British Biotechnology Journal
2(2): 102-114, 2012

SCIENCEDOMAIN *international*
www.sciencedomain.org

Screening Maize (*Zea mays* L.) Genotypes by Genetic Variability of Vegetative and Yield Traits Using Compromise Programming Technique

Atif Elsadig Idris[1*] and Hassan Ibrahim Mohammed[2]

[1]Department of Agronomy, College of Agricultural Studies, Sudan University of Science and Technology, Shambat, P.O. Box 71, Khartoum North, Sudan.
[2]Department of Agricultural Engineering, College of Agricultural Studies, Sudan University of Science and Technology, Shambat, P.O. Box 71, Khartoum North, Sudan.

Research Article

Received 9th March 2012
Accepted 21st May 2012
Online Ready 17th June 2012

ABSTRACT

The present study was made to develop a suitable procedure for selecting the most sustainable maize genotype to grow by considering genetic variability for vegetative, yield and yield components under irrigated farming. The experiment was conducted at the experimental farm, College of Agricultural studies, Sudan University of Science and Technology, Shambat, during summer seasons of 2007/08 and 2008/09, respectively. Significant variability was observed for plant height, stem diameter, number of rows per cob and ear length during the first season 2007/08 and for days to 50% flowering and 100-seed weight during the second season 2008/09. Frantic genotype scored maximum seed weight (81.0g) while Baladi had least seed weight (57.48g). Frantic genotype had maximum grain yield (0.577 ton/ha), while minimum grain yield ton/ha was recorded in Baladi (0.473 ton/ha). Data recorded for heritability showed that days to 50% flowering had maximum heritability (79.1%) while the minimum heritability (4.46%) was recorded for 100 seed weight. The present study revealed considerable amount of diversity among the tested populations which could be manipulated for further improvement in maize breeding in Sudan. However, significant differences of grain yield were observed among varieties. Due to the observed variability multi objective compromise programming technique is employed to screen these Maize (*Zea mays* L.) genotypes according to their vegetative and yield traits for purpose of selecting the best one that suit irrigated farming conditions of Shambat area. The study ranked the different Maize (*Zea mays* L.) genotypes and recommends the best alternative. Ranking of alternatives was explored in reference to

**Corresponding author: Email: atifelsadig@yahoo.com*;

selection criteria weights preferred by an agronomist, animal production specialist and nutrition scientist in comparison to equal weights.

Keywords: Heritability; Genetic variability; Maize; Genotypes; multiple-objective optimization; multi-criteria; compromise solutions.

1. INTRODUCTION

Maize (*Zea mays* L.) ranks as one of the world's three most important cereal crops. It is cultivated in a wide range of environments more than wheat and rice because of its greater adaptability (Koutsika-Sotiriou, 1999). It is grown at latitudes varying from the equator to slightly north and south of latitude 500, from sea level to over 3000 meters elevation, under 39 heavy rainfall and semi-arid conditions, cool and very hot climates.

In the Sudan, maize is considered as a minor crop and it is normally grown as a rain- fed crop in Kordofan, Darfur and Southern states or in small irrigated areas in the Northern states (Ishag, 2004; Ahmed and Elhag, 1999), with average production of about 0.697 ton/ha (FAO, 2005). Kim (1981), Ajala (1997) and Abdalla et al. (2010) reported that the lack of adapted lines with high yield potential and good resistance to water stress are the major limiting factors for maize production in the Sudan. Maize can occupy an important position in the economy of the country due to the possibility of blending maize with wheat for bread-making, the increase in the demand of maize for poultry feed and for forage as well as its great potential for export (to provide new source of hard currency).

The low productivity of maize was attributed to the low yielding ability of the local open – pollinated cultivars that normally grown and the greater sensitivity of the crop to water stress (Saliem, 1991). The production of crop and prediction of crop yield is function of cultivar selected. Recently, there has been an increasing interest in developing maize production in the Sudan as retch nutritional source of feed for poultry production. However, work on maize improvement in the Sudan is limited (Abdalla, 2010) and only three cultivars have been released.

These are var. 113, a selection from local material and Giza 2 and Mogtamaa 45. Genetic improvement in traits of economic importance along with maintaining sufficient amount of variability is always the desired objective in maize breeding programs (Hallauer and Miranda, 1988). Grzesiak (2001) observed considerable genotypic variability among various maize genotypes for different traits. Ihsan et al. (2005) also reported significant genetic differences for morphological parameters in maize genotypes. This variability is a key to crop improvement.

Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are inter alia, adapted cultivars, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources.

The increasing demand for maize for poultry feed or intermediary products for human nutrition have led to greater interest in this crop in Sudan. However, the relatively narrow gene pool and the heavy use of a small number of parents by competing breeding programs have led to a low genetic diversity among maize cultivars. Extensive use of closely related cultivars by producers could result in vulnerability to pests and disease (Duvick, 1984). Determination 70 of the genetic diversity of any given crop species is a suitable precursor for improvement of the crop because selection of the desirable genotypes for a certain trait will not be effective unless considerable genetic variation is existing in the material under study (Khalafalla and Abdalla, 1997).

Since grain yield in maize is quantitative in nature and polygenically controlled, effective yield improvement and simultaneous improvement in yield components are imperative (Bello and Olaoye, 2009). Selection on the basis of grain yield character alone is usually not very effective and efficient. However, selection based on its component characters could be more efficient and reliable (Muhammad, 2003). Therefore, the present study was conducted to screen and evaluate the performance of different Maize cultivars under irrigated farming conditions, assess the magnitude of diversity among them and employ compromise programming technique to select the best alternative to cultivate in the study area.

2. MATERIALS AND METHODS

2.1 Plant Materials and Data Collection

Nine open-pollinated genotypes of maize (Frantic, Huediba 1, Baladi, Huediba 2, Giza 2, Mogama 45.1, Var 113, Mogtama 45.2, Panama) were evaluated at Shambat (15°30'N; 32°31' E) during the two consecutive summer seasons 2007/08 and 2008/09 under irrigation conditions. These cultivars differ in their origin and days to 50% flowering (Table 1).

Table 1. Description and Days to 50% flowering of the nine 101 genotypes of maize

No	Name of genotypes	Description	Days to 50% flowering
1	Frantic	Received from ARC	62.30
2	Huediba 1	Open –pollinated variety improved by ARC	60.84
3	Balady	Local variety	50.84
4	Huediba 2	Open –pollinated variety improved by ARC	59.65
5	Giza 2	Introduced by ARC from Egypt	64.30
6	Mogama45.1	Introduced by ARC from Egypt	62.64
7	Var. 113	local material selected by ARC	58.00
8	Mogtama45.2	Introduced by ARC from Egypt	59.15
9	Panama	Introduced and released by ARC	61.50

ARC: refer to Agricultural Research Corporation, Sudan.

Table 2. Means yield and growth traits of maize genotypes evaluated during the season 2007/08 and 2008/09 respectively

a) 2007/08

Genotypes	Plant height	Days 50% flowering	Stem diameter	Number of seeds	Number of rows	Ear length (cm)	Seeds weight (g)	100- seed weight (g)	Yield (ton/ha)
Mogtama 45.1	198.6	60.67	7.3	7.49	18.53	0.696	375.5	13.73	14.77
Frantic	187.2	58.33	7.25	78.12	19.37	0.824	425.3	15.5	15.91
Huediba 1	195.3	60.67	6.96	62.23	17.83	0.386	384.5	14.83	13.57
Panama	181.4	61	6.92	70.55	19.7	0.749	3800.4	14.77	13.7
Huediba 2	177.1	53	5.96	64.76	19.67	0.688	349.5	14.4	14
Giza 2	181.6	62.33	8.3	80.71	19.23	0.821	426.8	14.48	15.71
Balady	203.7	54.67	6.77	67.47	19.3	0.671	347.5	13.47	13.17
Mogtma 45.2	187.8	56	7.16	71.53	19	0.755	397.4	13.77	14.07
Var. 113	211.9	55	6.99	67.98	20.4	0.704	345.2	14.1	14.17
Mean	191.6	57.96	7.07	70.62	19.23	0.733	381.26	14.34	14.36
LSD	20.91	3.31	0.69	21.25	3.08	0.29	86.33	0.93	1.83
SE +	6.98	1.1	0.23	7.0+	1.03	0.97	28.79	0.31	0.61

