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(RESEARCH ARTICLE)

Genetic diversity studies for morphological traits in pearl millet (*Pennisetum glaucum* L.) landraces of Northern Nigeria

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Abstract

Genetic variability which is the basic material for selection and improvement of any crop is fast eroding in pearl millet as natural habitats of wild cultivated species are being destroyed and modern cultivars replacing the traditional cultivars. On this premise collection and characterisation of the crop germplasm was carried to identify elite accession(s) for the crop improvement. Thirty five (35) pearl millet accessions collected from the major cultivated states in Nigeria were evaluated for morphological and yield parameters using a Randomised Complete Block Design (RCBD) with replicate three each. Wide range of significant ($P < 0.05$) variability was observed in all the morphological characters assessed with different trait been favoured by different genotypes. The highest plant height was recorded in KD-CK-01 (371.85 cm) and the least height in accession NG-ZA-05 with the value of 170.58 cm. Accession NG-ZC-03 had the highest weight of seeds per plot and weight of seeds per hectare with the value of 738.52 g and 1318.78 kg/ha respectively. Phenotypic coefficient of variance was higher than the corresponding genotypic coefficient variance for all the traits studied. Moderate (30-60%) to high (>60%) heritability was obtained among the traits studied while genetic advanced ranged from 21.92 to 127.27. Cluster analysis grouped the accessions into four major clusters based on their morphological similarity; cluster I consisting 14.29% of the genotypes, 17.14% in cluster II, 40.00% in cluster III and 28.57% were clustered in IV. The high variability recorded in the germplasm couple with high heritability and genetic advance in most of the parameters studied, indicate that the accessions and traits could be explored in the crop improvement.

Keywords: Genetic variability; Germplasm; Landraces; Morphology; Pearl millet

1. Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an annual crop mostly cultivated in the arid and semi-arid regions of the world. The crop is ranked as the sixth most important global cereal crop grown by the resource poor farmers in the semi-arid regions of sub-Saharan Africa and the Indian subcontinent [1]. Pearl millet serves as major sources of food and beverages for over 40 million subsistence farmers living in the most marginal agricultural lands of Northern Nigeria [2]. Due to its potential to withstand drought and adverse agro climatic conditions, it is mainly grown under low fertility soil with low rainfall [3, 4]. However, in view of global climate change ravaging most savanna region of Nigeria, genetic variability in this crop is fast eroding as the natural habitats of wild cultivated species are being destroyed and modern cultivars is replacing the traditional cultivars.

Despite the desirable characteristics and importance of pearl millet as a staple cereal with nutritional and medicinal value, it has received inadequate attention from the scientific community and funding agencies as compared to other

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major cereals [5], hence, the decline in production over the years. To surmount these challenges, sourcing for diverse and desirable agronomic traits among the available landraces has been considered as one of the viable and foremost options. However, in Nigeria, exploitation of the local landraces which serve as greatest reservoir of useful traits for any source of improvement in this crop was done only to a limited extent in a very unsystematic manner [6].These premises necessitate for collection and characterization of the crop germplasm and selection of promising genotypes with high yielding traits that could be used for the crop improvement.

2. Material and methods

A total of thirty five (35) pearl millet accessions were collected from the major cultivated states in Nigeria; twenty five (25) landraces from farmers through direct contact and 10 genotypes from National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria. These accessions covered the accessible growing state (Adamawa, Gombe, Jigawa, Kano, Nasarawa, Niger, Kaduna, Sokoto, Taraba, and Zamfara) in the Northern Nigeria. The genotypes were evaluated for qualitative and quantitative parameters using a Randomised Complete Block Design (RCBD) with each accession replicated three times. A total of 10 seeds per stand were sown for each accession on a ridge of 280 cm long with five stands per ridge, at a spacing of 50 cm for both inter and intra rows. The seedlings were thinned to 5 plants per stand at two weeks after germination, given a total of 25 plants per plot and 75 plants per accession. Application of NPK fertilizer was done two weeks after thinning and no pesticides were applied throughout the experimental period. Weeding was done manually using hoe when necessary. Data were collected on five (5) qualitative traits and twelve (12) quantitative traits base on standard descriptors for pearl millet [7] and modified method of Arun-Kumar *et al.* [8]. The qualitative parameters such as seed shape, cover and colour were observed and scored on 30 randomly seeds of each genotype using a stereo microscope, while the stem colour and panicle shape were visually accessed. Quantitative data such as plant height (PLH), number of leaves per plant (NLPP), number of internodes per plant (NIPP), stem diameter (STD), day to anthesis (DTA), panicle length (PAL), panicle diameter (PAD), weight of panicle (WPA), 1000 seed weight (1000SW), weight of seed per panicle (WSPP), weight of seed per plot (WSPPL) and weight of seed per hectare (WSPH) were collected from ten (10) randomly selected plants per accession.

