

# Evaluation of Some Local Sorghum (*Sorghum Bicolor* L. Moench) Genotypes in Rain-Fed

Ahmed M. El Naim<sup>1,\*</sup>, Ibrahim M. Ibrahim<sup>2</sup>, Mohammed E. Abdel Rahman<sup>1</sup>, Elshiekh A. Ibrahim<sup>1</sup>

<sup>1</sup>Department of Crop Science, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Elobeid, Sudan  
<sup>2</sup>Arab- Sudanese Seed Company, Elobeid Seed Station, Elobeid, Sudan

**Abstract** A two-year study was conducted on Sorghum (*Sorghum bicolor* L. Moench) across two environments in North Kordofan State, Sudan, to examine eight grain sorghum genotypes (Qusari, Wad-mergani, Sefera Red-Zinnari, Fraikh, Hamadi, Nilla and Kelash). The Quasari and Kelash genotypes are early flowering and early maturing. The genotype Quasari, Fraikh and Nilla were superior in yield and yield's performance across all environmental conditions. Positive and significant phenotypic and genotypic correlations were found. Grain yield per hectare had high significant positive correlation with number of grain per panicle and number of panicles per unit area. The variance components for the two environments showed that most of the characters had higher phenotypic and genotypic variance estimates than the environmental variance estimates.

**Keywords** Sorghum, Genotype, Correlation, Yield, Variability

## 1. Introduction

Sorghum (*Sorghum bicolor* L. Moench) is an important staple food crops and provide bulk of raw materials for the livestock and many agro-allied industries in the world (Dogget, 1970). Zinnari varieties are known to out yield local varieties on sandy soils of Kordofan (Sudan), under low rain fall conditions. The diversity of lines expresses a wide range of adaptability to different conditions, including different genotypes from early to late maturing, dwarf to tall, loose to compacted heads, white and red seeded. Zinnari lines are white- seeded types that meets the consumption habits of peoples, thus selection of adapted high yielding lines is highly accepted by consumers. Plant breeders are interested in developing cultivars with improved yield and other desirable agronomic and phenological characters. In order to achieve this goal, the breeders had the option of selecting desirable genotypes in early generations or delaying intense selection until advanced generations (Puri, *et al.* 1982). The selection criteria may be yield, or one or more of the yield component characters. However, breeding for high yield crops require information on the nature and magnitude of variation in the available materials, relationship of yield with other agronomic characters and the degree of environmental influence on the expression of these component characters. Since grain yield in sorghum is quantitative in

nature and polygenic ally 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, *et al.* 2003). Knowledge of association between yield and its component traits and among the component parameters themselves can improve the efficiency of selection in plant breeding. Correlation coefficient measures the mutual association between a pair of variables independent of other variables to be considered. Where more than two variables are involved, correlation coefficient alone does not give complete picture of the interrelationship (Fakorede and Opeke, 1985). To determine relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. The result of correlation is of great value in the evaluation of the most effective procedures for selection of superior genotypes. When there is positive association of major yield characters component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Nemati, *et al.* 2009).

The objectives of this study were to: study the variability in grain yield and agronomic characters among some sorghum genotypes in North Kordofan State of Sudan.

## 2. Materials and Methods

\* Corresponding author:

naim17amn@yahoo.com (Ahmed M. El Naim)

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## 2.1. Site of the Experiment and Climate

A field experiment was conducted during two seasons 2002/03 and 2003/04 under rain-fed conditions at two locations (Khorabied and Ayara) in North Kordofan State, Sudan (13° 12 and 3° 14 E). The area is located in arid and semiarid zone. The soil is sandy with low fertility. Rainfall range between 350-500 mm. (Monthly rainfalls during the experiment are represent in Table 1). Average maximum daily temperatures varied between 30°C to 35°C most of the year.

**Table 1.** Monthly Mean Rainfall (mm) During the Growing Season for Sorghum (July -October) in 2002 and 2003 in Khorabied and Ayara of North Kordofan of Sudan

Month	2002/03		2003/04	
	Khorabied	Ayara	Khorabied	Ayara
July	160	180	160	120
August	200	110	200	150
September	110	090	045	020
October	040	045	008	009
Total	510	425	413	299

## 2.2. Plant Materials

The materials used in this study consisted of eight indigenous grain sorghum genotypes representing the types widely grown in Kordofan and West White Nile districts of Sudan. The eight genotypes were Qusari, Wad-mergani, Sefera Red-Zinnari, Fraikh, Hamadi, Nilla and Kelash.