b) 2008/09

Genotypes	Plant height	Days 50% flowering	Stem diameter	Number of seeds	Number of rows	Ear length (cm)	Seeds weight (g)	100- seed weight (g)	Yield (ton/ha)
Mogtama 45.1	186	64.6	6.3	67.44	21.76	0.404	375.2	13.7	**14.3**
Frantic	190	66.3	6.5	86.11	21.47	0.239	342.7	14.4	**13.4**
Huediba 1	230	61	7	82.64	22.39	0.496	590.2	15.2	**13.2**
Panama	271	62	6.3	76.42	19.57	0.456	431.2	14.7	**15.2**
Huediba 2	121	66.3	6.1	51.01	15	0.306	334.6	14.4	**12.9**
Giza 2	186	66.3	6	48.87	20.25	0.29	360.6	14.6	**12.2**
Balady	152	47	6.5	47.48	16.24	0.275	335.6	13.8	**13.1**
Mogtama 45.2	182	62.3	7	57.02	2045	0.355	370.8	13.8	15.7
Var. 113	162	61	6.4	52.44	18.32	0.313	370.9	15.5	15.6
Mean	180	62	6.1	63.04	19.86	0.358	390.1	13.45	**15.34**
LSD	17	5.86	0.74	17.93	1.53	0.36	58.12	0.92	3.63
SE +	9.96	0.95	0.12	0.28	0.19	0.05	0.15	0.07	0.1

A randomized complete block design with three replications was used for laying out the experiment in the field. Each genotype was grown in two rows, each five meters long. Seeds were sown manually in holes along the ridges at rate of three seeds/holes and then thinned to two plants/hole three weeks after sowing. Spacing was 20 cm between holes and 70 cm between ridges. Sowing date was on 29th July and 2nd 92 August for the first and second seasons respectively. For fertilization, 85 kg/ha of urea were applied at sowing.

Weeding and spray against pests were carried out according to the standard cultural practices. As given in Table 2 data were recorded on seven yield parameters, namely number of cobs/plant, number of rows/cob, number of grains/cob, cob weight, 100 grain weight, grain yield/plant and grain yield ton/ha. Analysis of variance of the data was carried out according to the procedure described by Gomez and Gomez (1984).

2.2 Compromise Programming and Problem Solution

In this study, we used the Compromise Programming (CP) model for screening genetic variability for vegetative and yield traits in Maize (*Zea mays* L.) It is employed to rank different traits in maize (*Zea mays* L.) for studying the adoption of the best Maize (*Zea mays* L.) for Shambat locality. Multi- Criteria Decision Making (MCDM) includes of numerous mathematical techniques. In particular it employs both Multiple Objective Decision-Making (MODM) and Multiple Attribute Decision Making (MADM) (Zeleny, 1982). The main objective of MADM is ranking and choosing the best alternatives. In this study, based on objectives and different criteria related to various genotypes, we used the Compromise Programming (CP), which is one of the MADM that can be used in ranking possible alternative option and also determining the best one. CP is a distance – based technique designed to identify non-dominated solutions which are closest to an ideal solution using a quasi–distance measure (Cochrane and Zeleny (1973) and Zeleny (1974 and 1982)). The operative structure of CP is summarized in the following steps:

First step: the degree of closeness (dj) between the (jth) objective and its ideal is defined by:

$$dj = Z'' - Zj(x) \qquad (1),$$

when the (jth) objective is maximized, or as

$$dj = Zj(x) - Z^* \qquad (2),$$

when the (jth) objective is minimized.

Where Z'' is the ideal value and Zj (x) is the achieved scores with respect to attribute under study. When the units used to measure the objectives and the achieved scores of one indicator are different from that of other indicators, relative deviations rather than absolute deviations must be used. Thus, the degree of closeness is given by

$$dj = (Z^* - Z' (x)) / (Z j - Z^*j) \qquad (3)$$

Where Z^*j is the anti – ideal point for the (*j* th) objective (minimum value).

Second step: in order to measure the distances between each solution and the ideal point, CP introduces the following family of distance functions:

$$L\ p\ (Ai) = [\ \Sigma jk\ (uj\ dj)p]^{1/p} \qquad (4)$$

Where: *L p* (Ai*)* is the distance metric which is a function of the decision alternative (Ai) Parameter (P, *uj)* is the standardized form of the criterion weight where 1 ≤ *P* ≤ ∞ that shows the sensitivity of decision maker about evaluations. Compromise programming procedure is applied by following the sequence given in the conceptual flow chart of Fig. 1 (Tecle and Yitayew, 1990).