2.1. Data analysis

The data obtained on quantitative characters were subjected to analysis of variance (ANOVA) to determine the level of significance among the treatment while the post hoc test will be carried out using Duncan's Multiple Range Test (DMRT) to separate the means where necessary using SPSS software version 20. Correlation analysis was computed to examine the degree of association among the morphological traits. Diversity index of the qualitative traits was calculated and cluster analysis was also done based on euclidean distance matrix in a hierarchical using both the qualitative and quantitative parameter with the help of PAST software.

From the analysis of variance, the phenotypic, the environmental and genotypic components of variance were estimated following Burton methods [9] as adopted by Daudu *et al*. [10].

$$\text{Genotypic variance } (\sigma 2g) = \frac{Mg - Me}{\boldsymbol{r}}$$

Where,
Mg = mean sum of squares of genotypes (treatments)
Me = mean sum of squares of error
r = number of replications (blocks)

Phenotypic variance (σ^2p) = Genotypic variance (σ^2g) + Environmental variance (σ^2e)

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{\text{Phenotypic Variance}}}{\text{Ground Mean } (\boldsymbol{x})} \times 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sqrt{\text{Genotypic Variance}}}{\boldsymbol{x}} \times 100$$

The broad sense heritability (H^2_{bs}) was estimated for all characters as the ratio of genotypic variance to total or phenotypic variance. The heritability values was considered as low (<30%), moderate (30-60%) and high (>60%) [11].

3. Results and discussion

3.1. Qualitative characterisation of pearl millet accessions

The results of qualitative characterisation of the accessions showed heterogeneity in stem colour pigmentation. The stem colour varied from green, purple, brown to white among the accessions. Green stem pigment accession are the most abundant with a total of 16 accessions equivalent to 48.57% followed by white stem pigment accession (34.29%) and the least was purple pigment with 5.71%. All the stem colours were observed in accessions collected from Nasarawa and Niger States.

Four different types of panicle shape (cylindrical, conical, spindle and candle) were observed among the accessions collected (Figure 1). Cylindrical shape was the most dominant the genotypes with 14 accessions 40%, followed by candle shape with 37.14% of the total accessions. Accessions from Niger state had the highest panicle diversity with all the four shapes being represented and the least diversity was found in accessions from Gombe, Sokoto and Zamfara with homogenous (one) panicle type (Table 1). Seed colour examination revealed that light grey seed colour was the most dominant among the accessions collected with 40% and the least was grey brown (2.86%). The grey brown colour was only found in an accession collected from Nasarawa.

The predominant seed cover was the exposed type, recorded from 16 accessions followed by the intermediate (from 15 accessions) and the least in enclosed type (4.00). A ranged of variability in seed shape (Obovate, Oblanceolate, Elliptical, Hexagonal and Globular) was observed in the germplasm (Figure 2). The most frequent seed shape observed among the accession is Globular with percentage frequency of (48.57%), followed by obvate (25.71%) and the least elliptical (2.86%). The elliptical shape was observed only in an accession from Nasarawa. An overall allelic richness of H' = 2.81 for qualitative traits across the state was obtained using Shannon-Weiner diversity indices. Overall diversity in qualitative trait was highest in seed colour (H' = 1.39) and the least in seed cover (H' = 0.70). Within the state the highest overall diversity was in Nasarawa (H' = 2.68), follow by Niger (H' = 2.63) and least in Gombe, Sokoto and Zamfara with diversity index of H' = 1.609.

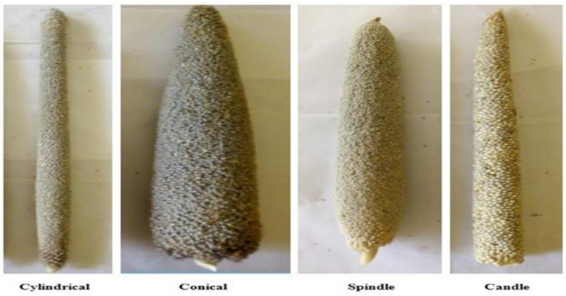

Figure 1 Variability in spike shape among pearl millet accessions from Northern Nigeria

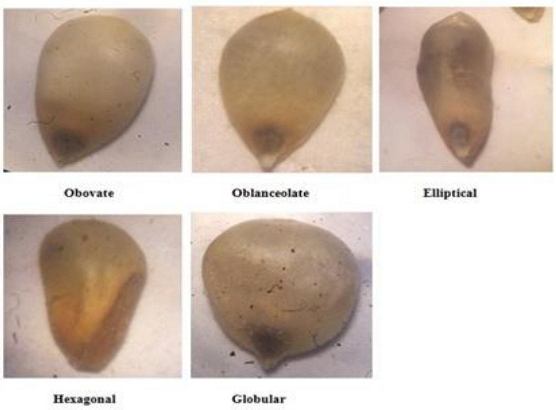

Figure 2 Seed shape variability in pearl millet (Magnification = X40).