## 2.3. Experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) in four replications. Each plot consisted of seven rows five meters long, 60 cm apart and intra-row spacing of 20 cm.

Before sowing, seeds were treated with Fernisan-D of 3g/kg seed against soil fungi and insects. Sowing was on 22<sup>nd</sup> of July, 2002 and 2003. Five seeds were sown in each hill. Seedlings were thinned to three plants per hill after three weeks from sowing. Hand hoeing weeding practiced twice, the first one after two weeks from sowing and the second after four weeks from sowing.

## 2.4. Data Collection

In each plot, the five middle rows were used to measure for the following characters:

1. Plant height (cm): measured from soil surface to the tip of the main head as an average of ten plants, randomly chosen, just before harvesting.
2. Days to 50% flowering were recorded as the number of days from the sowing date to the day on which 50% of the plants in a plot reached anthesis at least halfway down the panicle.
3. Days to maturity: the number of days from sowing date to the day on which 95% of the panicles in a plot reached physiological maturity, as monitored by the appearance of black glumes.
4. Straw weight (kg/ha): calculated by weighing the dry hay of harvested rows of each plot.

5. Number of panicles per plot: obtained by counting the total number of heads in each plot.

6. Panicle length (cm): Mean length of the panicle measured on a sample of ten panicle measured from the base to the tip of the head.

7. Panicle weight (g): random five heads of each plot weighed and divided by five.

8. Number of grains per panicle

9. Grain weight (g): based on random sample of 100-seeds taken four times from the bulked seeds of each experimental unit.

10. Grain yield per plant (g).

11. Grain yield (kg/ha): panicles from each plot were harvested, sun dried, threshed, weighed and converted to kg/ha.

## 2.5. Statistical Analysis

Individual analysis of variance was performed for all traits on each location according to the procedure described by Gomez and Gomez (1984) for the randomized complete block design. The combined analysis of variance was done, for all traits, following the method described by LeClerg *et al.* (1962), based on a randomized complete block design.

For mean comparison, the means were separated using Duncan Multiple Range Test (DMRT) at 0.05 level of significant, according to the procedure described by Gomez and Gomez (1984).

## 2.6. Phenotypic and Genotypic Variances

Phenotypic ( $\sigma_{ph}^2$ ) and genotypic ( $\sigma_g^2$ ) variances were estimated using individual analysis of variance as follows:

$$\sigma_g^2 = \frac{M2-M3}{r}$$

$$\sigma_{ph}^2 = \sigma_g^2 + \sigma_c^2$$

Where:  $\sigma_c^2$ : is the error variance (M3) for RCBD.

## 2.7. Heritability

The broad sense heritability ( $h^2$ ) was estimated for each trait according to Johnson *et al.* (1955), using the formula:

$$h^2 = \sigma_g^2 / \sigma_{ph}^2$$

The genetic coefficient of variation (GCV %) was computed, according to the formula suggested by Burton and De Vane (1953) as follows:

$$GCV\% = \frac{\sqrt{\sigma_g^2}}{GM} \times 100$$

## 2.8. Correlation coefficient

The correlation coefficient was determined by using the formula suggested by Miller *et al.* (1958), as follows

$$r = \text{cov.}x_1x_2 / (\text{var. } x_1) (\text{var. } x_2)$$

Where:

r= correlation coefficient

cov  $x_1 x_2$ = covariance between traits  $x_1$  and  $x_2$

var  $x_1$ = variance of trait  $x_1$

var  $x_2$ = variance of trait  $x_2$

### 3. Results and Discussion

Genotype had significant effect on plant height at the two locations in both seasons (Table 2). Kelash genotype had a lesser plant height. This result confirmed the results of previous studies of Abdalla (1991), Abd Rahaman (1985), Alejandro (1982), Bakheit (1990) and Hassan (2005). They found that the cultivars of grain sorghum significantly affect the plant height. Genotype had significant effect on number of days to 50% flowering and to days 95% physiological maturity. Quasari genotype was the earliest among all genotypes at the two locations in both seasons (Table 2). Mean time to anthesis and days to maturity varied very considerable from one location to another, probably as consequent of environmental conditions and genotypic differences. Similar findings were reported by Whiteman and Wilson (1965). Hassan (2005) found that the cultivars significantly differed in number of days to 50% flowering. Comparison of genotypes in respect to their values to earlier mature showed that three genotypes namely Qusari, Friakh and Nilla were superior in yield performance. The genotypes had significant effect on number of panicles/m<sup>2</sup>, panicle weight and straw yield (Table 3). Qussari had a highest number of panicles in season 2002/03. Hassan (2005) in previous study reported that, the sorghum cultivars examined had no significantly affect on the panicle weight and number of panicles /m<sup>2</sup>. The genotypes Kelash, Nilla, and Feraikh had highest number of grains per panicle.

There were significant differences among genotypes in grain yield and yield related characters at the two locations

(Table 4). Average yield over all genotypes in the two seasons at Khorabeid (982 kg/ha) was greater than Ayara (689 kg/ha). This was mainly due to the higher number of grains per head at Khorabeid than at Ayara. Dogget (1970) and Beil and Atkins (1967) reported that higher seed number generally is the most important yield component associated with increased in yield of sorghum. The reduction in the number of grains per panicle at Ayara was due to water stress at mid-season, caused by the relatively low amount of rains. Hultquist (1973) reported that water stress reduced significantly number of grains per panicle. The variance components for the two environments showed that most of the characters had higher phenotypic and genotypic variance estimates than the environmental variance estimates (Table 5). Therefore, expressions for most of the characters were genetic, which can be exploited in breeding programs. This finding is in agreement with the findings of Basu (1981) and Abu-Gasim and Kambal (1985) and Bello, *et al.* (2007) for several quantitative for characters in sorghum genotypes. Zaveri *et al.* (1989) also reported similar results in pearl millet. Lukhele (1981) and Bello *et al.* (2007) observed that high error or environmental variance estimate for some characters similar to what was obtained in this study could be attributable to sample size. To reduce error and consequently increase the precision and reliability of estimates, Allard and Bradshaw (1964) suggested increasing sample size and number of environments or years during trials. However the disadvantage of this suggestion would be delay in the release of results.

**Table 2.** Effects of Genotype on Plant Height, Days to 50% Flowering, and Days to 95% Maturity of Sorghum

Genotypes	Plant Height(cm)		50% Flowering (days)		95% Maturity (days)	
	Khorabied	Ayara	Khorabied	Ayara	Khorabied	Ayara
Qusari	109.6	93.7	60.00f	66.0	80.3f	79.5
Wad-Mergani	160.4	117	71.3b	72.0	97.5b	97.0
Sefera	131.3	105	77.8a	66.0	89.8d	89.8
Red zenari	157.00	120	64.3de	75.0	85.5e	85.5
Fereikh	162.8	13.	62.8ef	70.0	87.3e	88.3
Hamadi	153.6	128	75.7a	74.0	101.3a	101.
Nilla	152.3	138	68.7ab	73.0	93.0c	93.0
Kelash	103.4	89.9	66.7cd	66.0	91.5cd	90.0
CV%	7.14%	7.14	3.01%	3.01	1.73%	2.43

**Table 3.** Effects of Genotype on Straw Weight, Number of Panicles /m<sup>2</sup> and Panicle Weight of Sorghum

Genotypes	Straw Weight (kg/ha)		No. of Panicles/m <sup>2</sup>		Panicle Weight(g)	
	Khorabied	Ayara	Khorabied	Ayara	Khorabied	Ayara
Qusari	2.8cd	2.4	80.00a	43.0a	447	345
Wad-Mergani	5.3ab	2.7	58abc	26.0a	395	350
Sefera	6.3a	2.8	50bc	21.0b	252	134
Red zenari	5.9a	2.8	71ab	30.0a	402	35.0
Fereikh	4.8ab	3.9	57abc	38.0a	445	325
Hamadi	5.00ab	4.6	60abc	27.0a	387	210
Nilla	4.2bc	3.5	55abc	43.0a	372	280
Kelash	2.6d	2.4	42c	37.0a	252	295
CV%	21.9%	21.9	26.05	26.05	40.5	40.5

