two local checks (Var113 and Hudeiba-2)].

Entry no.	Pedigree	Seed color	Origin
1	TZBR Eld-3C5	White	IITA
2	TZBR Eld-4-WC1	White	IITA
3	TZBR Eld-4-YC1	Yellow	IITA
4	BR9922-DMRSR	White	IITA
5	BR9943- DMRSR	White	IITA
6	BRTZL ComP4DMRSR	White	IITA
7	Ama TZBR-WC3	White	IITA
8	TZBR ComP1-W	White	IITA
9	TZBR ComP2-W	White	IITA
10	TZBR ComP1-Y	Yellow	IITA
11	SOB SIY	Yellow	CIMMYT
12	98 TZEE- W STR 99TZEE-YQ P MC CO	Yellow	CIMMYT
13	2004 TZEE-Y POP STR CY	Yellow	CIMMYT
14	TZEE-Y POP STR CY	Yellow	CIMMYT
15	TZEE-Y POP QPM CO	Yellow	CIMMYT
16	POP EV-3	Yellow	CIMMYT
17	503 SLWMBR-1	White	CIMMYT
18	503 SIWAB -2	White	CIMMYT
19	HYDER ABAD 97 502 (RE)	White	CIMMYT
20	ECA QVE -2	White	CIMMYT
21	ECA QVE-6	White	CIMMYT
22	ECA STRIGOFF-153	White	CIMMYT
23	Var-113 (check)	White	Sudan
24	Hudieba-2 (check)	Yellow	Sudan

RESULTS AND DISCUSSION

Genotypic variation

The analysis of variance mean squares of the different characters in each season and in each location separately were significant for all the traits with the exception of ear diameter and length at Elsuki location in season 2017 (Table 2). The results showed a wide range of genetic variability for the different characters among the genotypes. The wide variability shown by the different genotypes particularly for grain yield allowed the exploitation of these materials in various ways and means of selection to improve this crop. These results are in agreement with those of Halluer and Miranda (1995), Alvarez and Las (1994) and Lu *et al.* (1994)

Table 2. Mean squares for ten traits of 24 maize genotypes evaluated at New Halfa, Kassala, Gezira, and Elsuki Research Stations Farms in two summer seasons (2017and 2018).

Trait	New Halfa	Kassala	Gezira	Elsuki
		Season 2017		
Days to 50% tasseling	25.492**	9.883**	11.362**	4.284**
Days to 50% silking	25.592**	10.435**	11.391**	4.275**
Plant height (cm)	441.3**	196.6*	181.35**	155.54**
Ear height (cm)	277.62**	128.24**	201.58**	191.39**
Ear diameter (cm)	0.05815**	0.21376**	0.08268**	0.05014
Ear length (cm)	1.5649*	4.709**	3.7432 **	1.912
Number of rows/ear	0.8464**	2.2481**	1.4623 **	1.3762**
Number of kernels/ rows	9.227**	55.11**	13.371**	26.589**
100-kernel weight(g)	7.827*	4.7736**	11.868**	4.574**
Grain yield (t/ha)	685242**	125331**	927692**	271770 **
		Season 2018		
Daysto50% tasseling	14.413**	4.200**	6.558**	40.096**
Daysto50% silking	12.954**	4.922**	6.587**	41.579**
Plant height (cm)	91.72**	190.47**	145.87**	104.73**
Ear height (cm)	110.05**	87.95**	98.76**	141.52**
Ear diameter (cm)	0.06449*	0.11617**	0.17478**	0.08464 *
Ear length (cm)	2.0765**	3.947**	6.236**	3.906 **
Number of rows/ear	0.8339*	0.8101*	3.161**	1.1753*

Number of kernels/row	9.411**	37.28**	43.74**	21.304**
100-kernel weight(g)	6.392**	1.8256**	28.53*	6.040**
Grain yield (t/ha)	374836**	212943**	874590**	412916**

*, ** and *** Significant at 0.05, 0.01 and 0.001 levels of probability, respectively.

Mean performance

Days to 50% tasseling and silking

This trait indicates the pollen shedding ability of maize genotypes and is an indicator to earliness. Though significant differences were shown for days to 50 % tasseling among the genotypes within seasons and within locations, over seasons and locations, most of the ITTA lines (white) were relatively late (60 - 61 days) while those of CIMMYT (yellow and white) were relatively early (57-58 days). Hudieba-2 (the yellow check) was the earliest (55 days) among the studied group of genotypes (Table 3). Silking trait is an indicator of pollen reception and effective fertilization in maize genotypes. However, silking followed the trend of tasseling, i.e. ITTA lines were relatively late (62 – 66 days) while those of CIMMYT were relatively early (60- 62 days).