Table 1 Phenotypic variations and diversity indices among pearl millet accessions from different states in Northern Nigeria

Traits	Sub Trait	Number of Accessions										Total Accessions	Percentage (%)	Diversity Index (H)
		AD	GB	JG	KD	KN	NG	NS	SK	TR	ZM			
Stem Pigmentation	Green	1	1	2	2	1	3	4	1	1	0	16	48.57	1.137
	Red	0	0	0	0	0	0	0	0	0	0	0	0.00	
	Purple	0	0	0	0	0	1	1	0	0	0	2	5.71	
	Brown	0	0	0	1	0	1	1	0	0	1	4	11.43	
	White	1	0	2	1	2	4	1	0	2	0	13	34.29	
Panicle Shape	Cylindrical	0	1	1	2	1	3	4	1	1	0	14	40.00	1.230
	Conical	0	0	0	1	1	2	0	0	0	0	4	11.43	
	Spindle	1	0	1	1	0	1	0	0	0	0	4	11.43	
	Club	0	0	0	0	0	0	0	0	0	0	0	0.00	
	Candle	1	0	2	0	1	3	3	0	2	1	13	37.14	
Seed Colour	Ivory	0	0	0	0	0	0	0	0	0	0	0	0.00	1.391
	Cream	1	0	0	1	0	5	1	0	0	0	8	22.86	
	Yellow	0	0	2	0	0	0	0	0	1	1	4	11.43	
	Light Grey	1	0	0	3	2	2	3	1	2	0	14	40.00	
	Deep Grey	0	1	2	0	1	2	2	0	0	0	8	22.86	
	Grey Brown	0	0	0	0	0	0	1	0	0	0	1	2.86	
Seed Cover	Exposed	0	1	3	1	1	6	2	0	2	0	16	45.71	0.699
	Intermediate	2	0	1	3	0	4	3	1	0	1	15	42.86	
	Enclosed	0	0	0	0	1	0	2	0	1	0	4	11.43	
Seed Shape	Obovate	0	0	1	1	1	3	1	0	1	1	9	25.71	1.267
	Oblanceolate	1	0	0	0	0	0	1	0	0	0	2	5.71	
	Elliptical	0	0	0	0	0	0	1	0	0	0	1	2.86	
	Hexagonal	1	0	1	1	1	1	0	0	1	0	6	17.14	
	Globular	0	1	2	2	1	5	4	1	1	0	17	48.57	
Diversity index		2.164	1.609	2.415	2.458	2.441	2.627	2.679	1.609	2.338	1.609	2.808		

AD – Adamawa State, GB – Gombe State, JG – Jigawa State, KD – Kaduna State, KN – Kano State, NG – Niger State, NS – Nasarawa State, SK - Sokoto State, TR – Taraba State, ZM – Zamfara State

