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Performance of sorghum recombinant inbred lines (RIL) developed by national breeding program under rain-fed areas of ~~the~~ Sudan

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ABSTRACT

In Sudan, sorghum (*Sorghum bicolor* {L) Moench) is the most widely produced and consumed cereal crop. However, productivity is low due to the fact that most of the crop (90%) is produced under favorable and unfavorable environments where the crop suffers from drought stresses at different growth stages.

In the present study, six sorghum developed inbred lines and two commercial checks were evaluated for grain yield potential, yield stability, some important agronomic characters and grain quality properties. A standard variety trial and yield verification plots in farmer fields were conducted at three rain-fed locations; Suki, Damazin and Elobeid, during three consecutive years (2005 to 2008). The selected locations represent low, medium and high rainfall areas of Sudan. The trial was laid-out in a randomized complete block design. The results revealed mean squares of genotypes, seasons, locations, location x season, location x genotypes, season x genotypes and season x location x genotype interactions as highly significant (P=0.01) for grain yield. The sorghum genotypes Edo 34-23-4, Edo 26-18 and Edo 16-dwarf gave substantially higher grain yields than commercial checks and the trial mean. Their percentage yield increase ranged from 5 to 75 % over commercial checks. The stability analysis revealed the above mentioned Edo-genotypes with high yield potentials and stable across a wide range of agricultural conditions. Moreover, the same Edo –lines showed as early maturity comparing to selected commercial checks and possess good food grains, market preferred and acceptable kisra making quality.

Keywords: Sorghum, RIL, G x E, rain-fed, Agriculture, Quality analysis, Sudan

INTRODUCTION

In Sudan, sorghum (*Sorghum bicolor* ({L.} Moench) is the stable food crop utilized in various forms for humans and feed for animals. The crop contributes with about 70% of total grain produced in the country. It ranks first in terms of total area cultivated as well as total tonnage produced. However, the cultivated areas and 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 grain total production varies between 3-4.5 million tonnes with an average of 0.6 tones/ha (Abdalla et al., 2011). Soil moisture content stands out as one of the most important factor of a biotic factors limiting sorghum productivity. In the country the rainfall, described as variable, unpredictable and poorly distributed. Rainfall was reported to be decreasing in eastern Sudan from 1960 to 1990 pointed out there was a high correlation between rainfall and sorghum yield(r =0.7) indicating that crop yields were dependant on rainfall (Larsson, 1996). The analysis of rainfall in twelve metrological stations located between latitudes 11º and 20º N showed a clear decrease in annual rainfall over the last 30-40 years (Osman And Ibrahim, 1998). This 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 higher than 50% of the total sorghum production area.

In these dry areas (250 mm – 400 mm), farmers used to grow their own local sorghums, which are low yielders and suffer drought stresses at almost any stage of crop growth. The outcome is either low yield or straw and chaff. In fact, sorghum is loosing ground in these important areas. The national breeding program was succeeded to develop improved, medium maturing, high yielding varieties and hybrids such as W. Ahmed, H. D-1 , Tabat.. etc., these varieties and hybrids, were not suitable for these low rainfall regions because it required 550 ~~mm~~ – 650 mm which is not available. Accordingly, early maturing varieties were developed through conventional breeding. To achieve that, two crosses were made between Geshiesh x W. Ahmed (Gew) and Eriana x Dorado (Edo) lines using pedigree method. Therefore, this study is aiming to evaluate the performance of six sorghum genotypes developed by national breeding program under different crop cultivated areas representing, low rainfall; Elobied, Suki; medium rainfall and high rainfall; Damazin of Sudan.

MATERIAL AND METHODS

GERMPLASM

The research plan was designed to develop early maturing and high yielding varieties suitable to different agricultural conditions. The original cross (F1) was made at Shambat, Khartoum North, research station in 1995. Then the plant materials were advanced further using pedigree breeding method (Table1).The plant material evaluated in this study consisted of eight entries, including six advanced breeding lines namely; Gew 22-15, Gew 3-2, Edo 16-dwarf, Edo 34-23-4 Edo 26-18 and Edo 27-3-25 and two commercial varieties; Wad Ahmed and Yarwasha were used as local checks. The six breeding lines were developed by the national breeding program by crossing local x exotic and local x local open pollinated varieties.

