International Journal of Sustainable Agricultural Research
2020 Vol. 7, No. 3, pp. 154-173.
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/journal.70.2020.73.154.173

ESTIMATION OF NATURAL VARIABILITY IN DIFFERENT PEARL MILLET (*PENNISETUM GLAUCUM L.*) SUDANESE GENOTYPES

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Article History
Received: 25 March 2020
Revised: 27 April 2020
Accepted: 2 June 2020
Published: 14 July 2020

Keywords
Pennisetum glaucum,
Natural variability
Agronomic parameters.

ABSTRACT

Millet is grown mostly as the main grain crop in the drier Western Parts of Sudan (Darfur and Kordofan States) where climatic conditions permit only millet production. Also there is a limited cultivation of millet in the Eastern region of the country. Most species of *Pennisetum* are protogynous, but pearl millet is more conspicuous in this regard. This facilitates the introgression of characters from other annual penicillaries into pearl millet and hence has helped in the genetic enrichment of this species. In this study 20 pearl millet genotypes were collected from different parts of the Sudan with concentration on the western states. They were evaluated to assess the extent of variation among them in morphological and yield parameters, using a randomized complete block design with two replications. The twenty pearl millet genotypes exhibited significant differences in most of the characters studied. Out of the 19 parameters, only yield per tiller panicle and total yield per plant were non-significantly different. There is a noticeable variation, not only among the different genotypes of the same species but also within the same genotype or cultivar. Such variation may be attributed to the open pollination system of this crop

Contribution/Originality: This study will add basic information to the existing literature concerning Sudanese genotypes. This study is one of very few studies which have investigated the Sudanese local *Pennisetum glaucum* genotypes, giving full botanical and agronomic characters. This study can elucidate the use of these genotypes in any future improving programs.

1. INTRODUCTION AND LITERATURE REVIEW

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a diploid species (2n=14) believed to have originated in the Sahel Zone of West Africa, which extends from Western Sudan to Senegal (Gill, 1991). It ranks sixth among cereals in the world in terms of production, following wheat, rice, maize, barely and sorghum (Brunken, 1977). Millet is grown mostly as the main grain crop in the drier Western Parts of Sudan (Darfur and Kordofan States) where climatic conditions permit only millet production. Also there is a limited cultivation of millet in the Eastern region of the country (Salih, 1997; Salih., El-Tigani, & Abdalla, 1999). *P. glaucum* is the third in importance after sorghum and wheat in the Sudan. The grain is particularly devoid of paste during storage and has long storage and keeping quality (Chandra & Matta, 1990).

Millet grain has little commercial status and marketable surpluses as direct share of agricultural sales are low, millet indirectly contributes to the receipt, from livestock sales of the grain remain largely unexplored (Kumar, 1993).

Pearl millet is protogynous, this helps the introgression of characters from other annual penicillaries into pearl millet and hence has helped in the genetic enrichment of this species as well as it can explain the non-homogeneity of many genotypes. Pearl millet responds very well to out breeding enhancement (heterosis breeding); Hazza (1994) indicated that the increase in grain yield of the hybrid over its parents could mount up to 74.2% due to out-breeding enhancement effect, thus hybrid seed production is possible (Jauhur, 1981). Concerning African pearl millet landraces, there is a long history of recombination among west-African subpopulations compared to other land races (Serba et al., 2019). Estimation of natural variability generally can provide more efficient way to identify potential accessions and help in the improvement of different genotypes collections in plant breeding (Kumari et al., 2016).

In Sudan the production of pearl millet was 28.6 million tons and average grain yield was 772.0 kg/ha in 1998 (FAO, 1999). Pearl millet provides staple food to 3.5 million people of Western Sudan. Ninety one percent of the total millet is produced in the western states of the country (Kordofan and Darfur). In these states, however, yield levels are lowest. The annual rainfall in the millet growing areas varies between 250-750mm.

The low yield of pearl millet in the Western parts of the country can be referred to many reasons, the most important are:

- Unpredictable low rain fall.
- The genotypes used almost are not adapted to the change in the period and the amount of rain. The rainy seasons becomes almost 90 days in duration whereas the local genotypes might take 4 months for maturing. Also, loss of seeds due to the dry seasons forced the farmers to buy seeds from markets without enough precautions, i.e. they almost lost their genotypes (Abuelgasim, 1999).
- Traditional managements and cultivation methods, the use of hands and simple tools rather than machinery (Jain & El Ahmadi, 1981).
- Social and economic reasons which played an important role directly and indirectly which was reflected in the absence of fertilizers and pesticides application.
- Pests and diseases; this crop is infected by many diseases and pests.

After the drought season in 1991, seeds of many genotypes were imported from West Africa without enough precaution which might resulted in the loss of yield due to pests and diseases (Abuelgasim, 1999). Pests rather than diseases cause extensive damage to pearl millet crop.

In addition to the low yield and the factors mentioned, pearl millet faces many problems; these can be summarized as follows:

- The literature and research published about pearl millet is far less than that known for other cereals especially for its genetics and cytogenetic.
- It is considered as a crop of second importance since it does not contribute to the economy of the country.
- It cannot be imported as flour (ground grain) since it cannot be stored.
- This crop is not popular, so rarely used in food technology and processing.

2. MATERIALS AND METHODS

Twenty accessions of pearl millet (*Pennisetum glaucum*), provided by Dr. Abdalwahab H. Abdallah, Department of Agronomy, Faculty of Agriculture, University of Khartoum, were used in this study. These accessions were collected from different parts of the Sudan with concentration on the western states. They were evaluated to assess the extent of variation among them Table 1.

Table-1. Twenty accessions of pearl millet used in the study and their origins.