Table 2 Morphological characteristic of thirty five (35) pearl millet landraces

Parameter	Plant Height (cm)	Number of Leaves Per Plant	Number of Internodes Per Plant	Stem Diameter (cm)	Days to Anthesis	Panicle length (cm)	Panicle Diameter (mm)	Panicle Weight (g)	Weight of 1000 Seeds (g)	Weight of seed/ Panicle (g)	Seed Weight /Plot (g)	Grains Yield (kg/ha)
NGB501	336.99h	13.80e	13.40e	1.40de	76.00b	60.15e	2.61ef	66.47fg	11.73g	24.17abcd	356.42bcde	636.47def
NGB514	262.87def	10.13bc	9.88bc	1.18ab	71.33ab	40.90c	1.72b	50.59def	8.15bcd	19.30abc	309.83bcd	553.27cde
NGB523	198.94b	8.00a	7.50a	1.26b	66.33a	39.32c	2.34cdef	36.07bcd	6.31ab	19.13abc	197.56ab	352.78abc
NGB528	243.10cd	10.40c	10.40bc	1.40de	86.00d	39.54c	2.36cdef	38.37bcd	7.42bc	17.65ab	291.76abc	390.75bc
NGB571	274.07defg	13.00d	12.80de	1.22b	71.00ab	29.27b	2.29cdef	25.12abc	5.75a	30.60bcdef	309.06bcd	551.89cde
NGB575	215.57bc	9.50abc	9.50b	1.12ab	82.33cd	53.37d	1.79b	61.39efg	10.59fg	31.53bcdef	552.00fgh	985.71gh
NGB578	214.00bc	8.33a	8.33ab	1.39de	122.00gh	40.11c	2.75f	62.71efg	7.76bcd	21.00abc	381.65cdef	681.52f
NGB589	251.09de	13.30de	13.40e	1.13ab	121.67gh	38.15c	1.28a	37.69bcd	9.57ef	19.37abc	269.39abc	481.05bcd
NGB594	271.18defg	8.50ab	9.00ab	1.33c	69.67a	55.84d	2.08bcd	46.17de	8.02bcd	20.14abc	304.65bcd	544.02cd
NGB606	304.94g	15.40f	15.40g	1.25b	124.33gh	26.42ab	1.94bc	33.09bcd	8.47bcde	20.26abc	358.86bcde	640.83def
NG-ZA-01	253.89de	9.60abc	10.00bc	0.97a	124.67gh	66.25f	1.09a	20.98ab	10.29fg	22.75abcd	363.71bcde	649.47def
NG-ZA-02	189.96ab	9.14ab	9.14ab	1.12ab	118.67g	26.20a	1.27a	9.30a	5.25a	17.57ab	160.40ab	286.43ab
NG-ZA-05	170.58a	8.25a	8.00a	1.27bc	120.67g	26.89ab	1.67ab	25.75abc	7.18b	24.49abcd	335.66bcd	599.39cde
NG-ZA-08	284.40efg	13.43de	12.29d	1.18ab	70.67ab	37.30bc	2.47def	68.81g	10.02efg	20.97abc	130.25a	232.58a
NG-ZB-01	287.39efg	14.60ef	13.60e	1.38d	72.33ab	30.44b	2.69f	45.99de	11.21g	31.78bcdef	467.09efg	834.09fg
NG-ZB-03	188.32ab	10.00bc	10.25bc	1.46ef	77.00b	22.67a	2.23cde	45.68de	7.33bc	31.85bcdef	556.95fgh	994.55gh
NG-ZC-01	287.46efg	12.90d	12.80de	1.35cd	78.67bc	30.02b	3.75h	76.52h	9.06def	36.19defg	653.85ghi	1167.58i
NG-ZC-02	292.20fg	12.00cd	11.40c	1.11ab	77.00b	35.85b	2.41cdef	62.92efg	13.10h	26.75abcd	491.38efg	877.47g
NG-ZC-03	297.54fg	10.00bc	10.67c	1.29bcd	77.00b	25.78ab	2.79fg	44.78de	10.16efg	34.97cdefg	738.52i	1318.78j
KD-KG-01	181.55ab	8.80abc	8.40ab	1.27b	122.67gh	29.03b	1.25cdef	10.85a	5.20a	14.47a	142.93a	255.23ab
KD-CK-01	371.85i	12.00cd	12.50d	1.43e	122.00gh	56.46de	1.98bc	69.59g	9.12def	22.00abcd	322.08bcd	575.15cde
KD-JB-01	160.80a	8.60ab	9.20ab	1.09a	73.00ab	26.58ab	1.26a	10.36a	5.67a	36.02defg	373.01cde	666.08def
KD-JM-01	272.30defg	14.33e	15.00g	1.16ab	129.33h	28.03b	2.55ef	42.90cd	11.55def	36.90defgh	698.25hi	1246.88ij
NS-JIL-01	252.89de	13.10d	13.00de	1.16ab	87.33de	29.56b	2.36cdef	36.74bcd	8.92de	24.62abcd	409.02defg	730.39efg
NS-YEL-02	276.70defg	15.50f	16.00h	1.41e	90.00e	26.98ab	2.43def	36.81bcd	9.32def	26.90abcd	474.43efg	847.19fg
NS-YEL-06	228.45c	10.67c	10.50bc	1.07a	84.00cd	30.42b	2.63ef	36.83bcd	11.71g	32.31cdef	520.05efgh	928.67gh
NS-YEL-07	276.20defg	13.10d	13.40e	1.12ab	87.67de	33.06b	2.65ef	46.89de	7.65bcd	43.61h	727.83i	1299.7ij
NS-GAN-04	279.90efg	11.67cd	12.00cd	1.15ab	78.33bc	25.07ab	1.67ab	20.69ab	8.68cde	22.86bcd	437.29efg	780.88efg
NS-GAN-05	280.30efg	15.11f	15.33g	1.45ef	78.00bc	29.76b	2.60ef	56.08def	11.18g	32.05cdef	520.75fgh	929.91gh
NS-GIN-03	269.36defg	14.83ef	15.67gh	1.58f	77.67bc	25.55ab	1.99bcd	22.55ab	7.39bc	22.93bcd	391.32defg	698.78ef
KN-MA-01	271.44defg	13.50de	14.00f	1.33bc	106.00f	33.58b	2.67ef	41.19cd	8.52cde	25.13bcde	572.74fgh	1022.76hi
KN-GU-02	279.63efg	14.70ef	13.80ef	1.28bc	77.67bc	37.32bc	3.13g	63.94fg	13.42h	41.34h	633.70ghi	1131.6i
JIG-DU-01	283.27efg	13.30de	13.80ef	1.24b	125.67gh	48.92cd	2.57def	75.55h	14.19h	35.38fg	545.66fgh	974.39h
JIG-BIR-01	283.55efg	14.13e	14.50fg	1.26bc	79.50c	26.04ab	2.39cdef	26.50abc	8.50cde	23.29bcd	338.88bcd	605.14de
ZF-ZM-01	168.54a	10.00bc	9.60b	1.40de	76.33b	39.05bc	2.19bcde	49.39def	9.53ef	29.30e	526.25fgh	939.73gh
Mean (x)	262.57	12.09	12.07	1.28	91.62	36.36	2.26	44.10	9.08	26.79	424.66	751.17
Standard deviation	53.30	2.62	2.64	0.21	21.65	23.42	0.68	22.45	2.32	10.61	175.71	320.84
Coefficient of Variation	0.20	0.22	0.22	0.17	0.24	0.64	0.30	0.51	0.26	0.40	0.41	0.43