Plant height (cm)

Plant height is strongly associated with the flowering dates both morphologically and ontogenetically, because internodes formation stops at floral initiation, which means the earlier maturing genotypes are shorter and late maturing ones are taller. Tallness is not a desirable trait in grain maize production, since tall maize plants tend to be susceptible to stem and root lodging in addition to late maturity, therefore, when selecting for grain yield, medium and dwarf varieties are preferred. Although the main effects of season, location, genotype and their first and second degree interactions on plant height were significant, it is very difficult to classify the genotypes into short and tall plants because their mean values were very close. Most of them were above 150 cm and below 160 cm (Table 3). It is worth mentioning that the earliest genotype Hudieba-2 was the shortest too (141cm), a confirmation of the fact that the two characters were negatively correlated.

Ear height (cm)

From combined analysis over seasons and locations, the mean ear height ranged from 59 cm for genotype 16 to 75 cm for genotype 4. Also, the results from combined analysis showed that the most genotype used in this study revealed higher ear placement which is a desirable trait against lodging (Table 3). Therefore, these results are in agreement with those of Elahmadi and Elahmadi (2012) who reported that maize genotypes having taller plants and high ear position are more preferred for forage production and mechanical harvesting.

Ear diameter (cm)

The mean ear diameter ranged from 3.4 cm for genotypes 1, 11, 15 and 23 to 3.7 cm for genotypes 2, 20, 21and 22 with an average mean of 3.5 cm. From these results, genotypes number 2, 20, 21and 22 and number 3,4,5,6,8,12 and genotypes number 7, 9,10,13,14,16,17,18 and 19 gave the highest ear diameter (3.7, 3.7, 3.7, 3.7, 3.6, 3.6, 3.6, 3.6, 3.6, 3.6, 3.5, 3.5, 3.5, 3.5, 3.5, 3.5, 3.5, 3.5 and 3.5 cm), respectively, compared to other genotypes (1, 11 and 15) which were given (3.4, 3.4 and 3.4 cm) and the two local checks (3.3 and 3.4 cm), respectively (Table 3).

Ear length (cm)

The mean ear length ranged from 13.9 cm for genotype 11 to 16 cm for genotypes 4, 5 and 7. From these results, genotypes number 4, 5, 7, 1, 6, 19, 2, 21, 8, 10, 22, 18, 9, 14, 20, 17, 16, 13, 3, and 24 gave the highest ear length 16.0,16.0,16.0, 15.8, 15.7, 15.6, 15.4, 15.4, 15.3, 15.3, 15.3,15.3, 15.2, 15.0, 15.0, 14.9, 14.8, 14.7, 14.6 and 14.6 cm), respectively, compared to other genotypes (11, 12 and15) and the local checks Va113 (13.9,14.3,14.1 and 14.1 cm), respectively (Table 4).

Number of rows /ear

The mean number of rows/ear ranged from 12.6 for genotype 15 to 13.9 for genotype 3. From these results, genotypes number 3, 2, 20, 21, 22, 8, 11, 12 and18 gave the highest number of rows/ear (ranging from 13.9 to 13.6) (Table 4). These results are in agreement with those of Malhotra and Khehra (1986) who reported significant differences among genotypes for grain yield, ear length, number of rows /ear, 100 kernel weight and days to 50% silking.

Genotype	DT	DS	PH(cm)	EH (cm)	ED (cm)
1	61	63	156	68	3.4
2	60	63	158	74	3.7
3	60	62	154	67	3.6
4	60	63	162	75	3.6
5	60	63	158	74	3.6
6	61	64	157	69	3.6
7	61	66	155	64	3.5
8	61	64	148	69	3.6
9	60	63	158	67	3.5
10	60	63	150	70	3.5
11	58	61	151	62	3.4
12	58	61	150	62	3.6
13	58	61	154	67	3.5
14	58	62	149	61	3.5
15	57	60	151	64	3.4
16	57	60	148	59	3.5
17	57	60	151	63	3.5
18	58	61	154	68	3.5
19	58	61	154	63	3.5
20	57	61	159	70	3.7
21	58	60	157	65	3.7

22	58	61	152	68	3.7
23	60	63	150	65	3.4
24	55	58	141	62	3.3
Mean	59	62	153	67	3.5
C.V%	2.8	2.7	4.6	9.0	6.2
SE±	0.33	0.33	1.43	1.23	0.045

Table 3. Mean of days to 50% tasseling (DT), days to 50% silking (DS), plant height (PH), ear height and ear diameter (ED) for 24 maize genotypes grown at New Halfa, Kassala , Gezira and Elsuki Research Stations Farms, seasons 2017and 2018 combined.