No.	Accession	Origin	Notes
	Shambat bulk	Bulk Selection	Selected
	Bauda	Darfur/Sudan	Check
	*JM 44/9	Darfur/Sudan	Selected
	Darmasa	Darfur/Sudan	Collection
	**SP2C2	Selection from SP2	Selected
	Ugandi	Uganda/adopted	Check
	*JM24/15	Darfur/Sudan	Selected
	***RP2C2	Selection from Rawakeeb P_2	Selected
	*JM23/13	Darfur/Sudan	Selected
	***RP1C2	Selection from RP_1	Selected
	*JM3/16	Darfur/Sudan	Selected
	Madlkawia	Kordofan/Sudan	Collection
	*JM21/2	Darfur/Sudan	Selected
	*JM25/10	Darfur/Sudan	Selected
	*JM30/13	Darfur/Sudan	Selected
	*JM49/17	Darfur/Sudan	Selected
	**SP1C2	Selection from Shambat P_1	Selected
	*JM36/11	Darfur/Sudan	Selected
	*JM48/18	Darfur/Sudan	Selected
	*JM45/7	Darfur/Sudan	Selected

Note: * JM: Jebel Marra. **SP: Shambat Population. ***RP: Rawakeeb Population.

3. METHOD

The first experiment was conducted during the late rainy season, at the University of Khartoum Farm, Shambat, longitude $32^{\circ}:32'$ E., latitude $15^{\circ}:40'$ N. and 380 meters above the sea level.

A randomized complete block design with two replications was used to execute the experiment. Each genotype was grown in 4×5 m^2/plot at the rate of 5-7 seeds/hill in ridges. Hill-to-hill and ridge-to-ridge spacing was 20 and 70 cm, respectively. Irrigation was applied at an interval of 12-14 days. Compensation was carried out a week after the sowing date. Thinning and weeding were conducted, 3 weeks after the sowing date. No pesticides were applied. For fertilization, nitrogen was applied at a rate of 3.5 kg per plot.

Ten randomly selected plants from each plot were used to estimate the following parameters:

1- Plant height (cm): measured from the soil surface to the tip of the main panicle.
2- Stem diameter (cm): measured at maturity on the main stalk at 10 cm above the soil level.
3- Days to 50% flowering: The numbers of days from sowing to the time when 50% of the plants within a plot had fully exerted heads.
4- Days to maturity: number of days from sowing to the day when all the heads in a plot had reached physiological maturity.
5- Leaf area (cm^2): the area of leaves of the internodes number 4-6 of the plant was measured and the leaf area was calculated as follows: maximum width × maximum length × 0.75.
6- Number of leaves per plant: average number of leaves per plant after panicle exertion.
7- Total leaf area (cm^2): average leaf area times the average number of leaves per plant.
8- Number of reproductive tillers per plant: average number of the panicle bearing tillers per plant.
9- Number of reproductive branches per plant: average number of the panicle bearing branches on each plant.
10- Main panicle length (cm): the length of the head beard on the main stem from the base to the tip of the panicle.
11- Main panicle diameter (cm): the average maximum diameter of the main panicles of ten random plants was used, excluding bristles when present.
12- Yield per main head (g): the average weight of grains produced by the main head.

13- Yield per tiller head (g): the average weight of the grains produced by tillers multiplied by the average number of tillers per plant.

14- Yield per branch head (g): the average weight of the grains produced by branches multiplied by the average number of branches per plant.

15- Total yield per plant (g): this was calculated as the summation of steps 12, 13 and 14.

16- 1000 seed weight (g): the weight of random samples of 1000 grains obtained from the grain yield of each plot.

17- Number of grains per plant: calculated by dividing the total yield per plant by the 1000 seed weight for each accession.

In addition to the previous numerical parameters, the following qualitative characters were also studied:

18- Anthers colour/colours: all the colours observed for each accession were recorded in order of their dominance: pale yellow, yellow, dark yellow, orange, brown, pale violet and violet.

19- Main panicle shape: according to Khairwal, Ram, and Chhabra (1990) and Bono (1971) there are nine shapes for *Pennisetum glaucum* panicles: cylindrical, conical, spindle, club, candle shape, sauna, lanceolate, oblanceolate, globosely and goosy.

20- Grain colour: these were scored as proposed by Murty, Upadhyay, and Marchonda (1967): white, yellow, deep yellow, brown, brownish grey, grey, deep grey, purple and purple black.

21- Seed embedding: Exposed intermediate and enclosed (Khairwal et al., 1990).

22- Glumes colour: light/dark.

3.1. Statistical Analysis

The collected data were subjected to analysis of variance then comparison among means was carried following Duncan's Multiple Range Test as suggested by Gomez and Gomez (1984).

4. RESULTS

The result of agronomic and botanical parameters are displayed as follows:

4.1. Plant Height (cm)

Analysis of variance reflected significant difference (P=0.000) between the different genotypes in plant height Table 2. The average plant height ranged between 197.4cm for JM 45/7; as the highest genotype; and 106.3cm for Ugandi the shortest. Dwarf plants (less than 50 cm in height) appeared among genotypes Ugandi and JM36/11.

Duncan's test for means grouped the 20 genotypes into 12 groups according to the plant height Table 3.

Variation within the population for plant height was observed in the following genotypes: Ugandi, JM24/15, RPIC2, JM25/10, JM36/11 and JM48/18.

4.2. Stem Diameter (cm)

Analysis of variance reflected significant difference (P=0.000) between the 20 pearl millet genotype in the stem diameter Table 2. The stem diameter ranged between 5.95cm for JM48/18 and 3.02cm for Ugandi i.e. the highest record is almost twice the smallest one.

Duncan's test for means grouped the 20 genotypes into 10 groups according to the stem diameter measurement Table 4. High variation within the population was noticed in JM48/18.

Table-2. Output of Analysis of Variance, comparing 20 pearl millet genotypes in 19 characters.