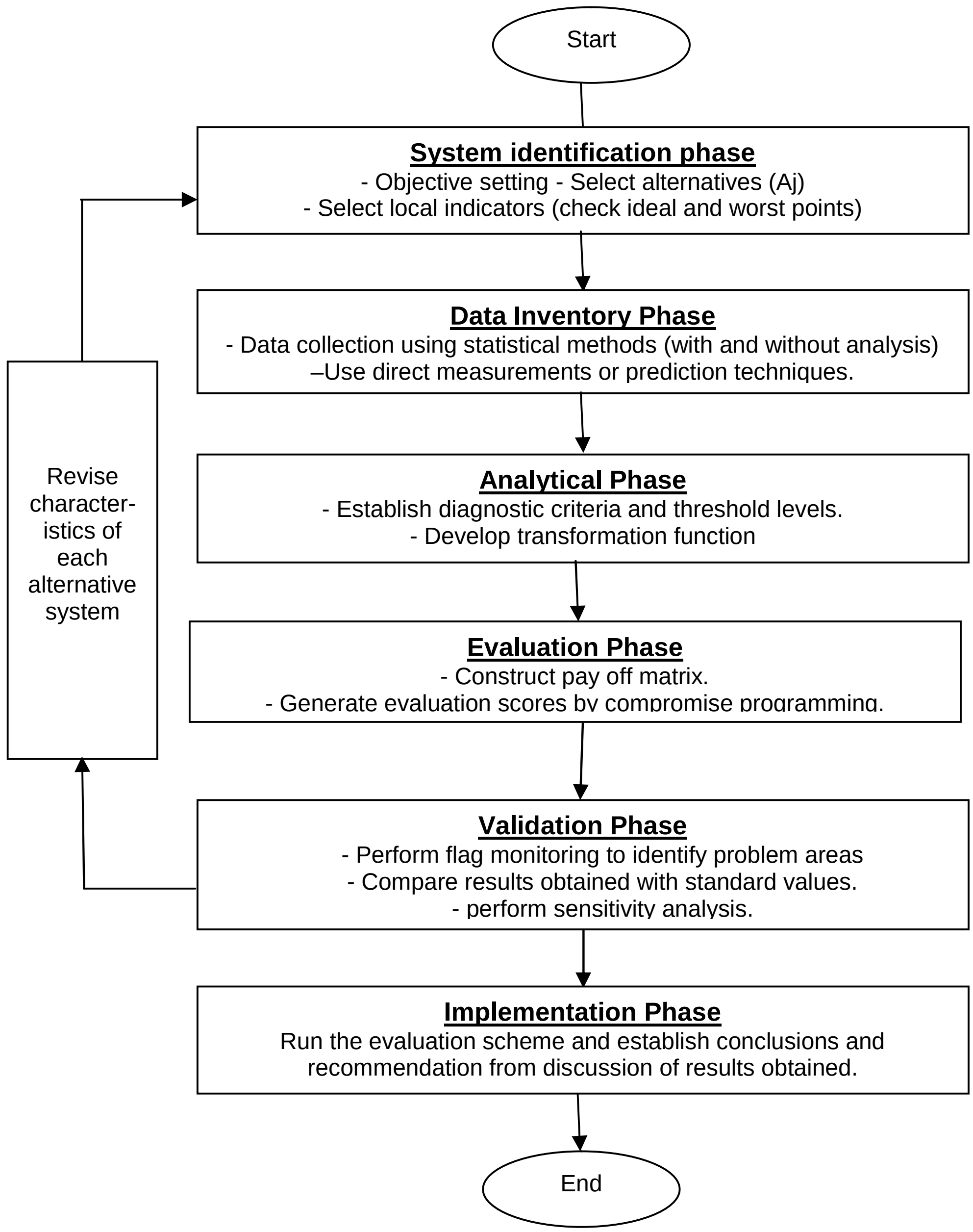

Fig. 1. Flow chart of the framework of conducting compromise programming technique

An excel sheet was made to estimate an overall evaluation index for each genotype as specified by the evaluation model. Payoff matrix of traits measured for each genotype combined for two seasons is depicted in Table 3.

2.3 Data Analysis

An excel sheets were employed for data analysis of descriptive statistics (means, standard deviation) and for multi criteria analysis. Analysis of variance was made using M.STST computer software.