Number of kernels/row

Highest number of kernels/row indicates an increase in ear length, ear weight and direct increase in grain yield, therefore, this trait is an important selection index for yield. The mean number of kernels/row ranged from 27.4 for local check Hudieba-2 to 32.8 for genotype 2. From these results, genotypes number 2, 4, 8, 10, 6, 21 ,1 ,20 , 22, 5 and 7 gave the highest number of kernels/row 32.8, 32.1, 31.7, 31.6, 31.5, 31.4, 31.0, 30.9, 30.9, 30.6 and 30.6), respectively (Table 4). These results are in agreement with those of Muhammad Rafiqu *et al*. (2004) who reported that effective selection for superior genotypes is possible considering number of kernels/row, ear length and ear diameter.

100 kernel weight (g)

The mean 100 kernel weight ranged from 17.4 g for local check (Var113) to 21.4 for genotypes. From these results, all genotypes gave highest 100 kernel weight more than the two local checks while, genotypes number 2, 3, 4, 5, 8, 12, 13, 14 , 15, 18, 19 , 20 and 22 gave the highest 100 kernel weight (20.1, 19.7, 20.1, 19.7, 19.6, 20.1, 20.3, 19.6, 20.0, 20.2, 21.4, 19.5 and 20.3g),respectively (Table 4). These results are in agreement with those of Malhotra and Khehra (1986) who reported that there were significant differences among genotypes for grain yield, ear length, number of rows/ear and 100-kernel weight.

Table 4. Mean of ear length (EL), number of rows/ear (NRE), number of kernels/row (NKR),100 kernel weight (100KW) for 24 genotypes grown at New Halfa, Kassala Gezira, and Elsuki Research Stations Farms, seasons 2017and 2018 combined.

Genotype	EL	NRE	NKR	100KW
1	15.8	13.3	31.0	19.2
2	15.4	13.8	32.8	20.1
3	14.6	13.9	29.6	19.7
4	16.0	13.4	32.1	20.1
5	16.0	12.9	30.6	19.7
6	15.7	13.1	31.5	18.9
7	16.0	13.4	30.6	19.4
8	15.3	13.6	31.7	19.6
9	15.2	12.9	29.9	19.0
10	15.3	13.2	31.6	18.9
11	13.9	13.6	27.2	19.4
12	14.3	13.6	28.7	20.1
13	14.7	13.0	28.4	20.3
14	15.0	12.9	29.4	19.6
15	14.3	12.6	28.3	20.0

16	14.8	13.3	29.7	19.4
17	14.9	13.1	28.9	19.1
18	15.3	13.6	28.9	20.2
19	15.6	12.7	29.1	21.4
20	15.0	13.8	30.9	19.5
21	15.4	13.8	31.4	19.0
22	15.3	13.6	30.9	20.3
23	14.1	13.2	30.1	17.4
24	14.6	13.0	27.4	17.6
Mean	15.1	13.3	30.0	19.5
C.V%	8.0	5.9	9.1	9.8
SE±	0.24	0.161	0.56	0.39

Grain yield (kg/ha)

The highest grain yield was shown by all genotypes and in seasons 2017 and 2018 at New Halfa location, i.e. the averages were 3305 and 3496 kg/ha in seasons 2017 and 2018, respectively. This was 3-fold that at Kassala location, *viz*. 1424 and 1129 kg/ha in the two seasons, respectively. The mean grain yields of the two seasons at Elsuki location were relatively high compared to that at Kassala and Gezira locations, probably due to the high rainfall at El-Suki location. Seasonal differences in grain yield within each location were not high. Across location and seasons, eight genotypes, 1, 3,4,10, 14, 18, 21 and 22, exceeded the yield of 2.5 t/ha. The overall average of the 24 genotypes was 2.4 t/ha. The two checks yielded around 2.1 t/ha each, i.e. almost all the introduced genotypes were high yielders compared to the checks. The high yielding eight genotypes were location specific, i.e. they gained their high average yield at New Halfa and Elsuki. Genotypes 1, 10, 14 and 22 exceeded the average yield of 2.6 t/ha and can be recommended to be grown across locations. Genotypes 1(white) and 10 (yellow seeded) and of ITTA origin, while genotypes 14 (yellow) and 22 (white) were of CIMMYT origin. In New Halfa, the highest yielding (average around 4 t/ha) genotypes were 2, 4, 8 and 14, while, in Kassala the highest yielding genotypes were 4,5,19, 20 and 22 (average less than 1.5 t/ha). The highest yielding (average above 3.0 t/ha) genotypes in Gezira were 10, 4, 15, and 21 while, in Elsuki were genotypes 1, 3, 11, 19, and 22 (average around 3.0 t/ha) (Table 5).