EXPERIMENTAL PROCEEDURE

Multi location sorghum variety trials were conducted for three seasons; 2005/06, 2006/07 and 2007/08 at four locations namely; Elsuki, Damazine, El Obied under rain-fed conditions. Land was prepared by disc harrowing and ridging. Trials were laid out in a randomized complete block design with three replications. A plot size of 4 rows of 5 meter length with an interrow spacing of 0.8 m was used across testing sites. Planting was performed at the first two weeks of July each season depending on effective onset of rains. About six to seven seeds were planted in each hole on the side of ridge 20 cm apart. Plants were then thinned to two plants /hill three weeks after seedling emergence, and kept weed free using hand weeding. A fertilizer dose of 80 kg/fed Urea was only applied at the irrigated site after thinning. Then the traits measured as follows:

1. Grain yield: weighted in (kg/plot) for the advanced yield trials and demonstration plots. Heads were cut sun dried, threshed, weighted and adjusted to kg/ha.
2. Grain quality traits: Grain physical and chemical properties were assessed at Food Research Center (FRC), Shambat, Sudan. Moisture, crude protein, fat acidity and total acidity were determined according to the methods of the AOAC (1990). The hardness of seeds was determined using a hardness tester No. 174886, Kiya Seisakusho Ltd, Tokyo, Japan. One hundred (100) seeds from each sample were used to assess the hardness. The Kisra quality was assessed by a group, a panel, following the national consensus on taste, durability and acceptability.

Also, three of the selected inbred lines, Edo 34-23-4, Edo 26-18 and Edo 16-dwarf, were tested with Arfa gadamc as local check, in verification yield trials in four locations at Sennar, Dwaim, Butana and Managil during 2005 and 2007.

DATA ANALYSIS PROCEEDURE

Each location in a particular year was treated as a distinct environment. Analysis of variance was performed on data collected from individual trials in each environment following the standard procedures for ~~RCBD design.~~ Combined analysis of variance was performed on data from each location over years, each year over locations and over all years and locations. The F-test for individual and combined analysis was made assuming random environments and fixed varieties (Finlay and Wilkinson,1963; Osman and Ibrahim 1998). Stability analysis of grain yield was made according to the model of

Eberhart and Russel (196~~6~~2). Then stable varieties across different environments were identified considering a regression coefficient equal to one (b_i =1), deviation from regression equal to zero, (S^2d_i = 0) and it should yield above the general mean and the higher is the better (Appenix1). Analysis of variance was executed by using MSTAT computer package for days to 50% flowering, while stability parameters for grain yield were obtained by using IRRISTAT model.

RESULTS AND DISSCUSSION

GRAIN YIELD:

Recombinant inbred lines (RIL), six lines were developed by national breeding program. The development of selected lines based on early maturing and high yield traits. The lines that showed early maturing and yield potentials were advanced and evaluated in preliminary and advance trials. The results showed superiority of three of the developed lines over the commercial checks across nine environments including low, medium and high rainfall areas of the country over three years (Table1, 2 and3).

Individual yield trials:

Separate analysis of variance for each location in each year (environment) showed significant differences (P = 0.01) among entries at all of the nine environments. The grain yields for each entry at each environment are given in Table (3). As expected the short maturing test entries produced higher grain yields under low rainfall environments compared to the commercial check W. Ahmed which excelled them under high rainfall years at Suki and Damazin. The highest grain yield (2722 kg/ha) was produced by genotype Edo 34-23-4 at Suki in 2006 crop season, while the lowest yield

(557 kg/ha) was produced by genotype GEW 3-2 at Obeid in 2007. Comparison of the superiority of the test material across the nine rain-fed environments (Table3) indicated superior to, comparable to or inferior of one entry to another. The entry Edo 34-23-4 was superior to W. Ahmed in 4 environments and comparable to it in five environments while it was superior to yarwasha in eight environments and comparable to it in one environment. Edo 26-18 was superior to W. Ahmed in three environments and comparable to it six environments while the reverse is true in case of Yarwasha. Edo 16-dwarf was superior to W. Ahmed in three environments, similar in four and inferior to it in two environments. It was superior to Yarwasha in five and comparable to it in four environments. When comparing the Edo lines together, Edo 34-23-4 was top followed by Edo 26-28 and Edo 16-dwarf as second and third, respectively.