**Table 4.** Effects of Genotype on Number of Grains per Panicle, 100-seed Weight and Grain Yield of Sorghum

Genotypes	No. of Grains/Panicle		100-Grain Weight (g)		Grain Yield Kg/ha	
	Khorabied	Ayara	Khorabied	Ayara	Khorabied	Ayara
Qusari	753	571.0	3.8bc	7.0	1206	870
Wad-Mergani	791	1024	4.6a	6.9	875	895
Sefera	756	669.0	3.5bc	8.8	553	377
Red zenari	726	518.0	4.00abc	7.9	1048	746
Fereikh	1051	581.0	3.3cd	7.7	1077	815
Hamadi	779	691.0	4.2ab	6.6	845	345
Nilla	973	504.0	3.6bc	6.3	1690	695
Kelash	1118	709.0	2.7d	6.2	501	842
CV%	33.97	35	12.76	17.4	53.62	48.2

**Table 5.** Estimate of Phenotypic ( $\sigma^2_{ph}$ ), Genotypic ( $\sigma^2_g$ ) and Environmental ( $\sigma^2_e$ ) Variances for Ten Characters

Character	$\sigma^2_{ph}$	$\sigma^2_g$	$\sigma^2_e$
Plant height(cm)	632.62	530.09	101.72
Days to 50% flowering	42.04	37.81	4.23
Days to maturity	46.47	44.02	2.46
Straw weight (kg/ha)	2.55	1.53	1.02
Number of panicles/plot	315.89	76.39	239.5
Panicle weight (g)	571953.67	4.27	571949.4
Number of grains/panicle (g)	91369.37	4278.27	87091.1
100-grain weight (g)	0.482	0.26	0.222
Grain yield/plant(g)	75.79	-10.05	85.74
Grain yield (kg/ha)	279590.8	66.79	279524.07

**Table 6.** Estimates of mean Genetic Coefficient of Variation (GCV%) and Heritability (h<sup>2</sup>) for Yield and Yield Components Combined across The Two Locations

Character	2002/03		2003/04	
	GCV%	h <sup>2</sup> %	GCV%	h <sup>2</sup> %
Plant height(cm)	17.00	84	10.71	18
Days to 50% flowering	9.00	90	5.00	72
Days to maturity	8.00	95	7.45	97
Straw weight (kg/ha)	27.00	60	12.00	07
Number of panicles/plot	15.00	25	20.33	14
Panicle weight (g)	4.00	01	10.53	12
Number of grains/panicle(g)	8.00	05	41.3	20
100-grain weight (g)	14.00	55	6.85	24
Grain yield/plant(g)	17.00	73	40.00	18
Grain yield (kg/ha)	27.00	03	25.00	08

The means, ranges and coefficient of variations a namely; genotypic coefficient of variation (gcv) and heritability estimates across the two locations are presented in Table 6. High gcv was also observed for some characters, this reveals that the genotypes have a broad base genetic background as well as good potential that will respond positively to selection. Similar results were obtained by William *et al.* (1987) while studying effect of environment on yield components of sorghum. In this study, characters such as plant height, days to 50% flowering and days to 95% maturity would respond positively to selection when selected because of their high broad sense heritability (Table 6) agreed with the findings of Eckebil *et al.* (1997), Totok (1997) and Biswas *et al.* (2001). On the other hand, grain weight per panicle, number of grains per panicle, 100- seed weight and grain yield would not respond to selection because of their low heritability estimates in this sorghum population.

However, similar results were observed by Bello *et al.* (2001) and Bello *et al.* (2007) they reported that the low heritability estimate of grain yield is due to the direct or indirect multiplicative effects of several yield components on grain yield. Obilana and Fakorede (1986) reported that, if a character is influenced by environment, its heritability would be low in a population in which plant environments vary widely. On the other hand, in another population in which the environment is rigidly controlled so that those variations do not occur, the same character would tend to have high heritability.