Simple linear correlation coefficient

Grain yield showed significant positive correlation coefficients with all the studied traits except ear height. Plant height showed significant negative correlation coefficients (Table 6). These results are in agreement with those of Parh *et al*., 1988; Kramer and Boyer, 1995; Devi *et al*., 2001; Yousuf and Seleem, 2001; Mohsan *et al*., 2002; Venugopal *et al.*, 2003 and Viola *et al*., 2003, who reported that grain yield/plant was positively and significantly correlated with days to 50 % tasseling, days to 50% silking, plant height, number of rows and kernels/ear and 100 kernel weight. Also, days to 50 % tasseling and days to 50% silking showed significant negative and low correlation with plant height and negatively correlated with ear height. Plant height was positively and highly significantly correlated with ear height (Table 6). Ear diameter showed high significant positive correlation with ear length (0.63***), number of rows/ear (0.37***), number of kernels/row (0.48***), 100 kernels weight (0.56***) and grain yield (0.60***). Also, ear length showed highly significant positive correlation with number of rows/ear (0.31***), number of kernels/rows (0.65***), 100 kernels weight (0.70***) and grain yield (0.65***). Number of rows per ear were significantly and positively correlated with number of kernels per row (0.23***), 100 kernel weight (0. 20***) and grain yield (0.20***), as presented in Table 6.

Path coefficient analysis

The highest significant correlation coefficient (0.67***) with grain yield was shown by 100-kernel weight and was mainly due to its direct effect but that with ear length (0.65***) was due to its direct effect (0.26) and its indirect effect through 100-kernel weight (0.26). The high correlation coefficient (0.60***) of grain yield with ear diameter was due mainly to its indirect effect (0.20) *via* 100-kernel weight and its direct effect (0.17). The high correlation coefficient (0.57***) of number of kernels/row with grain yield was indirectly *via* 100-kernel weight (0.25) and ear length (0.17) (Table 7).

The relatively low correlation coefficient of days to 50% silking (0.18***) and plant height (-0.22***) with grain yield were mainly due to their direct negative effects (-0.25 and -0.34, respectively) (Table 7). These results suggested the use of 100-kernel weight, ear length, and ear diameter as selection criteria for high grain yield of maize.

Table 5. Mean grain yield for 24 maize genotypes grown at New Halfa, Kassala, Gezira and Elsuki Research Stations Farms, seasons 2017 and 2018and their combined analysis.

Geno-type	New Halfa		Kassala		Gezira		Elsuki		
	2017	2018	2017	2018	2017	2018	2017	2018	Combined
1	3443	3202	1682	1187	1246	3174	3008	3881	2603
2	3964	3810	1246	1118	1606	2928	2196	2745	2452
3	3513	3538	1404	1279	2216	2663	2598	3248	2557
4	4210	3909	1330	1589	2291	2588	2177	2461	2569
5	3212	3522	1615	1449	1629	2099	2249	2774	2319
6	2942	3624	1588	1392	1575	2525	1978	3031	2332
7	3537	3415	1406	714	2533	2282	2275	3235	2427
8	3981	3992	1281	1308	1344	2393	2251	3358	2489
9	3753	3695	1369	833	2540	2515	2195	2761	2458
10	3562	3540	1465	1308	2650	3513	2111	2862	2626
11	2792	2906	1106	1085	2337	2404	2629	3286	2318
12	3185	3472	1662	752	2418	2105	1946	2874	2302
13	2860	3264	1336	1429	2506	2588	2438	3355	2472
14	3836	4216	1618	1081	2692	2889	2031	2539	2613
15	2801	3119	1379	812	3293	2708	2592	3260	2495
16	3399	3821	1272	723	2345	2071	1712	2994	2292