This trend was also confirmed by mean separation when ranking mean grain yields of the genotypes at the different environments (Table4). It showed that three entries, namely, Edo 34-23-3, Edo 26-18 and Edo 16- dwarf were consistently superior to other entries except W. Ahmed which was superior in three seasons at Damazin and one at El Suki. The trial demonstrated a wide range of variation in mean grain yield across years, locations (environments), and genotypes. Mean of grain yield at three locations ranged from 1969 kg/ha in 2005 at Damazin to 1200 kg/ha in 2007 at Obeid. The statistical separation of mean grain yield combined ranked the three Edo-lines as top, second and third followed by W. Ahmed, whereas Yarwasha ranked last. The best mean grain yields of genotypes across the nine environments were 2135 kg/ha, 2022 kg/ha and 1864 kg/ha, given by the genotypes Edo 34-23-4, Edo 26-18 and Edo 16-dwarf, respectively. Edo

34-23-4 and Edo 26-18 were not significantly different ($P = 0.05$), but both were significantly different from Edo -16 dwarf, whereas the three of them out-yielded all entries including W. Ahmed and the trial mean. It is noteworthy that mean percent increase of Edo 34-23-4, Edo 26-18 and Edo 16- dwarf over Yarwasha were 75%, 66% and 53%, and 24%, 17% and 8%, over W. Ahmed, respectively. The average ranking varies from 1.89 to 7.00 where the three Edo – lines Edo 34-23-4, Edo 26-18
And Edo 16 dwarf had an average ranking of (1.89), (2.33) and (3.11) respectively, followed by W. Ahmed (4.33) while Yarwasha (7.00) ranked at the bottom. The Other test materials were intermediate, Table4. The results also indicated low positive correlation coefficients (Table7) between rainfall and grain yield of the genotypes Edo 34-23-4 , Edo 26-18 , Edo 16-dwarf and Yarawasha ($r = 0.43$, 0.56, 0.19 , 0.41) respectively, confirming their lower water requirements . The correlation is positive and highly significant ($r = 0.73$) for W. Ahmed indicating its productivity depends on high rainfall.

As the variance of individual trials was proved to be homogeneous, combined analysis was made for grain yield in the nine rain-fed environments (Table5). The mean squares of genotypes, years, locations, year x location, location x genotype, genotype x year and year x location x genotype interactions were highly significant ($P > 0.01$). The location x year interaction indicated that locations ranked differently in different years. The significant ($P = 0.01$) genotype variance indicated that genotypes differed in their genetic potential for grain yield (Table5). The significance of genotypes x location interaction is an indication that some genotypes were location specific. However, the genotype by year variance was highly significant indicating differential response of the genotypes in the years (Table5). The three order interactions was showing that the genotypes responded differently at certain locations in different years.

Adaptability and stability:

Evaluation of varieties and hybrids aims at identifying genotypes that consistently produce stable yields over a range of diverse environments. Finlay and Wilkinson (5) used the variety regression coefficient and magnitude of mean yield to identify stability and adaptability. Eberhart and Russel (2) used the deviation from regression (S^2d) in addition to these two parameters and defined an ideal or an average stable variety as the one with $b_i = 1$, $S^2d = 0$ and higher than the overall mean grain yield of the trial. The stability analysis results showed clear differences in slopes of the regression lines (Table6). Some regression coefficients (b) exceeded unity while others were less than one. According to Eberhart and Russel (1966), the genotypes Edo 34-23-4 and Edo 26-18 which had high regression coefficients (b_i) of 0.934 and 0.809, and with minimum deviation from regression of 0.033 and 0.684, respectively, and also mean grain yield above the general mean of the trial; means that they have better response in unfavorable environments and therefore adaptable and predictable (high R^2 value) (Table6). Regression coefficients greater than one and had higher(S^2d) were observed for Gew 22-15 and Gew 3-2 with mean grain yield below the general mean yield, indicating that these two lines were not stable under adverse conditions but may respond better in favorable environments(Table6). The genotype Edo 16 dwarf had regression coefficient

b_i = 0.522 and a high deviation (S^2d = 10.977) and mean grain yield above the trial mean could be considered adaptable and suitable for general cultivation. The commercial variety W. Ahmed had the largest (b_i , 2.927) and significantly different deviation (166.548) but out-yielded the general trial mean confirming that it is only responsive to good growing conditions(Table3 and 6).

Verification plots:

Results of farmers at different regions are shown in Table8. Dependable farmers were selected by the extensions at the respective site. The entries used in the trials included Edo-34-23-4, Edo-26-18, Edo -16 dwarf and Arfa gadamac as a farmer variety. About 2kg seeds of each entry were given to each farmer for planting an area of 1/2 fed. Seeds were sown 7 to 6 in the furrow and then thinned to 2 plants / hill. All other cultural practices were done by the farmer. In spite of low rainfall (230-382 mm), except at Sennar,. grain yields obtained under these adverse conditions and under poor farm management were satisfactory. Some farmers reported that Edo-lines were *striga* tolerant and the plants have juicy, sweet stems. The technique of water harvesting (Chisel + terrace treatment) proved to be very useful in increasing yield substantially at Butana (N. Gedarif).

Agronomic Traits:

Results of analysis of variance of individual and combined trials over two years have revealed significant (P = 0.05, 0.01) differences for varieties and years and varieties x years for 50% flowering, plant height and plant population.

Grain Quality:

Results of assessment of some grain physical and chemical properties and Kisra acceptability for entries under investigation (Table9).

Grain size:

In Sudan, grain size is considered as an important factor determining grain quality and market price. Consumers usually prefer large sorghum grain. In most of sorghum research grain size is determined by the genetic make up and influenced by environment interactions. In this study grain size measured by 1000-seed weight were high for Yarwasha (49 g), medium for Edo 34-23-4 (32 g), Gew 3-2 (29 g), Edo 26-18 (27 g), Edo 16-dwerf (26 g) and low for W. Ahmed (23 g) (Table9)

Grain hardness:

Grain hardness influences Kisra qualities. A good Kisra is usually produced from soft, medium soft and medium hard grains (1). In this investigation, grain hardness was measured using a hardness tester, the force power applied (kg) for each sample of seed is used as a measure for hardness (Table9). The analysis indicated that Edo 34-23-4, Yarwasha and W. Ahmed were soft, and then followed, though not significantly different, by Edo 26-18 and Gew 22-15. Others may be considered medium hard grains.

Protein content (%):

It ranged from 14.57 for Yarwasha to 9.42 for Edo26-18, however the protein contents of all the test entries are higher than the minimum levels specified by the codex (minimum value is 8%) (Table9)

Fat acidity:

A level of fat acidity above 50 mg KOH/ 100g causes rancid flavour in Kisra product. The values obtained for all entries in this study ranged from 7.36 to 18.28. These values are far below the minimum level of 50 mg KOH/100g and are therefore all are acceptable (Table9)

Total acidity: (Titerable acidity)

It is associated with volatile acid loss during baking. Excessive loss of acids causes poor Kisra taste and could result from poor fermentation or grain variety. The optimum total acidity is found to be 1% lactic acid (1). The values obtained in this study were significantly ($P \leq 0.05$) below optimum and consequently very low acid losses are expected for all entries(Table9)

Kisra quality:

A panel of Kisra makers and tasters were adviced to give their opinions / scores on 1- Kisra colour 2- taste 3- consistency and 4- keeping quality. The entries included in the test were W. Ahmed (control), Edo 26-18, Edo 16-dwarf and Edo 34-23-4. The result indicated the three Edo lines were not different and comparable to the control. They give brown, palatable, soft, and of good keeping quality Kisra.