Head weight (g) had highly significant and positive correlation with hay weight, plant height, number of head per plot, while it had highly significant and negative correlation with days to 50% flowering, 100 grain weight, at the two locations. Hay weight had highly significant and positive correlation with plant height, yield weight, number of head per plot, while it had highly significant and negative correlation with 100 grain weight. Plant height was highly significant and positive correlation with yield /ha. Badwal (1997) observed that the plant positive correlation with yield. Yield (t/ha<sup>-1</sup>) was highly significant and positive correlation with number of heads per plot and number of grain per head. The correlation of yield with number of grain per panicle reported by many workers: Dabholkar *et al.* (1970), Liang *et al.* (1969) and Abifarin and Pickett (1970). Days to 50% flowering were significant and positive correlation with 100 grain weight and significant and negative correlation with number of heads per plot. Grain yield/ha had highly significant positive correlation with number of grains per head at the two locations in the two seasons .The similar results were found by Dabholkar *et al.* (1970), Kambal and Abael Gasim (1976), Liang *et al.* (1969) and Abifarin and pickett (1970).

## 4. Conclusions

Based on the results of this study, the superiority of the Quasari over the other genotypes suggests its adoption as one of the high yielding cultivars in this area. Quasari and Kelash genotypes are early flowering and maturity. They recommended for the short rainfall seasons in sandy soil of North Kordofan state of Sudan, where rainfall was less than 300

mm and might be used in breeding programs for development of early maturing genotypes in Sudan.