Values are mean of ten (10) randomly selected plants per accession. Values followed by the same letter(s) along the column are not significantly different at $p < 0.0$

3.2. Quantitative characterisation of pearl millet accessions

The results of morphological characterisation show that different trait was favoured by different accession of the collected pearl millet (Table 2). The highest plant was obtained from KD-CK-01 (371.85 cm), followed by NGB 501 (336.99 cm). These high values were significantly different ($p < 0.05$) from one another and the height of all other accessions. The least plant height was recorded in accession NG-ZA-05 with the value of 170.58 cm. This value was not significantly different ($p>0.05$) from the value of accessions KD-JB-01 (160.80 cm) and ZF-ZM-01 (168.54). The highest number of leaf per plant was recorded in NS-YEL-02 (15.50) and the least was obtained in NGB 523 with the value of 8.00. This highest value was not significantly different from number (15.11) obtained in NS-GAN-05. Accession NG-ZA-01, NG-ZC-03, ZF-ZM-01 had the same number of leaves with the value of 10.00. The number of internodes per plant also varied significantly from one accession to other with a range value of 7.50 per plant in NGB 523 to 16.00 in NS-YEL-02. Stem diameter ranged from 0.97 cm in accession NG-ZA-01 to 1.58 cm in NS-GIN-03. These values were significantly different from one another and from the value of all other accessions. On the basis of days to anthesis, the accessions could be group into early and late maturity. The early maturity days to anthesis ranged from 66.33 to 90.00 days and 106.00 to 129.33 days.

A wide range of variation in yield traits was recorded among the accessions. The panicle length ranged from 22.67 to 66.25 cm. The highest panicle length (66.25 cm) obtained in accession NG-ZA-01, was significantly different from the value of all other accessions while the least (22.67 cm) was obtained in NG-ZB-03. The panicle diameter varied significantly different ($p < 0.05$) with the highest diameter recorded in accession JG-DU-01 with the value of 3.13 cm. This value was not significantly different from the value (2.79 cm) of accession NG-ZC-03, but significant from the value of all other accession. Accession NG-ZA-01 had the least panicle diameter with the value of 1.09 cm. The highest panicle weight and weight of 1000 seeds were obtained in JG-BIR-01 with the value of 75.55 g and 14.19 g respectively (Table 2). This highest panicle weight (75.55 g) is significantly different from the panicle weight of all other accessions; while the highest weight of 1000 (14.19 g) seeds recorded in the accession was not significant from the value of NG-ZC-02 (13.10 g) and JG-DU-01 (13.42 g). Accession NG-ZA-02 had the least panicle weight and weight of 1000 seeds with the value of 9.30 g and 5.25 g respectively. Weight of seeds per panicle varied significantly ($p < 0.05$) between 14.47 and 43.61 g with NS-YEL-07 having the highest seeds per panicle and KD-KG-01 had the least. The highest weight of seeds per plot and weight of seeds per hectare were obtained in NG-ZC-03 with the values of 738.52 g and 1318.78 kg/ha respectively. These values were not significant to the values recorded in NS-YEL-07 for both parameters. Least values of eight of seeds per plot (130.25 g) and weight of seeds per hectare (232.58 kg/ha) were recorded in NG-ZA-08.