17	2467	2866	1093	941	2251	1454	2575	3219	2108
18	3372	3899	1219	1083	3137	2464	2467	2866	2564
19	2520	3093	1817	1389	2860	1619	2788	3485	2446
20	2825	3063	1702	1457	1818	1651	2131	2683	2166
21	3444	3571	1579	818	3214	3350	2099	2624	2587
22	3587	3728	1587	1353	2343	2362	2575	3308	2605
23	3388	3393	1245	952	2030	1538	2062	2577	2148
24	2723	3256	1160	1051	2475	2125	2185	2414	2174
Mean	3305	3496	1424	1129	2306	2417	2303	2993	2422
C.V%	15.4	7.4	16.2	11.9	11.6	11.9	12.8	7.4	12.2
SE±	293.0	159.9	133.1	77.4	154.0	165.9	170.5	128.6	60.0

Table 6. Simple linear correlation coefficients among various pairs of 10 traits of 24 maize genotypes (combined) over two seasons (2017 and 2018) and four locations (New Halfa, Kassala, Gezira and Elsuki).

Traits	DT	DS	PH	EH	ED	EL	NRE	NKR	KW
DS	0.99***								
PH	-0.08*	-0.08*							
EH	-0.03ns	-0.02 ns	0.68***						
ED	0.14***	0.14***	0.01 ns	0.25***					
EL	0.31***	0.31***	0.09*	0.26***	0.63***				
NRE	0.10**	0.09**	0.17***	0.32***	0.37***	0.31***			
NKR	0.36***	0.35***	0.07*	0.13***	0.48***	0.65***	0.23***		
KW	0.32***	0.32***	0.09*	0.12***	0.56***	0.70***	0.20***	0.68***	
GYD	0.18***	0.18***	-0.22***	0.01 ns	0.60***	0.65***	0.20***	0.57***	0.67***

*, **, ***, Significant at 0.05, 0.01 and 0.001 probability levels, respectively (n= 576).

DT= days to 50% tasseling; DS= days to 50% silking; PH = plant height; EH = ear height; ED = ear diameter; EL = ear length; NRE = number of rows per ear; NKR = number of kernels per row; KW= 100 kernel weight; GYD = grain yield.

Table 7. Path coefficient analysis of direct (in bold) and indirect effect of 9 traits of maize grain yield of 24 genotypes evaluated at New Halfa, Kassala, Gezira and Elsuki Research station farm season 2017 and 2018.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	Rij
X1	**0.14**	-0.25	0.03	0.00	0.03	0.08	0.00	0.05	0.12	0.19***
X2	0.14	**-0.25**	0.03	0.00	0.02	0.08	0.00	0.04	0.12	0.18***
X3	-0.01	0.02	**-0.34**	0.04	0.00	0.02	0.00	0.01	0.03	-0.22***
X4	0.00	0.01	-0.23	**0.06**	0.04	0.07	0.00	0.02	0.04	0.01
X5	0.02	-0.04	0.00	0.02	**0.17**	0.16	0.00	0.06	0.20	0.60***
X6	0.04	-0.08	-0.03	0.02	0.11	**0.26**	0.00	0.08	0.26	0.65***
X7	0.01	-0.02	-0.06	0.02	0.07	0.08	**0.00**	0.03	0.08	0.20***
X8	0.05	-0.09	-0.03	0.01	0.08	0.17	0.00	**0.13**	0.25	0.57***
X9	0.04	-0.08	-0.03	0.01	0.10	0.18	0.00	0.08	**0.36**	0.67***

X1 = Days to 50 % tasseling; X2= Days to 50 % silking; X3 =Plant height; X4= Ear height; X5 =Ear diameter; X6 = Ear length; X7 = Number of rows/ear; X8 = Number of kernels/row; X9 = 100-kernal weight.
rij= Simple linear correlation coefficients.

RECOMMENDATION

Based on grain yield potential, the genotypes TZBR Eld-3C5, BR9922-DMRSR, TZBR Comp-1-w, TZBR Comp-1-4-Y and TZBR YPOP STRCY were high yielding and recommended for the favorable supplementary irrigation conditions of New Halfa, Gezira and Elsuki, while the genotypes TZBREld-3c5, TZBREld-4-WC1, HYDERAB, 97502 (RE) and ECA STRIGOFE-153 were low yielders and stable and so were recommended for the unfavorable low yielding rainfed conditions of Kassala.

REFERENCES

Ahmed, F.E. and H.A. Elhag. 1999. Effect of watering intervals on yield and yield components of two maize (*Zea mays* L.) cultivars grown in summer and winter. University of Khartoum Journal of Agricultural Science 7 (1): 20 – 32.