3. RESULTS AND DISCUSSION

3.1 Determination of Objectives Function

The collected criteria vectors of maximum (best) and minimum (worst) values and criteria weight set for each genotype (treatment or alternative) are given in Table 4. To solve the multi-criterion problem using a compromise programming algorithm the vectors of ideal point values, Max, and worst values, Min, shown in columns 2 and 3 of Table 4 respectively, are first determined using equation 1, 2 and 3. These values are then used in equation 3 and 4 to compute Lp – distances from the ideal point of the elements in the payoff matrix of Table 4.

3.2 Statistical Analysis of the Problem

The analysis of variance mean squares revealed significant differences among maize genotypes for most of the traits measured in both seasons (Table 4). This variation could be attributed to genetic and environmental effects. Moreover, the results of the analysis revealed highly significant differences among the mean values for most of the traits i.e. plant height, days to 50% flowering, stem diameter, number of rows/cob and ear length during the first season 2007/08 and for days to 50% flowering and 100-seed weight during the second season 2008/09 (Table 4). Different researchers have reported significant amount of variability in different maize populations including top-crosses and open pollinated varieties (Sampoux et al., 1989), (Idris and Abualli, 2011) and (Kamara et al., 2003). Our results are in line with those of Grzesiak (2001), who also observed considerable genotypic variability among various maize genotypes. Similarly, Sokolove and Guzhva (1997) reported pronounced variation for different morphological traits among inbred lines.

Different Hybrids have also been evaluated for morphological and agronomic traits, showing significant amount of variation among these (Ihsan et al., 2005). Shah et al. (2000) and Iqubal et al. (2011) have reported significant amount of variability for different morphological traits. Table 5 shows that there are no significant results in number of seeds/cob, seed weight and grain yield Ton/Ha in the two seasons. These parameters only do not reflect final plant productivity and performance. It is thus essential to consider the other multi criteria for evaluation yield components.

Mitchell-Olds and Waller (1985) have also reported increased performance of heterogeneous populations over those resulted from selfing. Such genotypes can help farmers to compensate their inputs, as compared to hybrid cultivars, which ask for a strict crop production package. Low, medium and high estimates of broad sense heritability were found in different plant traits under study (Table 6).

Table 3. Payoff matrix of traits measured for each genotype combined for two seasons

Genotypes	Plant height, cm	Days 50% flowering	Stem diameter	Seeds Weight (g)	100-Seeds Weight (g)	Yield (ton/ha)	Number of seeds/cob	Number of seeds/cob	Ear Length, cm
Mogtema 45.1	192	63	6.800	69	20	0.550	375	13.715	14.535
Frantic	189	62	6.875	81	20	0.577	384	14.95	14.655
Huediba 1	213	61	6.980	72	20	0.591	487	15.015	13.385
Panama	226	62	6.610	73	20	0.603	406	14.735	14.45
Huediba 2	149	60	6.030	58	19	0.497	342	14.4	13.45
Giza 2	184	64	7.150	65	20	0.556	394	14.54	14.055
Baladi	178	51	6.635	57	18	0.473	342	13.635	13.135
Mogtema 45.2	185	59	7.080	64	20	0.555	384	13.785	14.885
Var. 113	187	58	6.695	60	19	0.509	358	14.8	14.885
Max	226	64	7	81	20	1	487	15	15
Min	149	51	6	57	18	0	342	14	13

Table 4. Vectors of maximum (best) and minimum (worst) values and four sets of criterion weights

Traits	Maximum	Minimum	Expert criteria weights (*u j*)			
			Equal	Agronomy	Animal production	Food technology
Plant height	226	149	1.00	0.05	0.2	0.00
Days to 50% flowering	64	51	1.00	0.05	0.05	0.14
Stem diameter	7	6	1.00	0.02	0.1	0.00
Seeds weight (g)	81	57	1.00	0.1	0.1	0.14
100- seed weight (g)	20	18	1.00	0.05	0.05	0.14
Yield (ton/ha)	1	0	1.00	0.55	0.1	0.16
Number of seeds/cob	487	342	1.00	0.1	0.2	0.14
Number of rows/cob	15	14	1.00	0.03	0.1	0.14
Ear length(cm)	15	13	1.00	0.05	0.05	0.14