Parameter	Df	Mean square	F	Sig.
Plant height	19	1099.801	43.862	.000
	20	25.074		
	39			
Stem diameter	19	1.460	108.989	.000
	20	1.340E-02		
	39			
Days to 50% inflorescence	19	38.074	9.639	.000
	20	3.950		
	39			
Days to maturation	19	29.637	49.395	.000
	20	.600		
	39			
Leaf area	19	4408.830	113.012	.000
	20	39.012		
	39			
Leaf count	19	3.627	106.663	.000
	20	3.400E-02		
	39			
Total leaf area	19	693222.342	169.769	.000
	20	4083.325		
	39			
Number of reproductive tillers	19	7.200	17.723	.000
	20	.406		
	39			
Number of reproductive branches	19	19.725	17.534	.000
	20	1.125		
	39			
Panicle length	19	22.069	4.951	.000
	20	4.458		
	39			
Panicle width	19	1.660	5.076	.000
	20	.327		
	39			
Main panicle yield	19	153.390	9.130	.000
	20	16.801		
	39			
Tiller yield	19	16.864	1.757	.110
	20	9.601		
	39			
Total tiller yield	19	4415.149	11.167	.000
	20	395.382		
	39			
Branch yield	19	21.155	4.305	.001
	20	4.914		
	39			
Total branch yield	19	5749.674	22.443	.000
	20	256.193		
	39			
Total yield	19	1574464.141	1.668	.132
	20	943790.007		
	39			
Seed weight	19	1.502	11.553	.000
	20	.130		
	39			
Seed count	19	2.293	5.018	.000
	20	.457		
	39			

Table-3. Duncan's Test for means of plant height output.

Genotype	N	Subset for alpha = .05											
		1	2	3	4	5	6	7	8	9	10	11	12
Ugandi	2	106.3000											
Sbv	2		117.5000										
Jm36/11	2		119.2000	119.2000									
Bauda	2		126.2000	126.2000									
Jm30/13	2			129.9000	129.9000								
Madlakawia	2				139.7000	139.7000							
Rp/c2	2					141.8000	141.8000						
Jm21/2	2					145.0000	145.0000						
Rp2c2	2					145.3000	145.3000						
Sp2c2	2						152.8000	152.8000					
Jm23/13	2							157.0000	157.0000	157.0000			
Sp/c2	2							160.3000	160.3000	160.3000			
Jm44/9	2							160.4000	160.4000	160.4000			
Jm3/16	2							163.7000	163.7000	163.7000			
Darmasa	2								166.9000	166.9000	166.9000		
Jm49/17	2									169.3000	169.3000	169.3000	
Jm24/1	2									171.2000	171.2000	171.2000	
Jm48/18	2										176.2000	176.2000	
Jm25/10	2											179.6000	
Jm45/7	2												197.4000
Sig.		1.000	.115	.055	.064	.318	.056	.063	.089	.066	.103	.072	1.000

Table-4. Duncan's test output for stem diameter (cm).

Genotype	N	Subset for alpha = .05									
		1	2	3	4	5	6	7	8	9	10
Ugandi	2	3.0200									
Jm3/16	2		3.3400	3.3400							
Sbv	2		3.5500	3.5500							
Bauda	2			3.6000	3.6000						
Jm36/11	2			3.6500	3.6500	3.6500					
Rp/c2	2			3.6700	3.6700	3.6700					
Jm21/2	2				3.8500	3.8500					
Sp/c2	2					3.8700					
Jm49/17	2					3.9100					
Rp2c2	2						4.1750				
Jm23/13	2						4.1800				
Jm30/13	2						4.2000				
Jm24/15	2						4.2800				
Sp2c2	2						4.3750				
Madlakawia	2							4.8400			
Jm44/9	2								5.2500		
Darmasa	2									5.5500	
Jm45/7	2									5.5600	
Jm25/10	2									5.6400	
Jm48/18	2										5.9500
Sig.		1.000	.085	.354	.060	.055	.135	1.000	1.000	.471	1.000

Note: Means for groups in homogeneous subsets are displayed a. Uses Harmonic Mean Sample Size = 2.000.

4.3. Days to 50% Flowering

Analysis of variance reflected significant difference (P=0.000) between the 20 genotypes. The shortest period for 50% panicle exertion was 31 days recorded fro RP2C2 and the longest period for 50% panicle exertion was 45 days recorded for: Darmasa, SP2C2, JM21/12 and JM48/18. Duncan's test for means grouped the 20 genotypes into 8 groups according to days to 50% inflorescence Table 5. Most of the genotypes took a period of 33.0-40.5 days.

4.4. Days to Maturation

Analysis of variance reflected significant difference (P=0.000) for the 20 genotypes Table 2. The Shortest period for days to maturation was recorded for the genotypes JM49/17 (73.5 days) and RP1C2 (74.5 days); while the longest period was found to be 85.5 days recorded for the genotype Dramasa. Duncan's test of means grouped the different genotypes into 9 groups Table 6.

4.5. Leaf Area (cm^2)

Single leaf area exhibited significant difference for the 20 pearl millet genotypes Table 2. According to Duncan's test of means, the 20 genotypes were grouped into 13 subsets Table 7. The smallest leaf area was found to be 59.9 cm^2 recorded for the genotype SBV (Shambat bulk variety), while the largest leaf area was 237.28 cm^2 recorded for JM 25/10, i.e. JM25/10 was almost 4 times Sbv. in leaf area.

4.6. Number of Leaves per Plant

Analysis of variance reflected significant difference (P = 0.000) for the 20 genotypes Table 2 in number of leaves per plant, which ranged between 6.3 (for Sbv.) and 10.4 (JM45/7). Ten homogenous subsets were displayed for the 20 genotypes using Duncan's test of means Table 8.

Table-5. Duncan's Test displayment for days to 50% inflorescence.

Genotype	N	Subset for alpha = .05							
		1	2	3	4	5	6	7	8
Rp2c2	2	31.0000							
Ugandi	2	33.0000	33.0000						
Madlakawia	2	34.0000	34.0000						
Jm44/9	2	34.5000	34.5000	34.5000					
Jm45/7	2	35.0000	35.0000	35.0000	35.0000				
Bauda	2		36.0000	36.0000	36.0000	36.0000			
Sbv	2		36.5000	36.5000	36.5000	36.5000			
Jm25/10	2		37.0000	37.0000	37.0000	37.0000			
Sp/c2	2		37.5000	37.5000	37.5000	37.5000			
Jm36/11	2		37.5000	37.5000	37.5000	37.5000			
Rp/c2	2			39.0000	39.0000	39.0000	39.0000		
Jm3/16	2				39.5000	39.5000	39.5000		
Jm30/13	2				39.5000	39.5000	39.5000		
Jm23/13	2					40.5000	40.5000	40.5000	
Jm24/15	2						42.5000	42.5000	42.5000
Jm49/17	2						42.5000	42.5000	42.5000
Darmasa	2							45.0000	45.0000
Sp2c2	2							45.0000	45.0000
Jm48/18	2							45.0000	45.0000
Jm21/2	2								45.0000
Sig.		.084	.063	.061	.063	.063	.133	.057	.195

Note:Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Table-6. Days to maturation subsets as displayed by Duncan's test.

