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Agro-Morphological Characterisation of Pearl Millet Accessions in Ghana

Asungre, A. P.
Savanna Agricultural Research Institute of CSIR, Ghana
Email: idkatokple@yahoo.com

Akromah, R.
Faculty of Agriculture, Kwame Nkrumah University of Science and Technology

Atokple, I. D. K.
Savanna Agricultural Research Institute of CSIR, Ghana

***Abstract* – One hundred and twenty six (126) pearl millet accessions were collected from Upper East, Upper West and Northern regions which are the domain for Pearl millet production in Ghana and evaluated at the Savanna Agricultural Research Institute of the Council for Scientific and Industrial Research (CSIR-SARI) station at Manga during the 2011 main season. The aim was to conserve Pearl millet germplasm, develop agro-morphological characterisation data base and to define core selections for future use. The days to fifty per cent booting (DFB) ranged from 37-125 days and based on that 123 of the collections were grouped into early (39-59), medium (60-100) and late maturing groups (>101). Clustering based on morphological data (values converted to 0s and 1s) helped to further group the early maturity group into three distinct clusters and five distinct clusters each for medium and late maturity groups using the Unweighted Pair-group Method with the Arithmetic Means (UPGMA) and Jaccard's coefficient range of 0-1. The agronomic data showed that the entire accession varied for seed colour and shape, head densities and shape. Plants heights ranged from 142 to 395 cm and the heads (spikes) made up of only cylindrical and candle shapes were short (15.3 to 29.7 cm). The major seed colours were deep grey and grey with globular shape being the dominant seed shape. Region of origin did not influence any particular trait except days to DFB. A core collection of 30 (7, 13 and 10 from early, medium and late maturity grouping respectively) accessions were generated, using the clusters and maturity groupings as guides.**

***Keywords* – Characterisation, Core Collection, Germplasm, Pearl Millet.**

I. Introduction

Millets are small-seeded grasses that are hardy and grow well in dry zones of sub-Saharan Africa as rain-fed crops, under marginal conditions of soil fertility and moisture [1], making them the preferred cereal crop in drier areas. One of the most widely cultivated species of millet in the world is Pearl millet (*Pennisetum glaucum* (L), R.Br). In Ghana, Pearl millet is grown in Upper East and Upper West, and Northern regions.

A Consultative Group on International Agricultural Research [2] report observed that conserving the rich diversity of crop varieties and related wild species is essential for providing farmers and plant breeders with raw material to improve and adapt crops to meet challenges such as climate change, land use change, diseases and pests upsurge. Adaptive and productive agriculture depends on crop diversity as its 'building block' which is being eroded due to inadequate funds for continuous and consistent collection and conservation [3]. Currently, World Information and Early Warning System (WIEWS) on Plant Genetic Resources for Food and Agriculture (PGRFA) indicate that about 7.4 million accessions of plant genetic resources aremaintainedglobally, an increase of 1.4 million over the reported figure in the first state of the world report [3].

Most farmers in Africa, especially West Africa, continue to plant traditional landrace cultivars that have not seen any improvement over the years and are under threat of extinction even though they constitute a diverse store of genetic traits for crop improvement and adaptation to the local conditions. The concept of core and mini core collections has been used to identify genetically diverse trait in specific crop germplasm.

Collection missions carried out by Savanna Agricultural Research Institute (SARI) in the Upper East Region between 2000 and 2004 assembled 43 accessions, without any comprehensive data. These were conserved at Plant Genetic Resources and Research Institute of Ghana (PGRRI) gene bank [4]. Earlier collection and evaluation work done in 1981 was limited more to the early-maturing types as reported by Appa Rao, *et al.*,[5]. The full genetic potential and diversity of these local landraces have not been explored since very insignificant database is available for the Ghanaian pearl millet germplasm. This poses a challenge to conservationists and breeders in identifying and exploiting their inherent potentials as well as eliminating duplicates. It was therefore important that a comprehensive database for pearl millet grown in Ghana, showing their variability, was developed, fine-tuned and core selections made easily accessible to more scientists.

II Materials and Methods

2.1 Collection Mission:

Collection which was done in May/June 2011 captured the ethno-botanical information, cultivation and management practices as well as location/community, ethnic group, local name, uses and problems associated with each accession. Seed samples (threshed and/or panicle forms) were taken only from homes between 20 – 45 km intervals along predetermined routes using a physical Map of Ghana (Fig 1), ensuring that there were at least one and at most three samples collected in each administrative district of the regions. In all cases, collections were seeds preserved from the 2010 cropping season.