Conclusion remarks

Six advanced sorghum genotypes and two commercial check varietes have been evaluated for grain yield across nine environments under rain-fed conditions in the country. The experimental data demonstrated the superiority of Edo 34-23-4, Edo 26-18 and Edo -16-dwarf over Wad Ahmed and Yarwasha in grain yield and some other agronomic traits.

Edo -34-23-4 : It was superior to all tested lines in terms of grain yield. It was reasonably stable (b; 0.934). According to tan plant color, high protein content (11.13 %) and medium –sized, clean, white feterita seed.

Edo 26-18: Its grain yield potential, stability and adaptability were similar to Edo 34-23-4. It has also tan plant color, short maturing. The grain is white, medium with brown testa but lower protein content (9.42%) compared to other genotypes. It was medium soft, low acidity and could provide acceptable Kisra just similar to W. Ahmed.

Edo 16-dwarf: It has good yield potential under rain but performs better under irrigation and high rainfall. It was moderately stable responding better to favourable environments. It is tan plant. The grain is white with brown testa, medium soft and medium in size. It ha an average protein content (10.26%), with low fat acidity and scored as having satisfactory Kisra quality.

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AUTHORS CONTRIBUTION

El Tayieb I. Hassan: research concept and design, data collection and assembly and writing the article

Ibrahim N. Elzein: research design and writing the article

Asma M. Ali: food quality analysis of examined lines

Lijuan Qiu: critical revision and writing the article

Yasir A. Gamar: contributed in statistical analysis and interpretation and writing the article

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest regarding the publication of this article

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Table 1: ***Designation, source and pedigree of tested material***

Designation	Source	*Pedigree*
Gew 22-15	*Local program*	*Geshiesh x W. Ahmed (Gew)*
Gew 3-2	*Local program*	*Geshiesh x W. Ahmed (Gew)*
Edo 16- dwarf	*Local program*	*Eriana x Dorado (Edo)*
Edo 26-18	*Local program*	*Erian x Dorado (Edo)*
Edo 34-23-4	*Local program*	*Eriana x Dorado (Edo)*
Edo 27-3-25	*Local program*	*Eriana x Dorado (Edo)*
Yarwasha	*Commercial*	
Wad Ahmed	*Commercial*	

Feterita Geshiesh and Feterita Eriana are local landraces while Dorado is an introduction from Latin America via Egypt, USDM Project

Table 2 : Rainfall amount (mm) during the testing period averaged over 3 years (2005-2007) at here locations:

Year	**2005**			**2006**			**2007**		
Month/location	**Sk**	**DM**	**OB**	**Sk**	**DM**	**OB**	**Sk**	**DM**	**OB**
May	-	72	-	-	69	-	-	11.5	-
June	29	138.5	20	22.5	103	5	54.5	102.5	10
July	131	221	97	161.5	146	200	170.5	228	243
August	131	272	184	118	192	57	134.5	266	242
Sept.	71	192	72	62	65	65	131.5	123	72
Oct.	-	18.5	-	-	70	-	17	128	-
Nov.	-	-	-	-	-	-	-	8	-
Total	362	914	373	364	645	367	508	867	567

SK; Suki, DM; Damazin and OB; Obeid

Table3: Analysis of variance for mean grain yield (kg/ha) for each environment and combined over locations