Table 5. Analysis of variance mean squares for nine vegetative traits and some yield components of maize genotypes evaluated during season 2007/08 and 2008/09 respectively

Characters	Season 2007/08		Season 2008/09	
	Means Square	CV%	Means Square	CV%
Plant height (cm)	402.16*	6.31	0207ns	14.4
Days to 50%floweing	273.63**	3.3	84.833**	3.97
Stem diameter (cm)	1.113**	5.61	0.698ns	12.94
Number of seeds/cob	2911.03ns	13.08	26230.47ns	16.72
Number of rows/cob	1.24**	3.73	1.025ns	6.64
100- seed weight (g)	1.61ns	9.24	14.57*	13.71
Seed weight (g)	105.05ns	17.43	706.00ns	28.46
Ear length (cm)	2.89*	7.95	3.606ns	9.87
Grain yield (ton/ha)	2.37ns	16.73	0.024ns	29.74

ns = non significance difference, * = significant at the 0.05 probability level and ** = high significant at 0.05 and 0.01 probability level.

Table 6. Genotypic, phenotypic coefficient of variations and heritability for some plant traits in maize

Characters	Season 2007/08			Season 2008/09		
	Phenotypic σ^2Ph	Genotypic σ^2g	Heritability h^2	Phenotypic σ^2Ph	Genotypic σ^2g	Heritability h^2
Plant height (cm)	274.697	128.732	46.86	0.091	0.012	23.3
Days to 50%floweing	13.833	10.185	73.063	39.16	33.13	84.57
Stem diameter (cm)	0.476	0.319	76.02	0.179	0.109	25.56
Number of seeds/ cob	2911.029	423.669	14.56	2.49	0.684	27.4
Number of rows/cob	6.354	1.779	28	6269.23	2254.09	35.9
100- seed weight (g)	2.642	-0.616	-19.53	449.96	18.02	28.45
Ear length (cm)	1.704	0.591	34.68	1.49	0.57	38.05
Grain yield (ton/ha)	2.669	-0.15	-5.62	0.017	0.004	21.86

Highest heritability estimates were found in days to 50% flowering (79.1%) and by plant height (36.4%). Swamy et al. (1971), Patil et al. (1972) and Singh and Chaudhry (1985) also reported similar findings. They computed high heritability estimates for grain yield per plant, days taken to silking and plant height. Bhalla et al. (1986) also reported high heritability for grain yield plant^{-1} and plant height. Results presented in this study and of the reported studies are in agreement with the findings of Jha and Ghosh (1998) and Henfy (2007).

3.3 Compromise Programming Analysis of the Problem

Following Compromise Programming working procedure given in Fig. 1, the Lp – distances are minimized to give a compromise solution for each weight set.

In this study, various criteria (traits) are used to evaluate and rank genotypes of Maize (*Zea mays* L.) that are shown in Table 4. For in depth investigation other different criteria were considered.

Consequently, three weight groups were employed. In the first group, all criteria have the same weight. In the second, third and fourth groups, criteria weights were assigned in the range of 0.0 to 1.0 by agronomist, economist and nutrition scientist (Table 4).

Table 7 is a compromise solution of the payoff matrix (Table 3) for a condition when the decision maker shows no preferences among the criteria. The condition of no preferences is represented by assigning a weight of one to every criterion. Similar tables are constructed for other sets of criterion weights under consideration.

Based on multi-criteria analysis given in Table 7, genotype Frantic ranked one in case of equal weights and by food technology expert and it ranked second by animal production expert (Ahmed and Elhag, 1999). At the same time Huediba 1 ranked first by both agronomist and animal experts while it ranked second by food technology expert and when equal weights are used. These results are in agreement with those reported by Abdalla et al (2010) for Nuba mountain of Sudan.