Genotype	N	Subset for alpha = .05								
		1	2	3	4	5	6	7	8	9
Jm49/17	2	73.5000								
Rp/c2	2	74.5000	74.5000							
Bauda	2		76.0000	76.0000						
Jm23/13	2		76.0000	76.0000						
Jm21/2	2			76.5000						
Jm3/16	2			77.0000	77.0000					
Jm36/11	2			77.5000	77.5000					
Sp2c2	2				78.5000	78.5000				
Jm30/13	2					80.0000	80.0000			
Rp2c2	2						80.5000			
Sp/c2	2						81.5000	81.5000		
Madlakawia	2							83.0000	83.0000	
Jm25/10	2							83.0000	83.0000	
Jm48/18	2							83.0000	83.0000	
Jm45/7	2							83.0000	83.0000	
Sbv	2								84.5000	84.5000
Jm44/9	2								84.5000	84.5000
Ugandi	2								84.5000	84.5000
Jm24/15	2								84.5000	84.5000
Darmasa	2									85.5000
Sig.		.211	.080	.096	.080	.067	.080	.096	.106	.260

Note:Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-7. Duncan's Test output for leaf area (cm^2).

Genotype	N	Subset for alpha = .05												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Sbv	2	59.9250												
Ugandi	2		86.1300											
Jm21/2	2			109.5100										
Jm36/11	2			114.4400	114.4400									
Jm24/15	2			119.8500	119.8500	119.8500								
Rp2c2	2			120.6300	120.6300	120.6300								
Jm23/13	2				126.3300	126.3300								
Bauda	2					129.7100	129.7100							
Sp/c2	2					130.6750	130.6750							
Jm49/17	2						141.0300	141.0300						
Rp/c2	2							147.4400						
Jm3/16	2							153.8800	153.8800					
Sp2c2	2								163.3700	163.3700				
Madlakawia	2									174.0250	174.0250			
Jm30/13	2										177.4500			
Jm44/9	2											199.3100		
Darmasa	2											203.0100		
Jm45/7	2												216.2400	
Jm48/18	2												219.6800	
Jm25/10	2													273.2850
Sig.		1.000	1.000	.117	.095	.134	.101	.064	.144	.104	.590	.560	.588	1.000

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-8. Duncan's Test output for average number of leaves per plant.

Genotype	N	Subset for alpha = .05									
		1	2	3	4	5	6	7	8	9	10
Sbv	2	6.3000									
Bauda	2	6.6000	6.6000								
Jm24/15	2	6.7000	6.7000								
Ugandi	2		6.8000	6.8000							
Rp2c2	2		6.9000	6.9000							
Rp/c2	2		7.0000	7.0000	7.0000						
Jm36/11	2		7.0000	7.0000	7.0000						
Jm21/2	2			7.2000	7.2000						
Jm30/13	2				7.4000	7.4000					
Jm23/13	2					7.7000	7.7000				
Sp/c2	2					7.7000	7.7000				
Sp2c2	2						8.1000				
Madlakawia	2							8.6000			
Jm3/16	2							8.7000			
Jm49/17	2							9.0000	9.0000		
Jm44/9	2								9.3000		
Jm48/18	2									9.9000	
Jm25/10	2									10.0000	10.0000
Darmasa	2									10.3000	10.3000
Jm45/7	2										10.4000
Sig.		.052	.067	.064	.059	.138	.052	.052	.119	.052	.052

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

4.7. Total Leaf Area (cm^2)

Similar to single leaf area and number of leaves per plant, the total leaf area exhibited significant difference among the 20 genotypes Table 2. The highest total leaf area was almost 6 times the smallest one Table 9. The different genotypes were grouped into 11 subsets according to Duncan's test of means.

4.8. Number of Reproductive Tillers per Plant:

Analysis of variance reflected significant difference between the 20 pearl millet genotypes (P = 0.000) in the number of reproductive tillers Table 2. According to the Duncan's Test of means, the 20 genotypes were grouped into 7 subsets Table 10. Eleven genotypes had the lowest number of reproductive tillers (2.2 – 3.5). Two genotypes only recorded the highest number of reproductive tillers (7.5 – 8.0), these were JM45/7 and JM48/18, while the rest had the range of (4.0 - 7.0).

4.9. Number of Reproductive Branches

The 20 pearl millet genotypes exhibited significant difference in the number of reproductive branches, where (P=0.000) Table 2. The different genotypes were grouped into 7 groups Table 11. They varied greatly in the number of reproductive branches which ranged between 1.2 and 12.75.

4.10. Main Panicle Length (cm)

The analysis of variance reflected significant difference (P = 0.000) between the 20 genotypes Table 2.
The main panicle length ranged between 18.7 cm for Ugandi up to 32.0 cm for JM44/9. Seven subsets resulted Table 12 according to Duncan's test of means.

Table-9. Duncan's Test output for total leaf area (cm^2).

Genotype	N	Subset for alpha = .05										
		1	2	3	4	5	6	7	8	9	10	11
Sbv	2	377.6950										
Ugandi	2		583.8850									
Jm21/2	2			788.47								
Jm36/11	2			801.0800								
Jm24/15	2			803.1850								
Rp2c2	2			532.1300								
Bauda	2			856.0850	856.0850							
Jm23/13	2				972.1700	972.1700						
Sp/c2	2					1006.2600						
Rp/c2	2					1032.0800						
Jm49/17	2						1269.2750					
Jm30/13	2						1313.8050					
Sp2c2	2						1323.3000					
Jm3/16	2						1338.1900					
Madlakawia	2							1496.6150				
Jm44/9	2								1855.5000			
Darmasa	2									2090.9750		
Jm48/18	2									2175.1950	2175.1950	
Jm45/7	2										2249.1700	2249.1700
Jm25/10	2											2372.8500
Sig.		1.000	1.000	.353	.084	.386	.335	1.000	1.000	.202	.261	.067

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-10. Average number of reproductive tillers per plant as displayed by Duncan's.