Fig.1. Regions where collection was made

2.2 Field Establishment at SARI Research Station, Manga:

The agro-morphological characterisation work was carried out at the Manga Agricultural Research Station of CSIR-SARI (Latitude 11^{o} - 01' N and Longitude 00^{o} -16^{o} W with elevation of 249 m above sea level). Soil samples, taken at a depth of 0-30cm (W-Pathway), were analysed for the determination of their physical and chemical properties at the CSIR-SARI soil laboratory. Planting was in June, 2011 at a spacing of 0.75m X 0.30m and row length of 3m giving approximately 20 stands per plot of 2 rows and replicated four times with 1m distance between replicates. A single dose of Nitrogen, Phosphorus and Potassium (NPK -15-15-15) fertiliser was applied at the rate of 75kg/ha 25 days after emergence. Selected quantitative and qualitative morphological parameters (growth and reproductive) usingthe standard millet descriptor as a guide [6] were observed and used for the characterisation.

III. Results and Discussion

A total of 126 accessions (Table 1) were collected across the entire pearl millet production regions of Ghana. Northern Region had the largest number of 56 accessions (44.44%) followed by Upper East Region with 44 (34.92%) and 26 (20.64%) from Upper West region. Upper East Region was noted for its high production and consumption of pearl millet, especially the early-maturing types. This gave credence to the fact that a relatively high number of such accessions were gathered across the region despite its small relative land size as compared to the other regions. Upper West did not record any early-maturing group because of incidence of bird attack over the years which have led to farmers abandoning the crop [7] is suspected that the three early-maturing millet accessions (SARMIL 076, SARMIL 077 and SARMIL 079) collected from Northern Region were carried there by settlers from Upper East Region since the communities share boundaries with Upper East Region. About 93.33% of the late-maturing group came from Upper West and Northern Regions (Table 1), a trend that could be attributed to the ecology since these Regions tend to have more "bush farms" where early-maturing millet is not preferred.

Table 1: Total number of Pearl millet Accessions collected by Region and their maturity grouping

Region	Maturity as given by farmers			Maturity as observed during field evaluation (DFB)		
	Early maturing	Late maturing	Total	Early (39-59)	Medium (60-100)	Late (101+)
Upper East	21	23	44	21	20	3
Upper West	0	26	26	0	17	9
Northern	6	50	56*	3	17	33
Total	27	99	126	24	54	45

DFB: Days to Fifty per cent Booting; * 3 failed to germinate during field evaluation

The ethno-botanical data indicated that pearl millet grain use in Ghana was mainly for the preparation of traditional dishes such as 'koko' (light porridge) 'masa' (fried cake) and 'tuo-zafi' (thick porridge), while the stalks are used as fuel and fencing in most households, thus corroborating the report by Appa Rao *et al*. [5]. Also none of the accessions/landraces collected was an improved or introduced material. The main source of seed supply has been selected from their previous harvest or from neighbours. This is because of the subsistence nature of agriculture practiced by farmers throughout the interior savannah [5]. This practice might have contributed to the close relationship that exists between and among some accessions from some neighbouring districts. Only nine (7.12%) farmers mentioned diseases such as downy mildew, stem borers, leaf folding and leaf drying as well as drying of whorls as having effect on pearl millet production.

The main desired traits that farmers look out for in pearl millet were Striga resistance, drought tolerance, early maturity, seed colour, hairy spikes as well as the crop's ability to grow under very poor and marginal soils. The late maturing lines were preferably grown on bush farms since birds do not normally attack them due to abundance of weed seeds at the time of maturity. However, the agro-morphological data collected during the characterisation work indicated that SARMIL 028 and SARMIL 029, which were seen as early maturing by farmers from the Sawla-Tuna district were rather late maturing as their days to fifty per cent booting was above 100 days.

3.1 Quantitative Trait Variations of The Accessions

The agro-morphological data revealed a lot of information regarding the materials relative to their source of collection. Monitoring the DFB, the entire collection was classified into three distinct classes (Table 2) as early maturing (39-59 days), medium maturing (60-100 days) and late maturing (above 100 days). Majority (54) were in the medium maturing group followed by late maturing group with 45 accession and 24 constituting the early maturing group. Upper West Region had no early maturity group thus confirming the passport data from the farmers.

With respect to medium maturing group, Upper West and Northern Regions contributed Seventeen (17) accessing each (62.96%) with Upper East contributing twenty (20) accessions. Whereas more early (87.5%) and medium (37.04%) maturing pearl millets were grown in the Upper East Region, Upper West and Northern Regions had more late-maturing group of pearl millet. In most of the cases the early-maturing group showed clear quantitative variations among the collections.