Table 7. Relative alternative distance from ideal point (L j) and rank of each genotype by each expert

Alternative genotype	Equal Wts		Agronomy Wts		Animal Wts		Food technology Wts	
	L j	Rank	L j	Rank	L j	Rank	L j	Rank
Mogtema 45.1	2.682	7	0.373	6	0.292	6	0.401	7
Frantic	0.698	1	0.170	3	0.093	2	0.136	1
Huediba 1	1.148	2	0.120	1	0.061	1	0.166	2
Panama	1.903	3	0.135	2	0.229	4	0.199	3
Huediba 2	4.312	8	0.713	8	0.377	7	0.620	8
Giza 2	2.221	5	0.352	5	0.195	3	0.395	6
Baladi	4.833	9	0.822	9	0.471	8	0.720	9
Mogtema 45.2	2.023	4	0.338	4	0.229	4	0.357	4
Var. 113	2.482	6	0.572	7	0.289	5	0.376	5

Under equal criteria weights the least preferred alternative genotype is determined to be Var.113 followed by Huediba 2. Considering sensitivity analysis of the results when criteria weight is employed with preference of other decision makers (Agronomy, Animal and food Technology experts) it is evident from Table 7 that Baladi genotype is the least preferred alternative with reference to Agronomy and food Technology experts while it comes as second least when judged by Animal expert.

4. CONCLUSIONS

The screened genotypes used in this study exhibited some variability for most of the measured vegetative and agronomic traits of yield and yield components under Shambat-Sudan conditions. This can be verified by the significantly observed variability for plant height, stem diameter, number of rows per cob and ear length during the first season 2007/08 and for days to 50% flowering and 100-seed weight during the second season 2008/09. The observed high amount of diversity among the tested populations could be manipulated for further improvement in maize breeding in Sudan. Based on the results obtained via compromise programming, the superiority of the cultivars Frantic and Hudeiba 1 over the other cultivars for the all measured traits suggests their adoption as ones of the high yielding cultivars in this area. Their characteristics gave them the advantage to be useful in the breeding programs for development of adequate yield potential cultivars suitable for expanding maize into the central warmer non-traditional maize areas of Sudan.

However, further investigation, under a range of environments, is needed for studying the role and contribution of the different plant morphophysiological traits to heat tolerance and water scarcity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdalla, E.A., M.F., Mahmoud, M.F., El Naim, A.M. (2010). Evaluation some maize (*Zea mays* L.) varieties in different environments of the Nuba mountain of Sudan. Australian Journal of Basic and Applied Sciences, 4(12), 6605-6610.

Ahmed, F.E., El Hag, H.A. (1999). Effect of watering intervals on yield and yield's components of two maize (*Zea mays* L.) cultivars grown in summer and winter. Journal of Agric. Sciences, l7(1).

Ahmed, F. E., Elhag, H.A. (1999). Effect of watering intervals on yield and yield components of two maize (*Zea mays* L.) cultivars grown in summer and winter. U.K.J. Agric. Sci., 7(1), 20-32.

Ajala, S.O., (1997). The Potential of some tropical maize genotypes as sources of high yielding bred lines. Discovery and Innovation, 4, 4.

Bello, O.B., Olaoye, G. (2009). Combining ability for maize grain yield and other agronomic characters in a typical southern guinea savanna ecology of Nigeria. African Journal of Biotechnology, 8(11), 2518-2522.

Bhalla, S.K., Bali, S., Sharma, S., Sharma, B.K. (1986). Assessment of genetic variability and correlation in indigenous maize germplasm of Himachal Pradesh. Drought tolerance in maize by molecular markers. I. Yield components. Theo. Appl. Himachal J. Agric. Res., 12, 75–81.