Genotype	N	Subset for alpha = .05						
		1	2	3	4	5	6	7
Jm49/17	2	2.2000						
Sbv	2	2.5000						
Darmasa	2	2.2500						
Jm21/2	2	2.7500	2.7500					
Jm36/11	2	2.7500	2.7500					
Jm23/13	2	2.8500	2.8500					
Jm24/15	2	3.0500	3.0500	3.0500				
Rp2c2	2	3.1000	3.1000	3.1000				
Jm3/16	2	3.2500	3.2500	3.2500	3.2500			
Jm30/13	2	3.3500	3.3500	3.3500	3.3500			
Sp2c2	2	3.5000	3.5000	3.5000	3.5000			
Sp/c2	2		4.0000	4.0000	4.0000	4.0000		
Rp/c2	2			4.4500	4.4500	4.4500		
Ugandi	2			4.5000	4.5000	4.5000		
Bauda	2				4.7500	4.7500		
Madlakawia	2					5.2500		
Jm25/10	2						6.8500	
Jm44/9	2						7.0500	
Jm45/7	2						7.5000	7.5000
Jm48/18	2							8.5000
Sig.		.094	.104	.060	.051	.092	.347	.132

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-11. Average number of reproductive branches per plant as displayed by Duncan's.

Genotype	N	Subset for alpha = .05						
		1	2	3	4	5	6	7
Sp2c2	2	1.2000						
Jm36/11	2	1.2000						
Sbv	2	2.0500	2.0500					
Jm23/13	2	2.1500	2.1500					
Bauda	2	2.1500	2.1500					
Ugandi	2	2.2500	2.2500					
Rp/c2	2	2.3000	2.3000					
Jm24/15	2		3.7500	3.7500				
Rp2c2	2		3.7500	3.7500				
Madlakawia	2		4.2000	4.2000				
Jm3/16	2			5.2500	5.2500			
Darmasa	2			5.5000	5.5000	5.5000		
Sp/c2	2			5.5000	5.5000	5.5000		
Jm49/17	2			6.1000	6.1000	6.1000		
Jm25/10	2				7.2500	7.2500	7.2500	
Jm21/2	2					7.7500	7.7500	
Jm45/7	2					7.9000	7.9000	
Jm44/9	2						8.7500	
Jm30/13	2						9.2500	
Jm48/18	2							12.7500
Sig.		.372	.092	.065	.104	.057	.104	1.000

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-12. Main panicle length (cm) as displayed by Duncan's.

Genotype	N	Subset for alpha = .05						
		1	2	3	4	5	6	7
Ugandi	2	18.7000						
Bauda	2	21.1500	21.1500					
Jm49/17	2	21.3000	21.3000					
Sp/c2	2	22.5000	22.5000	22.5000				
Jm36/11	2	22.9000	22.9000	22.9000				
Rp/c2	2	23.5000	23.5000	23.5000	23.5000			
Sp2c2	2		24.2500	24.2500	24.2500			
Jm48/18	2		24.2500	24.2500	24.2500			
Jm24/15	2		24.6000	24.6000	24.6000			
Jm23/13	2		24.7500	24.7500	24.7500	24.7500		
Darmasa	2		25.5000	25.5000	25.5000	25.5000	25.5000	
Madlakawia	2		25.5000	25.5000	25.5000	25.5000	25.5000	
Rp2c2	2			26.4500	26.4500	26.4500	26.4500	
Jm3/16	2			27.0000	27.0000	27.0000	27.0000	
Jm30/13	2			27.1500	27.1500	27.1500	27.1500	27.1500
Jm45/7	2				28.1000	28.1000	28.1000	28.1000
Sbv	2				28.6000	28.6000	28.6000	28.6000
Jm25/10	2					29.7500	29.7500	29.7500
Jm21/2	2						30.0000	30.0000
Jm44/9	2							32.0000
Sig.		.056	.091	.073	.051	.053	.079	.054

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

4.11. Main Panicle Width (cm)

Analysis of variance reflected significant difference (P=0.000) between the different pearl millet genotypes Table 2. Duncan's test for means grouped the 20 genotypes into 7 subsets Table 13 with the range of 7.2 cm up to 10.6 cm.

It is worth mentioning that the genotype: JM24/15, JM30/13 and JM36/11 had bifurcated main stem panicles

4.12. Main Panicle Yield (g)

Analysis variance reflected significant difference (P = 0.000) between the 20 genotypes in the yield per main stem panicle Table 2. The main panicle yield ranged between 21.75g for RP2C2 up to 55.00g for JM44/9 Table 14. The 20 genotypes were grouped into 6 subsets according to the yield of the main panicle, using Duncan's test for means.

4.13. Average Tiller Panicle Yield (g)

The average yield per tiller exhibited no significant difference (P = 0.110) among the 20 genotypes Table 2. The yield per a single tiller panicle ranged between 16.95g up to 26.75g Table 15. According to Duncan's mean of test the 20 genotypes were divided into 3 groups only Table 15.

4.14. Total Tillers Panicle Yield (g)

This was computed by the multiplication of average number of reproductive tillers per plant by the average yield per tiller panicle (g). Although the average tiller panicle yield exhibited no significant difference between the 20 genotypes, the total yield per tillers exhibited significant difference (P = 0.000). Table 2 and Table 16, reflects the variation of the tillers yield, which ranged between 53.75g up to 207.00g. The different genotypes were grouped into 5 groups.