## REFERENCES

- [1] Abdalla, H. A. Evaluation of exotic and local parental lines of sorghum (*sorghum bicolor* L.Moench) and their F1 hybrid at different environments .M.SC.Thesis (Agri.) University of hartoum.1991
- [2] Abdel-Rahman, M.E. Selection for grain yield under water-stress in sorghum (*sorghum bicolor* (L.) Moench). Ph. D. Diss. Univ. of Nebraska.Lincoln .USA. 1985
- [3] Abifarín, A. O. and Pickett, R. C. Combining ability and heterosis for yield, protein ,lysine and certain plant characters in 18 diverse inbreds and 65 hybrids in (*sorghum bicolor* (L.) Moench ). *African Soil*, 1970;15: 399-416
- [4] Abu-Gasim, E.H. and Kambal, A. E. Variability and interrelationship among characters in indigenous grain sorghum of the Sudan. *Crop Sci.*, 1985; 11: 308-309
- [5] Aljenandro, F. R. Selection of sorghum genotypes for tolerance to water stress .Thesis. Univ. of Philippines at Los Bano-scollage, Laguna, Philippines. 1982; PP:91
- [6] Allard, R.W. and Bradshaw, A.D. Implication of , genotype x environment interaction in applied plant breeding. *Crop Sci*. 1964; 4:503-507
- [7] Badwal, S. S., Correlation between grain and fodder yield in Jowar. *Madras Agri.Jour.* 1971; 58:531-533
- [8] Bakheit, B. R. Variability and correlation in grain sorghum genotypes (*Sorghum bicolor* L.Moench ) under drought conditions at different stages of growth;1990
- [9] Basu, A.K., Variability and heritability estimate from Inter-season Sorghum Cross. *Ind. J.Agric.Sci.* 1981; 41: 116-117
- [10] Beil, G. M. and Atkins, R. E. Estimates of general and specific combining ability in F1 hybrid for grain yield and its components in grain sorghum (*Sorghum vulgare* Pers.). *Crop Sci*, 1967; 7: 225-228
- [11] Bello, D., Kadams, A.M. and Simon, S.Y. Correlation and Path Coefficient analysis of grain yield and its components in Sorghum. *Nig. J. Trop. Agric.*, A Publication of SAAT, FUT, Yola, 2001 Nigeria,3: 4-9
- [12] Bello, D., Kadams, A.M., Simon, S.Y. and Mashi, D.S. Studies on Genetic Variability in Cultivated Sorghum (*Sorghum bicolor* L. Moench) Cultivars of Adamawa State Nigeria. *American-Eurasian J. Agric. & Environ. Sci.* 2007; 2 (3): 297-302
- [13] Bello, O. B. and Olaoye, G. Combining ability for maize grain yield and other agronomic characters in a typical southern guinea savanna ecology of Nigeria. *Afr. J. Biotechnol.* 2009; 8 (11): 2518-2522
- [14] Biswas, B.K., Hasanuzzaman, M., Eltaj, F., Alam, M.S and Amin, M.R. Simultaneous selection for fodder and grain yield in sorghum. *J. Biol. Sci.*, 2001; 1: 319-320
- [15] Burton, G. W. and De vane, E. M. Estimating heritability in tall fescue (*Fescue arundianae*) from replicated colonial material. *Agron. J.* 1953;45: 478-481
- [16] Dabholkar, A. R., Telang, S. W. and Patal, K. C. Correlations in sorghum hybrids .*Sci. Cult.* 1970, 36: 466
- [17] Dogget, H. Sorghum. Longmans, London. 1970; P.403
- [18] Ekebil, J.P., Ross, M.W., Gardnerand, C.O. and Maranville, J.W. Heritability estimates, genetic correlation and predicted gains from S . progeny test in sorghum in three grain sorghum population. *Crop Sci. J.* 1977; 17: 373-377
- [19] Fakorede, M. A. B., Opeke, B. O. Weather factors affecting the response of maize to planting dates in tropical rain forest location. *Exp. Agric.* 1985; 21: 31-40
- [20] Gomez, K. A. and Gomez, A. A. Statistical Procedures for Agricultural Research .Second Edition, John Wiley and Sons, New York; 1984
- [21] Hassan, A. E. Effect of plant population on grain yield of sorghum in South Kordofan. *Proceedings of the Meetings of the National Crop Husbandry Committee 37th (2005), Agricultural Research Corporation (ARC) – Sudan, 2005;pp: 6-13*
- [22] Hutlquist, J. H. Physiologic and morphologic investigation of sorghum (*sorghum bicolor* (L.) Moench). 1: vascularization .11.Respones to internal drought stress .Ph.D. Diss. Univ. of Nebraska, Lincoln, Neb, USA. 1973
- [23] Johnson,H. W, Robison H. F. and Comstock, R. E. Estimates of genetic and environmental variability in soybean. *Agron. J.* 1955; 47:314
- [24] Kambal, A. E. and Abuelgasim, E. H. Manifestation of heterosis in grain sorghum .*Expt. Agri.* 1976;12: 33-42. 314-318
- [25] Leclerg, E. L., Leonard, W. H. and Clark, A. G. Field plot technique .Second ed. Burgass publishing Co., Minneapolis, Minnesota,1962
- [26] Liang, G. H. L., Overley, C. B and Casal, A. J. Inter-relationships among agronomic characters in grain sorghum. *Crop Sci.* 1969; 9:299-302
- [27] Lukhele, P.E. Estimation of genetic variability in sorghum population. Unpublished M.Sc. thesis,Ahmadu Bello University Zaria, Nigeria. 1981
- [28] Miller, P. A., Wiliams, J. C. Robinson, H.P. and Comstock, R. E. Estimation of genotypic and environmental variances and covariance in upland cotton and their implications in selection .*Agron.J.*1958;50:126-131
- [29] Muhammad, B. A., Muhammad, R., Muhammad, S.T. Amer, H, Tariq, M. Muhammad, S. A. Character association and path coefficient analysis of grain yield and yield components in maize.*Pak. J. Biological Sci.* 2003;6 (2); 136-138
- [30] Nemati, A., Sedghi, M. Sharifi, R. S and Seiedi, M. N. Investigation of correlation between traits and path analysis of corn (*Zea mays* L.) grain yield at the climate of Ardabil region (Northwest Iran). *Not. Bot. Hort. Agrobot. Cluj* 2009; 37(1): 194-198
- [31] Puri, Y. P., Qualset, C. O., Williams, W. A. Evaluation of yield components as selection criteria in barley breeding. *Crop Sci.* 1982; 22: 927-931

- [32] Totok, A.D.H.E estimating heritability values and genetic correlation, in several agronomic characters. *Am. J. Bot.* 1997; 87: 145
- [33] Obilana, A.T. and Fakorede, M.A.B. Heritability: A Treatise. *Samaru J. Agric. Res.* 1986; 1: 72-82
- [34] Whiteman, P. C. and Wilson, G. L. Effect of water stress on there productive development of (*Sorghum vulgare pers*). *Univ. Queensl. Pap. Bot.* 1965;4: 233-239
- [35] William, W.T., C.A.P. Boundy and A.J. Millington. The effect of sowing date on the growth and yield of three sorghum cultivars. The component of growth and yield. *Aust. J. Agric. Res.*, 1987;28: 381-387
- [36] Zaveri, P.P., Phul, P.S and Dillon, B.S. Observed and predicted genetic gains from single and multi trait selections using three mating designs in pearl millet. *Plant Breeding Abstract*, 1989; 60: 127-132