3.3. Estimated genetic parameters

The result showed that for all the traits studied, phenotypic variance (PV) were higher than the corresponding genotypic variance (GV) (Table 3). The highest phenotypic and genotypic variance due to weight of seeds per hectare (WSPH) with the value of 105142.18 and 77158.09 respectively and the least was obtained for stem diameter (STD) with the value of 0.07 for PV and 0.04 for GV. The GV for most of the traits were higher than their corresponding environmental variance (EV), aside the panicle length (PAL) and weight of seed per panicle (WSPP) where the EV (472.76 and 75.10 respectively) was higher than the GV (208.26 and 62.46 respectively) estimated. With the exception of stem diameter with moderate PCV (20.16%) and GCV (14.65%), high coefficient variability (value > 20) were obtained for both phenotype and genotype in all the parameters studied. However, the PCV was higher than the GCV for all the traits except for WSPP with the value of 29.50% and 45.41% respectively. The highest PCV was recorded for WPA (74.25%) followed by PAL (71.78%) and PAD (44.47%). The genotypic coefficient of variation was highest for weight of seeds per plot (WSPPL) (74.49%) followed by WSPH (73.38%) and WPA (67.73%). Broad sense heritability estimate was moderate (30-60%) for stem diameter (52.80%), panicle length (30.58%), WSPP (43.78%), WSPPL (41.68%) and WSPH (43.17%). In all other parameters high magnitude (>60%) of heritability were obtained with the highest in days to anthesis (DTA) (96.36%) followed by 1000 seeds weight (1000WS) with the value of 91.58%. Genetic advanced (GA) was high (>60) for PAD, WPA, WSPPL and WSPH with percentage value of 81.13, 127.27, 63.96 and 65.26 respectively; while all other traits were moderate with the value between 30 to 60% (Table 3).

Table 3 Genetic parameters estimate for morphological traits in 35 pearl millet accessions

Traits	Means	GV(∂)	PV	EV	GCV	PCV	(H^2b)	GA
PLH	262.57	5708.31	6476.84	768.53	28.77	30.65	88.13	55.65
NLPP	12.09	11.27	13.09	1.83	27.76	29.92	86.06	53.05
NIPP	12.07	11.71	13.48	1.76	28.36	30.42	86.91	54.46
STD	1.28	0.04	0.07	0.03	14.65	20.16	52.80	21.92
DTA	91.62	456.10	473.33	17.22	23.31	23.75	96.36	47.14
PAL	36.36	208.26	681.01	472.76	39.69	71.78	30.58	45.22
PAD	2.26	0.90	1.01	0.12	41.85	44.47	88.56	81.13
WPA	44.10	892.21	1072.19	179.99	67.73	74.25	83.21	127.27
1000 SW	9.08	5.01	5.48	0.46	24.65	25.76	91.58	48.60
WSPP	26.79	62.46	137.57	75.10	45.41	29.50	43.78	40.95
WSPPL	424.66	23333.56	31322.72	7989.16	74.49	35.97	41.68	63.96
WSPH	751.17	77158.09	105142.18	27984.09	73.38	36.98	43.17	65.26

GV – Genotypic Variance, PV – Phenotypic Variance, EV – Environmental Variance, GCV – Genotypic Coefficient Variance, PCV – Phenotypic Coefficient Variance, H^2b – Broad Sense Heritability, GA – Genetic Advanced

3.4. Cluster analysis

Cluster analysis of the 35 collected accessions base on their similarity distance revealed that there was high diversity among the pearl millet genotypes in terms of the morphological traits, with accessions from different state been clustered in the same group (Figure 4 and Table 4). On the basis of morphological similarity, the accessions were clustered into four major groups, with cluster I consist 14.29% of the genotypes, 17.14% in cluster II, 40.00% in cluster III and 28.57% were clustered in IV. Accession NGB 528 and NGB 589 were group together as a distinct unit in cluster II while similar strong association was obtained between NGB 514 and NGB 594 in cluster III.