Percentage downy mildew (DM) incidence (except at dough stage for early-maturing group), average stover yield plant^{-1} and productive tillers plant^{-1} did not reveal any significance difference (P>0.05) (Table 2). There were significant variations in response to downy mildew incidence among the early-maturing group at dough stage. This phenomenon would be useful for trait identification when targeting downy mildew in any breeding programme for this maturity group. However there was a general increasing trend in downy mildew incidence for all maturity groups (with a mean of 7.4% for the late group to 39.8% for early group) as the plants aged (Table 2). Arun and Manga [8] reported that environmental factors such as temperature, humidity, rainfall cloudiness and intensity of radiation enhance downy mildew development and spread as well as the disease cycle of the *Sclerospora graminicola* (Sacc.) Schroet pathogen. This probably explained why the progressive increase in the incidence observed in the accessions. The medium-maturing and late-maturing groups had lower incidences than the early-maturing ones. This is due likely to the fact that the former mature at a time that the environmental conditions were not favourable for disease development.

The incidence levels recorded indicated that some of the materials were resistant (<10%) while others were susceptible (>10%) to the downy mildew disease. The mean downy mildew values recorded (Table 2), showed that the Ghanaian pearl millet generally has problems with the disease and therefore require good timing on when to plant during the year. Arun and Manga [8] reported that yield loss attributed to downy mildew is incomplete due to variability in incidence from field to field, farmer to farmer and from season to season. But Wilson *et al*. [9], in studies conducted in some West African countries, revealed that downy mildew incidence is negatively correlated with grain yield. However, Singh *et al*. [10] reported that global yield loss due to downy mildew may not exceed 20% even though there were localised situations, especially in India, where yield loss could go as high as 40%. These values were however lower than what was reported by Nutsugah, *et al*.[11], that downy mildew was the most important disease limiting pearl millet production in Ghana, contributing up to 60% grain yield losses annually.

The mean DBF for the accessions was 79 days and that of plant height was 273.2 cm with mean head length of 21.0cm (Table 2). The early-maturing group had plants with the shortest mean height of 160 cm and head lengths of 18.31 cm while the medium-maturing group had the tallest plants with mean height of 341.3 cm and longest heads with mean length of 23.8 cm. These results are fairly consistent with Appa Rao *et al*. [5] who reported ranges of 39-140 days, 120-315 cm and 6-53 cm for days to fifty per cent flowering, plant height and head length respectively, for Ghanaian pearl millet landraces. Generally these traits tend to correlate positively with grain yield in most locations in West Africa where pearl millet is grown [9]. The variations in head length are attributed to the allogamy in pearl millet. Trait affecting head size of pearl millet cultivars is reported to exert a considerable amount of influence on its productivity [12] and is appreciated in breeding of improved cultivars. Appa Rao *et al*. [5] reported only two maturities; early- and late-maturing groups in the Ghanaian pearl millet and that the differences in flowering between them are determined by 2 genes, L_1 and L_2 without dominance. However Bilquez and Clement [13] reported within the early-maturing group, several genes governed flowering with additive effect. This probably explained the variations in the accessions evaluated. The maturity groupings in the current studies were different from what had been reported earlier. For instance Appa Rao *et al*. [5] considered 70 days as the upper limit for the early-maturing group and 71 days as the lower limits for the late-maturing group. However both the medium and late types in the current studies were harvested between early October and mid-December. It was therefore prudent to separate these into two different groups. The late-maturing ones can be recommended for bush fields where they are free from animal destruction while the medium-maturing are maintained for the compound farms.

Table 2: Influence of time to maturity on selected quantitative traits of 123 accessions planted at Manga station in 2011 main season.

Trait measured	Early-maturing			Medium-maturing			Late-maturing			Overall
	Range	Mean	SE	Range	Mean	SE	Range	Mean	SE	Mean
DM incid @ 30 days (%)	0-29	11.3	12.6	0 -17.9	7.5	10.7	0 -23.8	7.4	10.9	8.7
DM incid @ 70 days (%)	11.9-63.0	39.6	15.2	0 -70.9	23.9	18.1	3.6-47.9	24.2	19.1	29.2
Ave. head girth (cm)	7. 5-9.2	8.4	0.7	6.4-11.9	8.4	1.0	7.2-10.7	9	1.5	8.6
Ave. head length (cm)	15.3-24.7	18.3	2.9	18.2-29.7	23.8	3.8	17.2 -24.3	20.9	2.9	21
Ave. plant height (cm)	141.5-175.8	159.8	13.4	276.2 -394.5	341.3	33.2	263.5 -368	318.5	35.6	273.2
Stover yield (kg) plant^{-1}	0.2-0.6	0.3	0.2	0.6-1.9	1.1	0.5	0.4 -1.2	0.7	0.4	0.7
1000 seed weight (g)	8.9 -12.2	10.4	2.1	5.7 -12.1	9.5	2.0	4.5-9.6	7.6	1.7	9.2
Ave. total tillers plant^{-1}	4 – 8	6	1.2	6 – 11	7	1.6	5 – 12	8	1.4	7
Ave. prod've tillers plant^{-1}	3 – 7	4	1	4 – 8	5	1.3	1 – 7	3	1.2	4
Days to 50% booting	37-45	40	2.7	69 -100	84.8	10.7	101 -123	110.6	10.9	78.5
Plant stand plot-1	4.5 -20	16.1	3.6	11 – 20	16.3	4.2	9.5 -20.8	15.9	3.9	16.1