Table-13. Main Panicle width (cm) as displayed by Duncan's

Genotype	N	Subset for alpha = .05						
		1	2	3	4	5	6	7
Jm3/16	2	7.2000						
Jm25/10	2	7.5500	7.5500					
Jm24/15	2	7.8000	7.8000	7.8000				
Rp2c2	2	7.8000	7.8000	7.8000				
Ugandi	2	8.1000	8.1000	8.1000	8.1000			
Jm23/13	2	8.5000	8.5000	8.5000	8.5000	8.5000		
Rp/c2	2		8.6000	8.6000	8.6000	8.6000		
Jm49/17	2		8.9000	8.9000	8.9000	8.9000	8.9000	
Jm36/11	2		8.9000	8.9000	8.9000	8.9000	8.9000	
Jm45/7	2			9.1500	9.1500	9.1500	9.1500	
Jm21/2	2				9.2000	9.2000	9.2000	
Jm44/9	2				9.2500	9.2500	9.2500	
Madlakawia	2				9.3500	9.3500	9.3500	9.3500
Sp/c2	2				9.4500	9.4500	9.4500	9.4500
Sp2c2	2					9.5000	9.5000	9.5000
Jm48/18	2					9.5000	9.5000	9.5000
Bauda	2					9.7500	9.7500	9.7500
Darmasa	2						10.0000	10.0000
Sbv.	2						10.5000	10.5000
Jm30/13	2							10.6500
Sig.		.056	.052	.052	.054	.075	.099	.060

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-14. Main panicle yield (g) as displayed by Duncan's.

Genotype	N	Subset for alpha = .05					
		1	2	3	4	5	6
Rp2c2	2	21.7500					
Jm3/16	2	23.6500					
Ugandi	2	28.1500	28.1500				
Jm45/7	2	30.3500	30.3500	30.3500			
Bauda	2	31.0000	31.0000	31.0000			
Rp/c2	2	31.0000	31.0000	31.0000			
Jm49/17	2		34.8500	34.8500	34.8500		
Jm23/13	2		35.8000	35.8000	35.8000		
Jm24/15	2		36.4500	36.4500	36.4500		
Jm21/2	2			38.3500	38.3500	38.3500	
Madlakawia	2			39.1500	39.1500	39.1500	
Sp2c2	2			40.1000	40.1000	40.1000	
Jm36/11	2				40.9500	40.9500	
Jm25/10	2				41.3000	41.3000	
Darmasa	2				42.1000	42.1000	
Sbv	2				42.7000	42.7000	
Sp/c2	2				43.8500	43.8500	
Jm48/18	2					47.1000	47.1000
Jm30/13	2						53.7000
Jm44/9	2						55.0000
Sig.		.058	.090	.052	.073	.078	.082

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-15. Duncan's Test output for average yield (g) per a tiller panicle.

Genotype	N	Subset for alpha = .05		
		1	2	3
Sp/c2	2	16.9500		
Ugandi	2	19.0000	19.0000	
Rp2c2	2	19.3500	19.3500	19.3500
Jm3/16	2	20.3500	20.3500	20.3500
Bauda	2	20.7000	20.7000	20.7000
Madlakawia	2	21.3500	21.3500	21.3500
Jm23/13	2	21.5500	21.5500	21.5500
Rp/c2	2	21.7000	21.7000	21.7000
Jm25/10	2	22.6500	22.6500	22.6500
Jm44/9	2	23.4000	23.4000	23.4000
Jm21/2	2	24.1000	24.1000	24.1000
Jm49/17	2		24.5000	24.5000
Jm48/18	2		24.5000	24.5000
Darmasa	2		24.8500	24.8500
Sbv	2		25.2500	25.2500
Jm24/15	2		25.9500	25.9500
Sp2c2	2		26.5000	26.5000
Jm45/7	2		26.5000	26.5000
Jm36/13	2			26.7500
Jm36/11	2			26.7500
Sig.		.061	.053	.056

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-16. Total Yield per tillers panicle (g) as displayed by Duncan's.

Genotype	N	Subset for alpha = .05				
		1	2	3	4	5
Jm49/17	2	53.7500				
Darmasa	2	56.5250				
Sbv	2	57.3000				
Rp2c2	2	60.0100				
Jm23/13	2	61.7850				
Jm3/16	2	66.9750	66.9750			
Sp/c2	2	67.3500	67.3500			
Jm21/2	2	67.5000	67.5000			
Jm36/11	2	73.4500	73.4500			
Jm24/15	2	79.6200	79.6200			
Ugandi	2	86.0000	86.0000			
Jm30/13	2	90.2950	90.2950			
Sp2c2	2	92.7500	92.7500			
Rp/c2	2	96.4500	96.4500			
Bauda	2	98.1500	98.1500			
Madlakawia	2		111.9750	111.9750		
Jm25/10	2			152.0500	152.0500	
Jm44/9	2				166.5000	166.5000
Jm45/7	2					198.8500
Jm48/18	2					207.0000
Sig.		.071	.065	.057	.476	.067

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

4.15. Yield per Single Branch Panicle (g)

The average yield per single branch tiller exhibited significant difference (P = 0.001) between the 20 millet genotypes Table 2. Duncan's test for mean grouped the different genotypes into 4 groups (table 4.16). The mean branch tiller yield ranged between 8.5g up to 90.7g. Almost 15 genotypes were grouped into one subset with mean ranged between 10.5g – 14.7g Table 17.

4.16. Total Branch Tillers Yield (g)

Similar to the yield per single branch tiller, total branches tillers exhibited significant difference (P = 0.000) between the 20 pearl millet genotypes Table 2 this ranged between 17.47g up to 231.0g Table 18. Again Duncan's test for means grouped the 20 genotypes into 8 groups. The genotypes JM48/18 had the highest record (231.9g) exhibited alone a single subset.

4.17. Total Yield per Plant (g)

This was calculated by the summation of the: Yield per main panicle, total tillers panicle yield and total branches panicle yield. The analysis of variance reflected no significant difference (P = 1.32) among the 20 pearl millet genotypes Table 2 although significant difference was exhibited for main panicle yield and total branch yield. Total yield per plant Table 19 ranged between 630.59g and 3621.22g. Duncan's test for means grouped the 20 genotypes into 3 subsets Table 19.

Table-17. Yield per a single branch tiller (g) as displayed by Duncan's.