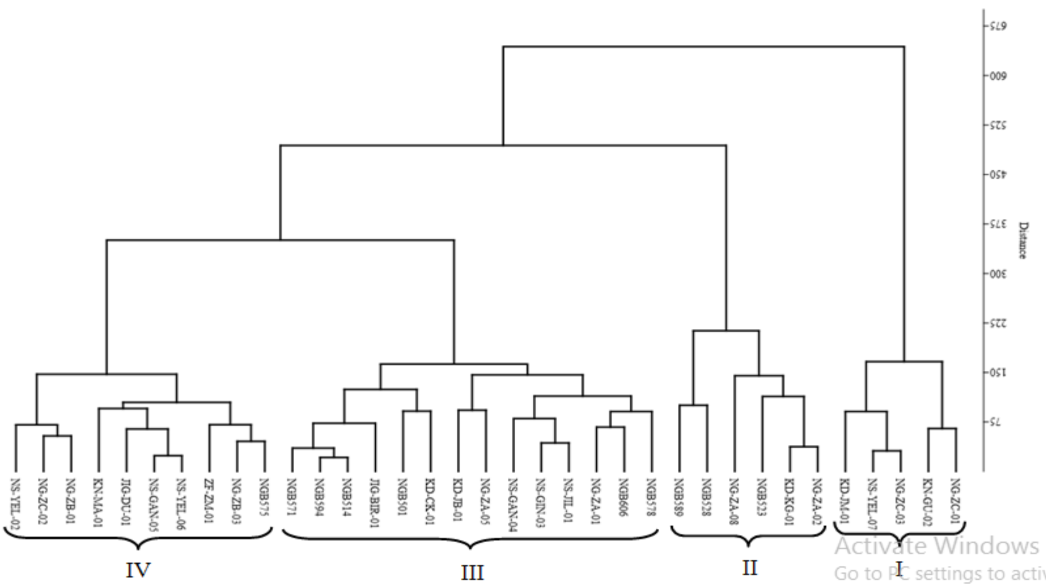

Figure 4 Hierarchical euclidean clustering dendrogram of pearl millet accessions based on similarity distance of 17 morphological traits

Table 4 Grouping of accession based on similarity distance

Cluster	Accessions
I	NG-ZC-01, KN-GU-02, NG-ZC-03, NS-YEL-07, KD-JM-01
II	NG-ZA-02, KD-KG-01, NG523, NG-ZA-08, NGB528, NGB589
III	NGB578, NGB606, NG-ZA-01, NS-JIL-01, NS-GIN-03, NS-GAN-04, NG-ZA-05, KD-JB-01, KD-CK-01, NGB501, JIG-BIR-01, NGB514, NGB594, NGB571
IV	NGB575, NG-ZB-03, ZF-ZM-01, NS-YEL-06, NS-GAN-05, JIG-DU-01, KN-MA-01, NG-ZB-01, NG-ZC-02

4. Discussion

Landraces are most often heterogeneous with a blend of different individual plant maintained significant portion in the gene pool of cultivated crops [12].Characterization of pearl millet germplasm is imperative for categorization of landraces and identification of the desirable genotypes for introgression into breeding programs. Variation in qualitative characters of plant is important in characterisation of any plant, since the traits are only influence by gene(s). In line with this statement visually observable traits such as seed shape and seed colour could be used in classification of genotypes into few broad groups [8], because it reflects genetic, physiological, ecological components and affects yield, quality, and market price[13]. The dominant and high frequency of the globuse shape and light grey among the germplasm could be attributed to consumer preference for the traits in production of soft drink, leading to selection for these characters by the farmer for cultivation year after years.

The highly significant differences recorded in all the morphological parameters among the accessions, demonstrate the adequate variability that exit in the gerrmplasm; indicating the heterogeneity of the collected pearl millet accessions. In agreement with this result Khairwa *et al*. [14] who studied 2375 germplasm lines, 180 landraces and 504 accessions of core collection of pearl millet for grain and fodder yield and their related traits reported wide range variability for almost all the traits studied. The high variability in the plant has been attributed to the allogamous nature of pearl millet couple with protogyny and time lag between stigma emergence and anther dehiscence favour complete cross pollination leading to greatest morphological diversity among the accessions [15]. Also, in corroboration with this result tremendous phenotypic variability has been reported in pearl millet for many agronomic traits such as plant height, number of tillers, weight of 1000-seeds, flowering time, panicle length, grain and stover characteristics [16].

The minimum plant height (160.80 cm) recorded in this study fall within the range reported by earlier authors; 45.2 to 358.0 cm by Khairwa *et al*. [14], 150 to 350 cm by Angarawai *et al*. [17] who worked on pearl millet. However, the maximum height of 371.85 cm obtained in this studied exceed the maximum value reported by the authors. Also, in congruence with this result, the genetic diversity among 126 maiwa landraces earlier studied in Nigeria resultedin a ranged height of 168 to 377 cm [6]. The close agreement of these results could be attributed to similarity in the sources, ecology of the seed collection and the climatic condition of the research areas. In contrast to these results, a ranged of 64.35 to 165.78 cm was reported by Anuradha *et al*. [18]. Leaf area and number of leaves per plant is an essential trait for photosynthesis and enhanced fodder yield and quality as well as increases production of pearl millet crop in turned. Variation in number of leaves per plant obtained in this study fall within the ranged 11 to 15 as earlier reported Shah *et al*.[19]. Variation in number of leaves per plant had earlier been reported by Khan *et al*.[20].