DM = Downy mildew incidence; Se = Standard deviation, Ave = Average, Prod've = Productive

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In terms of productive tillers and thousand grain weight, the accessions showed a mean value of four (4) with a range of 1-8 tillers per plant while the mean value for grain weight was 9.2 g (range of 4.5-12.2g). This indicated that the accessions had potential for yield and biomass improvement since tillering was positively correlated with grain and fodder yields as suggested by Harer and Karad [14] and Khairwal *et al*. [15]. However, the result deviated from Appa Rao *et al*., [5] and Afribeh, [16] who asserted that the Ghanaian pearl millet populations have a range of 1-3 tillers per plant. Consumer preference of a cultivar is often influenced by grain size (bold grains), and by extension grain yield and quality hence an important trait in pearl millet [17]. According to Rai *et al*. [18], grain sizes (1000 seed weight) can be categorised into very small (<5 g), small (5.0-7.50g), medium (7.6-10.0g), bold (10.1-12.50g) and very bold (>12.50g) grains. In the current studies only SARMIL 041 had very small grain, 23 accessions had small, 72 had Medium, and 27 had bold grain. There was no very bold grain type. These variations corroborated earlier reports by Appa Rao *et al*.[5].

3.2 Qualitative Trait Variations Within The Accessions:

Following the codes provided by the Royal Horticultural Society, the Ghanaian accessions exhibited five main seed colours of ivory, yellow, grey, deep-grey and brown-grey (Fig. 2). The colours grey (38.2%) and deep-grey (42.3%) formed the majority, whereas the early-maturing group had deep-grey as its dominant colour followed by grey-brown. The late-maturing group showed the reverse and the dominant seed colour for the medium group was grey followed by deep-grey (Fig. 2). The early-maturing group did not have ivory and yellow seed colours while the medium- and late-maturing groups did not produce grey-brown seeds. The results agree with Appa Rao, *et al*., [5] that the Ghanaian pearl millet is dominated by grey seed colour.

Only two head (spike) types namely lose and semi-compact heads were revealed by the collections (Fig 3). However majority (101 accessions) were the semi-compact types. These included 46 accessions of the medium, 38 of the late and 17 of the early-maturing accessions. The variations observed here was at variance with what had been reported by Khairwal *et al*. [15] using core collections under Indian conditions which showed extensive variations. This means it is possible to encounter wider variations in pearl millet landraces in Ghana if the collections were done on the field during the crop growth. In terms of head shape types, 110 (89.43%) of the accessions had cylindrical head shape while 13 (10.57%) were candle shaped (Fig. 3). Even though the results were consistent with those obtained by Appa Rao *et al*. [5], it did not include conical head shape as reported by the latter. This could be due to human error since the trait is qualitative confirming the fact that some of the accessions that were observed to have cylindrical head shapes in Ghana became either spindle or conical and vice-ci-versa in India [5].

All collections revealed basically three seed shapes (Fig.4) namely obovate (16%), hexagonal (24%) and globular (60%). The trend in terms of prominence was similar for individual maturity groups except for the early group where obovate showed higher percentage (25 %) than hexagonal (16.67%).