Cochrane, J.L., Zeleny, M. (1973). Multiple criteria decision making. University of South Carolina Press. Columbia.
Duvick, D.N. (1984). Genetic diversity in major farm crops on the farm and in reserve. Econ. Bot., 38, 157-174.
Elkarouri, M.O.H., Mansi, M.G. (1980). Performance of sorghum (*Sorghum vulgare*) and maize (*Zea mays*) as forages in irrigated saline soils of the Sudan. Expl. Agric., 16, 431-436.
FAO. (2005). Production year book, vol-2, FAO, Rome.
Gomez, K.A., Gomez, A.A. (1984). Statistical Procedures for Agricultural 305 Research. 3rd Edition. John Wiley, New York.
Grzesiak, S. (2001). Genotypic variation between maize (*Zea mays* L.) single-cross hybrids in response to drought stress. Acta Physiologiae Plantarium, 23(4), 443-456.
Hallauer, A.R., Miranda, F.O.J.B. (1988). Quantitative genetics in maize breeding. Second edition. Iowa State University Press, Ames, Iowa.
Henfy, M.M. (2007). Estimation of quantitative genetic parameters for nitrogen use efficiency in maize under two nitrogen rates. International Journal of Plant Breeding and Genetics, 1(2), 54-66.
Idris, A.E., Abuali, A.I. (2011). Genetic variability for vegetative and yield traits in maize (*Zea mays* L.) genotypes. International Research Journal of Agricultural Science and Soil Science, 1(10), 407-411.
Ihsan, H., Khalil, I.H., Rehman, H., Iqbal. M. (2005). Genotypic variability for morphological traits among exotic maize hybrids. Sarhad J. Agric., 21(4), 599-602
Iqbal, M., Khan, K., Sher, H., ur-Rahman, H., Al-Yemeni, M.N. (2011). Genotypic and phenotypic relationship between physiological and grain yield related traits in four maize (*Zea mays* L.) crosses of subtropical climate. Scientific Research and Essays, 6(13), 2864-2872.
Ishag, A.A. (2004). Estimation of general and specific combing ability of some maize inbred lines (*Zea mays* L.) PhD. Thesis, faculty of Agriculture, University of Khartoum.
Jha, P.B., Ghosh, J. (1998). Genetic variability in fodder maize. J. Res. Birsa Agri. Univ., 10, 139–43. John Willey and Sons (ed). New York, USA.
Kamara, A.Y., Menkir, A., Badau-Apraku, B., Ibikunle, O. (2003). Reproductive and stay green trait responses of maize hybrids, improved open-pollinated varieties and farmers local varieties to terminal drought stress. Mydica., 48, 29-37.
Khalafalla, M.M., Abdalla, A.H. (1997). Performance of some maize genotypes (*Zea mays* L.) and their F1 hybrids for yields and it is components. U.K. J. Agric. Sci., 5(2), 56-69.
Koutsika-Sotiriou, M. (1999). Hybrid seed production in maize. In Basra AS (Ed.), Heterosis and Hybrid Seed Production in Agronomic Crops. Food Products Press, New York, 25-64.
Koutsika-Sotiriou, M. (1999). Hybrid seed production in maize. In Basra, A.S. (Ed.), Heterosis and Hybrid Seed Production in Agronomic Crops. Food Products.
Kim, S.K. (1981). Line Development. IIT Annual Report., Ibadan, Ngeria, IITA.
Mitchell-Olds, T., Waller, D.M. (1985). Relative performance of selfed and outcrossed progeny *Impatiens capensis*. Evolution, 39(3), 533-544.
Muhammad, B.A., Muhammad, R., Muhammad, S.T., Amer, H., Tariq, M., Muhammad, S.A. (2003). Character association and path coefficient analysis of grain yield and yield Components in maize. Pak. J. Biological Sci., 6(2), 136-138.
Patil, S.J., Swamy, R.T., Ramamurty, S. (1972). Genetic variation, heritability and genetic advance of quantitative characters in maize. Genetic Polonica., 13, 181–2. Press, New York, 25-64.
Saliem, B.A. (1991). Report of national committee of maize production improvement in Sudan. Ministry of Agriculture and Forestry, Sudan.

Sampoux, J.P., Gallais, A., Lefort-Buson, M. (1989). S1 value combined with top cross value for forage maize selection. Agronomie, 9(5), 511-520.
Shah, R.A., Ahmed, B., Shafi, M., Jehan Bakht. (2000). Maturity studies in 336 hybrid and open pollinated cultivars of maize. Pak. J. Biol. Sci., 3(10), 1624-1626.
Singh, R.K., Chaudhry, B.D. (1985). Biometrical methods in quantitative genetic analysis. 38–54. Kalyani Pub., New Dehli, India.
Sokolov, V.M., Guzhva, D.V. (1997). Use of qualitative traits for genotypic classification of inbred maize lines. Kukuruza I Sorgo, 3, 8-12.
Swamy, R., Ramamurty, T.A., Patil, S.J., Aradhya, R.S. (1971). Genetic variability and heterosis in maize. Madras Agric. J., 58, 620–3.
Tecle, A., Yitayew, M. (1990). Preference ranking of alternative irrigation technologies via a multicriterion decision-making procedure. Transaction of ASAE, 33, 1509-1517.
Zeleny, M. (1974). A concept of compromise solutions and the method of the displaced ideal. Computers and Operations Research, 1(3-4), 479-496.
Zeleny, M. (1982). Multiple criteria decision making. New York, McGraw-Hill.