Alvarez, A. and J.M. Las. 1994. Collecting and preliminary evaluation of local maize in northern Spain. Plant Genetic Resources Newsletter 100: 21 – 23.

Amaregouda, H.M. 2007. Combining ability analysis of S2 lines deprival from yellow pool population in Rabi maize. M.Sc. Thesis, Department of Genetics and Plant Breeding, College of Agriculture, Dharwad University of Agricultural Sciences, Pakistan.

Chaudhry, A.R. 1983. Maize in Pakistan. Punjab Agricultural Co-ordination Board, University of Agriculture, Faisalabad, Pakistan.

CIMMYT. 1989. International Maize and Wheat Improvement Center, Maize Research and Development in Pakistan. ARC/CIMMYT Collaborative Programs, Pakistan.

DACNET. 2014. Directorate of Economics and Statistics, DAC, Ministry of Agriculture, Government of India, New Delhi.

Devi, I.S., S. Muhammad and S. Mohammed. 2001. Character coefficient analysis of grain yield and its components in double crosses of maize. Crop Research, Hilary 21: 355 - 359.

Dowswell, C. R., R.L. Paliwal and R.P. Cantrell. 1996. Maize in the Third World. West View Press, Inc., Colorado, USA. Crop Science 39:1215–1221

Elahmadi, A. and A.B. Elahmadi. 2012. A proposal for the release of two maize hybrids for irrigated center clay of Sudan. A paper submitted to the Variety Release National Committee. Ministry of agriculture Conference Hall, Khartoum Sudan, March 2012.

Golam, F., N. Farhan, N. Zain, M.F. Majid, N.Z. Rahman and M.A. Kadir. 2011. Grain yield and associated traits of maize (*Zea mays* L.) genotypes in Malaysian Tropical Environment. African Journal of Agricultural Research 16(1):123-126.

Hallauer, A.R. and J.B. Miranda. 1995. Quantitative Genetics in Maize Breeding, 2nded. Ames, Iowa State University Press, PP: 468.

Kramer, P.J. and J.S. Boyer. 1995. Water Relations of Plant and Soils. Academic Press, San Deigo lowa State. University. Coop. Ext. Serv. Spec.Rep.48.

Lu, H., Y.L. Zheng, X.Z. Yiong, J.S. Li, Z. Yiong and J.L. Liu. 1994. Allozyme polymorphism within and among local varieties of maize in south western China. Maize Genetics Cooperation Newsletter 68: 113-115.

Malhotra, V.V. and A.S. Khehra. 1986. Genotypic variation in indigenous germplasm of maize. Indian Journal of Agricultural Science 56 (2): 811 – 816.

Meng, E. and J. Ekboir. 2002. Current and Future Trends in Maize Production and Trade. CIMMYT World Maize Facts and Trends. Mexico.

Mohsan, Y.C., D.K.K. Singh and N.V. Rao. 2002. Path coefficient analysis for oil and grain yield in maize (*Zea mays* L.) genotypes. National Journal of Plant Improvement, India 4(1):75-77.

Muhammed Rafique, H.T. Amer and M.B. Alviayub. 2004. Heritability and interrelationships among grain yield and yield components in maize (*Zea mays* L.) International Journal of Agriculture and Biology: 35-38.

Parh, D.K., M.A. Hamid, M.H. Rehman and M.Z.I.Talukdar. 1988. Correlation, path coefficient and selection indices in open-pollinated maize. Bangladesh Journal of Agriculture 15 (1): 69-74.

Thimothy, D. H., P. H. Harvey and C.R. Dowswell. 1988. Development and Spread of Improved Maize Varieties and Hybrids in Developing Countries. Bureau for Science and Technology, Washington, D. C.

Troyer, A.F. 2006. Adaptedness and heterosis in corn and mule hybrids. Crop Science 46:528-548

Venugopal, M., N. A. Ansari and T. Rajankanth. 2003. Correlation and path analysis in maize (*Zea may* L.). Crop Research, Hisar 25 (3): 525 – 529.

Viola, G., M., Ganesh, S.S. Reddy and C.V.S. Kumar. 2003. Study on heritability and genetic advances in elite baby corn (*Zea mays* L.) lines. Progressive Agriculture 3(2): 127 – 128.

Yousuf, M. and M. Seleem. 2001. Correlation analysis of S1 Families of maize for grain yield and its components. International Journal of Agricultural Biology 4:387-388.