. Year	2005			2006			2007			Combined analysis		
Entry/location	**SK**	**DM**	**OB**	**SK**	**DM**	**OB**	**SK**	**DM**	**OB**	**SK**	**DM**	**OB**
1- Gew 22-15	1308bc	1449 de	727 cd	1846 cd	1343 d	1050 c	1642 bc	1447 d	658 c	1599 (6)	1413 (6)	812 (7)
2- Gew 3-2	1340 b	1788 cd	728 cd	1881 cd	1404 cd	1363 bc	1621 bc	1349 cd	557 c	1614 (5)	1514 (5)	883 (6)
3- Edo 16-dwarf	1845 a	2092 bc	1335 ab	2362 ab	1580 c	2103 a	1847 b	2014 c	1602 ab	2018 (3)	1895 (4)	1680 (3)
4- Edo 26-18	1779 a	2468 ab	1421 a	2221 bc	1977 b	2133 a	2322 a	2162 b	1711 ab	2107 (2)	2202 (3)	1755 (2)
5- Edo 34-23-4	1990 a	2281 ab	1448 a	2722 a	2170 b	1908 a	2307 a	2403 b	1989 b	2340 (1)	2285 (2)	1780 (1)

6- Edo 27-3-25	1081 ed	1713 cde	1257 ab	1660 de	1224 d	1671 ab	1617 bc	1211 d	1235 b	1453 (7)	1383 (7)	1388 (4)
7-yar washa	904 d	1315 e	1037 bc	1347 e	1177 d	1360 bc	1300 c	1318 d	1214 b	1184 (8)	1270 (8)	1204 (5)
8- W.Ahmed	1138bcd	2642 a	617 d	1689 de	2452 a	1078 c	2647 a	2655 a	634 c	1825 (4)	2583 (1)	776 (8)
Mean	1423	1969	1071	1966	1666	1583	1913	1820	1200	1767 (2)	1818 (1)	1285 (3)
C.V.%	9.51	11.61	18.59	10.6	7.41	18.14	11.23	8.54	22.07	14.87	7.50	12.39
Sing.	**	**	**	**	**	**	**	**	**	**	**	**
SE $\pm$	78.12	131.93	114.95	120.40	71.28	114.95	124.02	89.78	157.32	151.77	78.72	97.92

*; ** P = 0.01 and SK =Suki, DM= Damazin and OB=Obied

Means having letter within the same column are not significantly different according to DMRT. Entry rank is bracketed

Table4: Summary of level of superiority of best lines compared to the checks across rainfed environments

ENT NO.	No env	**Level of entry superiority**							Rank
Edo 34-23-4	9	5a	1ab	3b	0bc(d)	0c	0de	0e	1
Edo 26-18	9	4a	2ab	2b	1bc(d)	0c	0de	0e	2
Edo 16-dwarf	9	2a	3ab	1b	1bc(d)	2c	0de	0e	3
W.Ahmed	9	4a	0ab	0b	1bc(d)	2c	2de	0e	4
Edo 27-3-25	9	0a	2ab	1b	1bc(d)	1c	3de	1e	5
Gew 3-2	9	0a	0ab	1b	2bc(d)	6c	0de	0e	6
Gew 22-15	9	0a	0ab	0b	2bc(d)	4c	3de	0e	7
Yarwasha	9	0a	0ab	1b	2bc(d)	1c	3de	2e	8

Table 5: Mean squares from combined analysis of variance for grain yield measured in three locations over three years.

Source of variation	df	Ms	*SE*±
Years (Y)	*2*	*1153265.7 ***	*24.69*
Location (L)	*2*	*6244225.9 ***	*24.69*
Y x L	*4*	*1622784.6 ***	*42.77*
R (LY)	*18*	*113841.6*	*74.08*
Genotypes (G)	*7*	*3479862.1 ***	*40.32*
Y x G	*14*	*109049.9 ***	*69.84*
L x G	*14*	*822733.6 ***	*69.84*
Y x L x G	*28*	*115050.2 **	*120.98*
Error	*126*	*43909.7*	

Table6: Mean grain yield of each genotype and its regression b_i (slope) on means of grain yield at each site.