The panicle length of 22.67 to 66.25 cm recorded in this study was within the range of 5.00 to 135.00 cm earlier reported for pearl millet cultivated in rain raining season [16] and 14.70 to 51.10 cm recorded by Khairwa *et al*. [14]. In contrast, a ranged of 15.00 to 31.00 cm was reported with both minimum and the maximum value less than the values obtained in this study Shah *et al*.[19]. The difference is these results could be attributed to the difference in genetic composition of accessions, their geographical origin and environmental factors of the experimental region. The panicle diameter ranging from 5-13cm earlier obtained among '*Maiwa Type*' of Pearl Millet [6] was greater than a range of 1.09 - 3.75 cm recorded in this study. In agreement with range value of 5.20 to 14.19 g for 1000-seed weight obtained in this study, a range of 2.50 to 20.00 g was earlier reported for local cultivars of pearl millet Khairwal *et al*. [21]. Similarly, a range value of 4.67 to 12.85 was obtained by Anuradha *et al.* [18].

Variation in days to anthesis; 66.33 to 90.00 days for early variety and 106.00 to 129.33 days for late variety observed in this study corroborate with the earlier findings of60 days reported for early flowering accessions and 120 days for late flowering accessions in finger millet [22]. These values are higher than the values (ranged of 44 to 56 days) earlier reported Animasaun *et al*. [23], and attributed the differences in anthesis time to photoperiodic sensitivity of the plant [23]. The variation in these results could be attributed to the difference in the response of plant to the environmental condition and the genetic nature of seeds. The early anthesis accessions obtained in this study could be selected for breeding programme of early maturing variety. The yield per panicle obtained in this study fall within the range of 26.90 to 89.36 g earlier reported Anuradha *et al.* [18]. The range of 232.58 to 1318.78 kg/ha for grain yield per hectare in this study is similar to the range of 255.44 to 1087.00 kg/ha earlier reported in a study on selected cultivars of the crop and their hybrids in the North-Eastern Nigeria [24]. The difference in the results could the attributed to variation in the ecological and environmental factors of the experimental site.

High coefficient of variation among the characters studied for both PCV and GCV buttress the fact that high variability exists in the crop for morphological parameters. High coefficient of variation in the characters of crops has been attributed to the heterogeneity existing among germplasm accessions of such crops [25]. In agreements with the results of this study where all phenotypic co-efficient of variation (PCV) was higher than genotypic co-efficient of variation (GCV) for all the traits studied, Singh *et al.* [26] who obtained similar results attributed this to the influence of environmental factors on the expression of the characters.

Heritability estimate in conjunction with the genetic advance is more reliable to pin pointing characters enforcing selection, since heritability is influenced by environment. The high heritability in conjunction with moderate to high genetic advanced obtained for all the studied traits indicate the importance and reliability of these characters for selection. High heritability coupled with moderate genetic advance has been attributed to equal importance of additive and non – additive gene actions [26]. High estimates of heritability have been reported to be one of the major indicators of phenotypic variability in the characters of any crops contributed by additive gene effects [27]. Selectionbased on these traits could assist in successful isolation of desirable genotypes [28]. Hence, these traits could be selected for, in the crop improvement.

Grouping of the accessions into four clusters with each cluster group containing accessions from different state and source, indicate that there was no association between pattern of clusters and geographical distribution of accessions. The clustered of accessions NGB 528 and NGB 589; and NGB 514 and NGB 594 as a distinct similar genotypes in their various cluster groups could be attributed to trans-boundary movement of crop by the agrarian farmers and become adapted to that environment after years of cultivation. In agreement with this statement, clustering of accessions based on geographical origin or genetic difference and further small clusters based on similar characteristics, pedigree relation or close area of cultivation within the main group had earlier been reported Ercan *et al*. [29].

5. Conclusion

It is established that considerable high variability exists among the landraces of pearl millet in the country. Clustering of the genotypes independent of the state or source of collection suggested that, hybridizing the genetically diverse parents of the crop belonging to different clusters of could provide an opportunity for bringing genes of diverse nature together for it improvement.The high variability recorded in the germplasm couple with high heritability and genetic advance in most of the parameters studied, indicate that the accessions and traits could be explored in the crop improvement.

Compliance with ethical standards

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Disclosure of conflict of interest

All the authors have declared no competing interest.

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