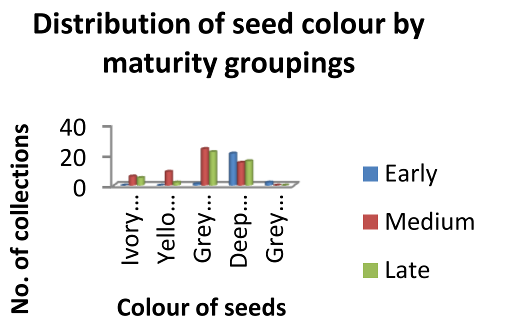

Fig.2. Colour Distribution of 123 Accessions Collected

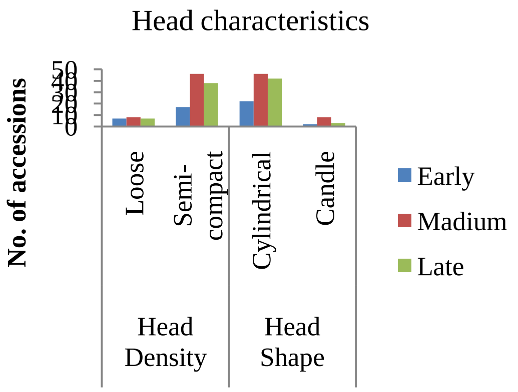

Fig.3. Head density and shape distribution of 123 accessions

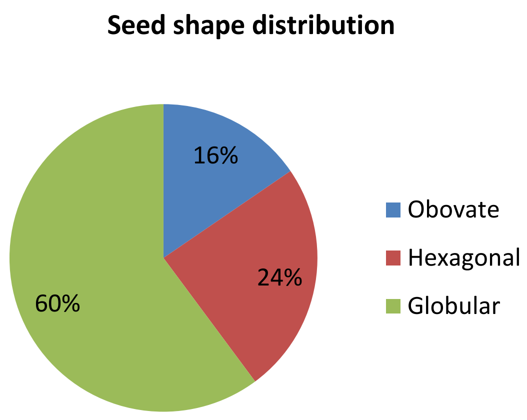

Fig.4. Seed shape distribution of 123 accessions

3.3 UPGMA Clustering

Fifteen agronomic traits (both qualitative and quantitative) gathered were transformed into 0s and 1s and then used to construct three separate UPGMA, on a Jaccard's coefficient scale of 0-1, based on maturity grouping.

With a coefficient of 0.692, the early-maturing group produced three distinct clusters (Fig. 5). Cluster A had only one accession (SARMIL 092) which came from the

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Bongo district of Upper East Region and was influenced mainly by quantitative agronomic traits especially stover yield plant^{-1}. It was only similar to the rest of the group at 0.65 on the scale. Cluster B was made up of 12 (50%) of the total 24 accessions whiles cluster C contained 11 (45.83%) accessions. Clusters B and C each contained one set of duplicates at 0.95 on a scale of 0-1 (SARMIL 105 & 119 for B and SARMIL 111 & 115 for C) which came from different locations. Clusters B and C were both influenced largely by globular, hexagonal and obovate seed shapes in order of magnitude. Again it was observed that whereas cluster C was influenced by three seed colours such as grey, deep-grey and deep-brown, cluster B had only deep-grey seed colour.

At Jaccard's similarity coefficient of 0.552 (Fig. 6), five main clusters were observed with the medium maturity group. Cluster 1 consisted of three accessions (5.56%), Cluster 2 was made up of eight accessions (14.81%), cluster 4 made up of SARMIL 045 and SARMIL 070 (3.70%) and 40 other accessions (74.07%) belonging to Cluster 5. SARMIL 044 (1.86%) stood alone as a unique one among the entire collection as cluster 3 which came from the Savelugu district of Northern Region. The groupings revealed that all accessions of cluster 1 (Fig. 6) came from Upper West Region and in communities such as Hapan-Hamile, Wuli and Chabatan-Babile in Lambusei-Karni, Jerapa and Lawra Districts respectively along the border with Burkina Faso. Qualitative traits such as head shape and seed colour were the main determinants of this cluster. Clusters 2 and 5 cut across all three Regions, with Upper West contributing about half (two each from Sisala West and Lawra districts) to accessions of cluster 2. Obovate (75 %) and globular (25.00%) seed shapes together with cylindrical and candle (75 % and 25 % respectively) head shapes were the main dominant qualitative traits of cluster 2. The two members of cluster 4 came from different Northern Region districts. In accessions SARMIL 065 and SARMIL 059 belonging to cluster 5 (Fig. 6) were observed to be duplicates (with coefficient of 1.00) even though they were from different districts (Chereponi and Yendi respectively) in the Northern Region.

At coefficient level of 0.0694, Five (5) clusters (I: 2.22%, II: 17.78%, III: 8.89 %, IV: 60 % and V: 11.11%) were produced from a total of 45 accessions, constituting the late-maturing group (Fig. 7). Cluster I had SARMIL 026 as the only accession which came from Wa central district of Upper West Region and was only related to the other clusters at coefficient of 0.63 on the scale. Even though it possessed similar qualitative traits as SARMIL 048 in cluster IV, they differed in quantitative traits such as downy mildew incidence and plant height. Cluster IV was the largest with 27 accessions (18, 6 & 3 from Northern, Upper West and Upper East Regions respectively) and was dominated by cylindrical, semi-compact head type and globular seed shape. However, there were two sets of duplicates (at 0.95) in this cluster. SARMIL 019 and SARMIL 028 as one set and SARMIL 021 and SARMIL 034 as another set appeared to have been influenced more by head and grain qualities and not location. Cluster II consisting of SARMIL 025, SARMIL 031, SARMIL 032, SARMIL 038, SARMIL 040, SARMIL 052, SARMIL 054 and SARMIL 057 was the second largest group and came from Northern region except SARMIL 025 which came from Upper West Region. This cluster was influenced heavily by semi-compact and cylindrical head type (87.50%) as well as grey and globular seed colour and shape types (75 %). Clusters III was made up four accessions namely SARMIL 046, SARMIL 050, SARMIL 056 and SARMIL 058 which exhibited total homogeneity, showing cylindrical semi-compact heads, having globular grains with grey colour, while cluster V had five accessions consisting of SARMIL 012, SARMIL 041, SARMIL 042, SARMIL 060 and SARMIL 061. Even though all members of cluster V had cylindrical head shape just as in cluster III, they were not homogenous in terms of their source of collection, head density (60% lose heads), seed shape and colour (20% grey and hexagonal, 80% deep grey and globular grain types).