Variety	Mean(t/ha)	b_i	S^2d_i	R^2
1-Gew 22-15	1.274	1.328	31.857	37
2-Gew 3-2	1.337	1.359	24.410	48
3-Edo 16-dwarf	1.864	0.522	10.977	78
4-Edo 26-18	2.022	0.809	0.684	90
5-Edo 34-23-4	2.135	0.939	0.033	95
6-Edo 27-3-25	1.403	0.038	1.745	99
7-Yarwasha	1.219	0.078	1.696	99
8-W. Ahmed	1.728	2.927	166.548	79

Slope - b_i slopes of regressions of variety means on site index

S^2d_i- Deviations from regression component of interaction

R^2 – Squared correlation between residual from the main effects model and the site index

Table7: Simple correlation coefficient between mean grain yield (kg / ha) of three superior sorghum genotypes with two commercial checks and rainfall across nine environments:

Genotypes	***Correlation (r^2)***
Edo16-dwarf	~~0.19~~
Edo 26-18	~~0.56~~ *
Edo 34-23-4	~~0.43~~
Yarwasha 4	~~0.41~~
W.Ahmed	~~0.73~~ **

*, ** siginificant at (P = 0.05 and 0.01). Respectively

Table8: Mean grain yield (kg/ha) of verification plots at different sites under rain during 2005 and 2007

Entry	**Sennar (475 mm)**	**Dwaim (358 mm)**	**N. Gedarif Butana (230 mm)**	***Managil 2007, (382 mm)***
1-Edo 34-23-4	*1134*	*450*	*NA*	*NA*
2-Edo 26-18	*1550*	*653*	*1761* (544)***	*NA*
3-Edo 16-dwarf	*1725*	*564*	*NA*	*396*
4-Arfagadamac	*927*	*413*	*NA*	*90*

* chisel + terrace treatment.

** control (flat planting).

Table9: Physiochemical analysis of sorghum grains.

Samples	Moisture (%)	Protein (%)	Fat acidity (mg. KOH/100 g)	Titerable acidity (mg NaOH/100 g)	Hardness (kg)
Gew 3-2	7.78^{a}	13.25^{b}	17.35^{a}	0.285 x 10 ~~$^{-4}$ a~~	5.548^{a}
Wad Ahmed	7.23^{e}	10.74^{e}	7.36^{d}	~~0.187 x 10^{-4} c~~	2.460^{c}
Edo 26-18	7.37^{d}	9.42^{h}	12.96^{b}	~~0.220 x 10^{-4} b~~	3.404^{bc}
Gew 22-15	7.20^{e}	12.86^{c}	18.21^{a}	~~0.220 x 10^{-4} b~~	3.112^{bc}
Yarwasha	7.18^{e}	14.57^{a}	18.21^{a}	~~0.220 x 10^{-4} b~~	2.380^{c}
Edo 27-3-25	7.68^{b}	10.31^{f}	18.28^{a}	~~0.220 x 10^{-4} b~~	3.748^{b}
Edo 34-23-4	7.533^{c}	11.13^{d}	10.81^{c}	~~0.2200 x 10^{-4} b~~	2.536^{e}
Edo-16	7.017^{f}	10.26^{g}	12.90^{b}	~~0.1600 x 10^{-4} d~~	3.832^{b}

Mean having different subscript letter(s) in each column differ significantly ($P \leq 0.05$).

Appendix

Appendix1. The classification model of varieties and hybrids on the basis of stability parameters

Situation	**Coefficient of regression**	**Deviation from regression**	***description***
a)	*bi = 1.0*	$S^2d_i = 0$	*Stable material*
b)	*bi = 1.0*	$S^2d_i > 0$	*Good response in all environments but inconsistent*
c)	*bi < 1.0*	$S^2d_i = 0$	*Better response in unfavorable environment and consistant*
d)	*bi < 1.0*	$S^2d_i > 0$	*Better response in unfavorable environments and inconsistent*
e)	*bi > 1.0*	$S^2d_i = 0$	*Better response in favorable environments and consistent*
f)	*bi > 1.0*	$S^2d_i > 0$	*Better response in favorable environments but inconsistent*

Courtesy of Vartan .G and Ing Luciano Rameriz, 1986. ICRISAT, Mexico