Genotype	N	*Sunset for alpha = .05*			
		1	2	3	4
Ugandi	2	8.5000			
Jm25/10	2	8.5500			
Jm3/16	2	10.5000	10.5000		
Darmasa	2	10.6000	10.6000		
Sp/c2	2	10.7500	10.7500		
Jm30/13	2	10.8000	10.8000		
Jm49/17	2	11.2500	11.2500		
Rp/c2	2	11.3500	11.3500		
Jm23/13	2	11.5000	11.5000		
Rp2c2	2	11.9500	11.9500		
Bauda	2	12.0000	12.0000		
Jm44/9	2	12.4000	12.4000		
Jm24/15	2	13.0000	13.0000		
Jm21/2	2	13.7500	13.7500	13.7500	
Madlakawia	2		14.4000	14.4000	
Sbv	2		14.6000	14.6000	
Sp2c2	2		14.7500	14.7500	
Jm48/18	2			18.2500	*18.2500*
Jm36/11	2			18.8000	*18.8000*
Jm45/7	2				*20.7000*
Sig.		*.056*	*.115*	*.055*	*.309*

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

4.18. 1000 Grain Weight (g)

Analysis of variance reflected significant difference (P = 0.000) among the 20 genotypes in 1000 grain weight Table 2, with value ranged between 6.15g to 9.05g Table 20. Duncan's test grouped the 20 genotypes into 8 subsets.

4.19. Number of Grains per Plant

This was calculated by dividing the total yield per plant by 1000 grain weight for each accession. Significant difference (P = 0.000) was exhibited between the 20 genotypes Table 2. The number of grains per plant ranged between 3.48×10^3 for Rp2c2 and 7.43*10 for Jm30/13 Table 21. According to Duncan's test of means, they were grouped into 6 subsets.

4.20. Qualitative Characters Results

The 20 pearl millet genotypes were compared in: Anther color/colors, panicle shape, grain color/colors, glume color and seed exposure. The results for these qualitative characters are represented in Table 22.

Table-18. Total Yield of branch panicles (g) as displayed by Duncan's.

Genotype	N	Subset for alpha = .05							
		1	2	3	4	5	6	7	8
Sp2c2	2	17.4750							
Ugandi	2	19.0000							
Jm36/11	2	22.4700	22.4700						
Jm23/13	2	24.7400	24.7400	24.7400					
Bauda	2	25.9000	25.9000	25.9000					
Rp/c2	2	26.2700	26.2700	26.2700					
Sbv	2	29.5700	29.5700	29.5700					
Rp2c2	2	47.0250	47.0250	47.0250	47.0250				
Jm24/15	2	48.5000	48.5000	48.5000	48.5000				
Jm3/16	2	55.0000	55.0000	55.0000	55.0000				
Sp/c2	2		57.8500	57.8500	57.8500				
Darmasa	2		58.3000	58.3000	58.3000				
Madlakawia	2		59.4800	59.4800	59.4800				
Jm25/10	2			62.2250	62.2250				
Jm49/17	2				69.2550	69.2550			
Jm30/13	2					100.5750	100.5750		
Jm44/9	2					104.3000	104.3000		
Jm21/2	2						105.8500		
Jm45/7	2							163.5000	
Jm48/18	2								231.0000
Sig.		.053	.060	.057	.239	.050	.759	1.000	1.000

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-19. Total Yield (g) as displayed by Duncan's.

Genotype	N	Subset for alpha = .05		
		1	2	3
Sbv	2	630.5950		
Ugandi	2	918.0550	918.0550	
Jm21/2	2	1240.2300	1240.2300	1240.2300
Jm24/15	2	1259.4550	1259.4550	1259.4550
Jm36/11	2	1263.0450	1263.0450	1263.0450
Rp2c2	2	1280.8200	1280.8200	1280.8200
Bauda	2	1330.6300	1330.6300	1330.6300
Jm23/13	2	1511.9550	1511.9550	1511.9550
Sp/c2	2	1575.1650	1575.1650	1575.1650
Rp/c2	2	1594.6200	1594.6200	1594.6200
Jm49/17	2	1956.1900	1956.1900	1956.1900
Jm3/16	2	2042.7600	2042.7600	2042.7600
Sp2c2	2	2045.100	2045.100	2045.100
Jm30/13	2	2051.2600	2051.2600	2051.2600
Madlakawia	2	2303.6500	2303.6500	2303.6500
Jm44/9	2	2865.7500	2865.7500	2865.7500
Darmasa	2		3199.6150	3199.6150
Jm48/18	2			3333.4450
Jm45/7	2			3419.2800
Jm25/10	2			3621.2250
Sig.		.064	.059	.050

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-20. 1000 grain weight (g) output for the 20 genotypes.

Genotype	N	Subset for alpha = .05							
		1	2	3	4	5	6	7	8
Jm3/16	2	6.1500							
Rp2c2	2	6.2500	6.2500						
Jm21/2	2	6.2500	6.2500						
Jm49/17	2	6.2500	6.2500						
Jm23/13	2	6.7500	6.7500	6.7500					
Ugandi	2	6.9000	6.9000	6.9000	6.9000				
Madlakawia	2	7.0000	7.0000	7.0000	7.0000				
Jm36/11	2	7.0000	7.0000	7.0000	7.0000				
Sbv	2		7.1000	7.1000	7.1000				
Bauda	2		7.1000	7.1000	7.1000				
Jm25/10	2			7.2500	7.2500	7.2500			
Jm30/13	2			7.2500	7.2500	7.2500			
Sp2c2	2			7.5000	7.5000	7.5000	7.5000		
Jm24/15	2			7.5000	7.5000	7.5000	7.5000		
Jm48/18	2				7.7500	7.7500	7.7500		
Sp/c2	2					8.0000	8.0000	8.0000	
Jm45/7	2						8.2500	8.2500	8.2500
Jm44/9	2							8.7500	8.7500
Rp/c2	2							8.7500	8.7500
Darmasa	2								9.0500
Sig.		.052	.054	.087	.055	.075	.069	.054	

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

Table-21. Total number of grains per plant as grouped according to Duncan's analysis. The values are multiple of 10^3.