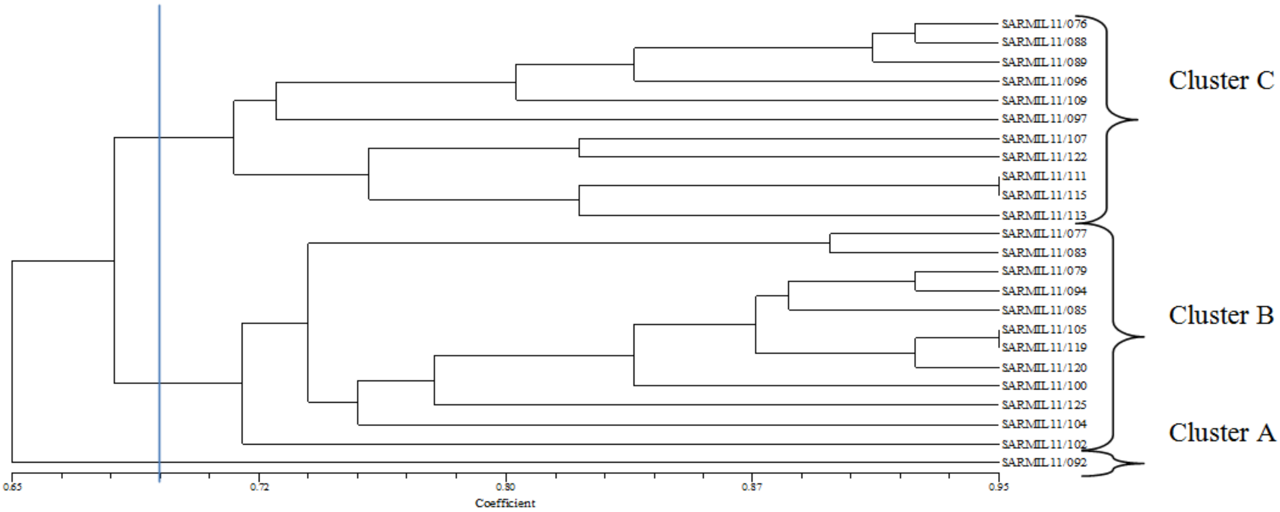

Fig.5. UPGMA phylogenetic analyses of agronomic traits of 24 Early-maturing Pearl millet accessions in northern Ghana (NTSYS-pc). The tree is constructed based on fifteen agronomic traits and clustering demonstrated at a Jaccard's coefficient of 0.692 (vertical line)