Genotype	N	Subset for alpha = .05					
		1	2	3	4	5	6
Rp2c2	2	3.4800					
Rp/c2	2	3.5450					
Jm45/7	2	3.6850					
Jm3/16	2	3.8500	3.8500				
Ugandi	2	4.0800	4.0800	4.0800			
Bauda	2	4.3650	4.3650	4.3650	4.3650		
Darmasa	2	4.6550	4.6550	4.6550	4.6550	4.6550	
Jm24/15	2	4.9100	4.9100	4.9100	4.9100	4.9100	
Jm23/13	2		5.2900	5.2900	5.2900	5.2900	
Sp2c2	2		5.4250	5.4250	5.4250	5.4250	
Sp/c2	2			5.4800	5.4800	5.4800	
Jm49/17	2			5.5700	5.5700	5.5700	
Madlakawia	2			5.5900	5.5900	5.5900	
Jm25/10	2				5.7150	5.7150	
Jm36/11	2				5.8500	5.8500	
Sbv	2					6.0150	6.0150
Jm48/18	2					6.1100	6.1100
Jm21/2	2					6.1550	6.1550
Jm44/9	2					6.2750	6.2750
Jm30/13	2						7.4300
Sig.		.079	.053	.066	.072	.053	.073

Note: Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000

5. DISCUSSION

Selection of favorable genotypes for certain characters depends mainly on the amount of variation present in the material under consideration. In this regards, the assessment of morphological and agronomic characters variation among populations is of great importance for successful application of selection procedures for the improvement of populations. The phenotypic variance is attributed to genotypic as well as environmental factors.

Table-22. Different qualitative characters results recorded for the 20 pearl millet genotypes.

Genotype	*Anther colour	**Panicle shape	***Grain colour	Glume colour	Seed exposure
Sbv	Org	Cyl, Csh	Gry	Light	Exposed
Bauda	Yel	Cyl	Wh	Light	Exposed
JM44/9	Yel.	Cyl,Csh	Gry, yel	Light	Exposed
Darmasa	Org, yel, vio	Cyl, Cl	Gry, yel	Dark	Exposed
SP2C2	Org, yel	Cyl	Gry, l. yel	Dark	Exposed
Ugandi	Wh, yel	Cyl	Gry, d.gry	Light/dark	Exposed
JM24/15	Org, yel	Cyl	Gry, d. gry	Light	Enclosed
RP2C2	Yel	Cyl	Gry, d. gry	Dark	Enclosed
JM23/13	Wh, yel, org	Cyl	Gry	Light/dark	Enclosed
RP1C2	Org, yel, vio	Cyl	Gry, yel rn	Light/dark	Intermediate
JM3/16	Og, yel	Cyl	Gry, d. gry, yel	Light	Exposed
Madekawia	Wh, yel, org	La, gos	Yel, gry, d. gry	Light	Exposed
JM21/2	Wh, yel, org, vio	Cyl	Gry, d. gry	Light/dark	Exposed
JM25/2	Wh, org, yel	Cyl	Yel, d. gry	Light	Exposed
JM30/13	Yel	Csh	Yel, l. gry	Dark	Exposed
JM49/17	Yel, d. yel	Cyl	Yel, gry, l. gry	Light	Exposed
SP1C2	Org, yel, vio	Cyl	Yel, gry, d. yel	Light	Enclosed
JM36/11	Org, yel	Cyl	Yel, gry	Light	Intermediate
JM48/18	Org, yel	Cyl, Csh	Yel, gry, d. gry	Light	Intermediate
JM45/7	Yel, vio	Cyl	Yel, gry	Light	Exposed

Note: * Anther colour/colours: The abbreviations: org= orange, yel = yellow, wh = white, vio = violet and d.yel = dark yellow.
** Panicles shapes: Cyl = cylindrical, Csh = candle shape, Cl = Club, La = Lanceolate, gos = goosy.
*** Grain colour: gry = grey, wh = white, d. yel = dark yellow, yel = yellow, l. yel = light yellow, d. gry = dark grey, l. gry = light grey and brn = brown.

In the present study, the twenty pearl millet genotypes exhibited significant differences in most of the characters studied. Similar findings were obtained by many workers in pearl millet and different cereal crops and under different environments (Abuelgasim, 1999; Fadlalla, 2002). Considering the twenty genotypes studied, there is a noticeable variation, not only among the different genotypes of the same species but also within the same genotype or cultivar. Such variation may be attributed to the open pollination system of this crop (Jauhur, 1981; Khairwal et al., 1990) and to independent domestication and emigrational events (Harlan, 1976). The genotypes Bauda, Darmasa, Madlkawia and JM45/7 had unnoticeable variation within the population itself, i.e. these genotypes have higher degree of homogeneity and stability.

In the 19 parameters studied, the different genotypes exhibited significant difference for most of the parameters except for: yield per tiller panicle and total yield per plant.

This variation between the different genotypes can be of a special value for adaptation to the local agro climatic conditions. For example the unpredictable rainfall in the western dry parts of the country can cause loss of the main stem and hence loss of the main stem panicle. The high tillering (ability to produce tillers) capacity genotypes can compensate for the loss of the main panicle succeeding in preventing a famine and starvation. The same value can be related to the variation in days to 50% inflorescence and days to maturation. Earlier blooming genotypes can be very successful in areas of unpredictable rainy season duration. There are some genotypes with special and unique characters, which might be of importance to the plant protection. Example the long bristles possessed by the spike of the genotype Madlkawia which is thought to be useful against birds attack. It seems from this study that the bristles may be a good defence only during the end of the season, i.e. after the seed ripening since these bristles are soft during the milky stage, they become only pointed and stiff after seed ripening. Thus the high variability regarding the plant morphological features and head characteristics (Jain & El Ahmadi, 1981) helped in the high adaptation to the local agro climatic conditions especially to the dry western parts of the Sudan with its unpredictable amount and duration of the rainy seasons.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Acknowledgement: All authors contributed equally to the conception and design of the study.

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