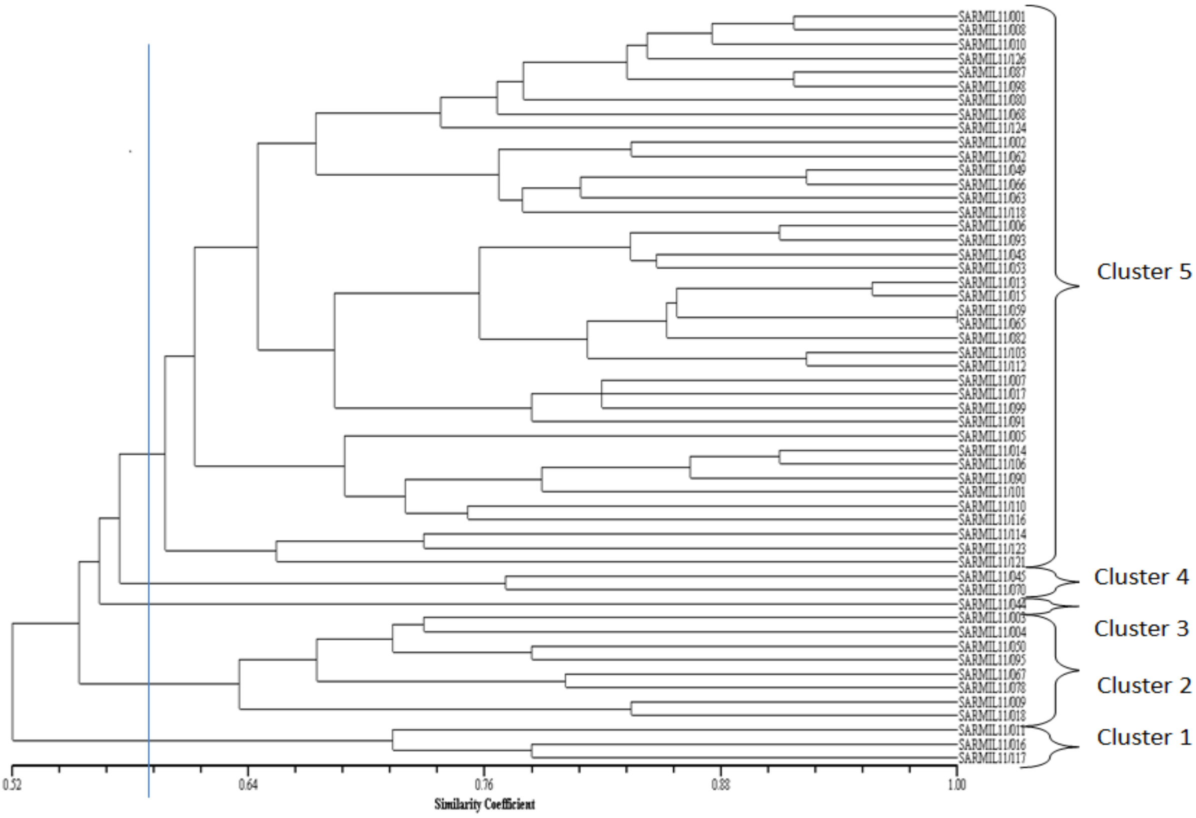

Fig. 6: UPGMA phylogenetic analysis of agronomic traits of 53 medium-maturing Pearl millet accessions in northern Ghana (NTSYS-pc). The tree is constructed based on fifteen agronomic traits and clustering demonstrated at a Jaccard's coefficient of 0.552 (vertical line)

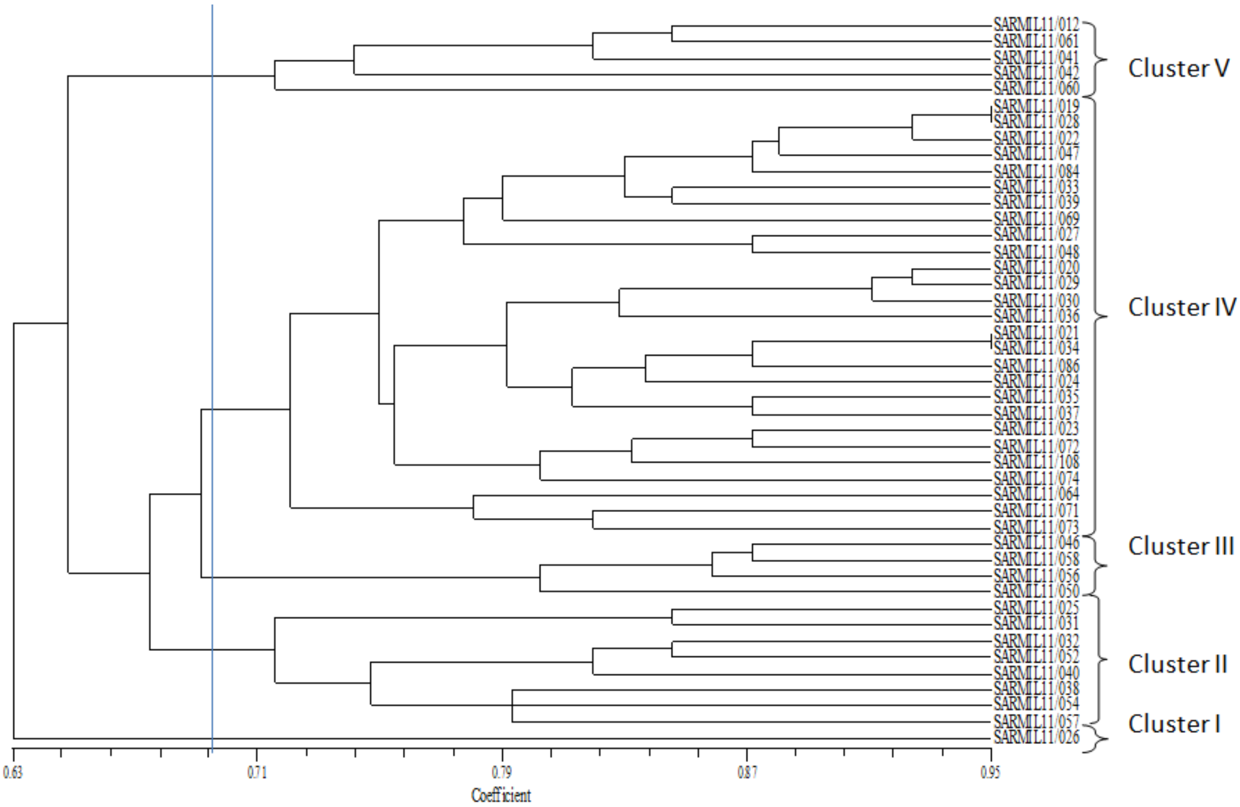

Fig.7. UPGMA phylogenetic analysis of agronomic traits of 45 Late-maturing Pearl millet accessions in northern Ghana (NTSYS-pc). The tree is constructed based on fifteen agronomic traits and clustering demonstrated at a Jaccard's coefficient of 0.694 (vertical line)

3.4 Core selection

Brown [19] defined core collection as a 'limited set of accessions derived from an existing collection, chosen to represent the general spectrum in the collection'. This should comprise a greater proportion of the genetic diversity as possible. Core collection can be used for precise evaluation of trait of agronomic importance and biotic and abiotic stresses as well as mapping with molecular markers for identification of trait-specific germplasm and discovery of new genes. The current work came up with a total of 30 (24.39% of the entire collection.) core selection comprising 12, 6 and 12 accessions from the Upper East, Upper West and Northern Region respectively. These were made up of seven (29.17%), thirteen (24.07%) and ten (22.22%) from the early, medium and late maturity groupings respectively (Table 3). Clusters, geographic locations as well as agronomic trait data collected were all taken into account in coming out with the core from each group.

SARMIL 077, SARMIL 104 and SRMIL 113 for instance, were chosen for their earliness, head length and plant height qualities among the early group while SARMIL 092 had good stover quality. SARMIL 097 had good qualities in terms of head length (24.67 cm) and boldness of grain (10.67 g/1000 seed). SARMIL 002, SARMIL 005, SARMIL 009, SARMIL 016, all from Upper West Region and belonging to the medium maturing group, encompass traits like high and low downy mildew, long heads, good stover yield, thick and thin head types among others. Average thousand grain weight of 19 g for accessions from Ghana and Togo has been reported by Anand Kumar and Appa Rao, [20].

Table 3: Selected core pearl millet accessions by maturity groupings and regions of Ghana

Region	Maturity Group			Total Core Selected
	Early	Medium	Late	
Upper East	SARMIL 085, SARMIL 092, SARMIL 097, SARMIL 102, SARMIL 104, SARMIL 113	SARMIL 091, SARMIL 095, SARMIL 110, SARMIL 121, SARMIL 124	SARMIL 084	12 (27.27 %)
Upper West	Nil	SARMIL 002, SARMIL 005, SARMIL 009, SARMIL 016	SARMIL 024, SARMIL 026	6 (23.08 %)
Northern	SARMIL 077	SARMIL 044, SARMIL 053, SARMIL 070, SARMIL 082	SARMIL 036, SARMIL 050, SARMIL 054, SARMIL 060, SARMIL 064, SARMIL 069, SARMIL 074	12 (22.64 %)
Total	7 (29.17 %)	13 (24.07 %)	10 (22.22 %)	30 (24.39 %)

IV. Conclusion

The climate change effect as well as land use change has had a big impact on agricultural lands in the three regions of Northern Ghana over the years, leading to annual reduction in the total number of rainy months. All farmers in the studied area are using their traditional landraces as planting material year after year. No new variety had been introduced to the area in the last 40 years. Pearl millet remains paramount in the food security system of drought-prone and infertile areas of Northern Ghana where it is used as a stop-gap to the hunger periods of June to September each year.

Generally, the results did not show any pattern to suggest that certain agronomic traits are the preserve of a particular location or region of Ghana. Thus it is possible to use any accession at any location within the area. The fact that farmers in Northern and Upper West Regions are not growing the early-maturing millet types is purely based on farmers' interest or choice.

The agro-morphological results revealed a wide range of variation for most of the traits and thus can serve as a very good source of genetic variability and valuable genes for pearl millet breeding work in the country and for exchange.

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AUTHOR'S PROFILE

Mr. Peter Aanabire Asungre

graduated from the KNUST, Kumasi in 2014 with MSc. Agronomy (Plant Breeding). He has been working with the Savanna Agricultural Research Institute of Council for Scientific and Industrial Research (CSIR-SARI) since 1993. He is currently head of the Pearl millet breeding programme of the Institute at Manga, based in Upper East Region, Ghana.

Richard Akromah

is a Professor of Plant breeding and biotechnology. He is currently the Provost of the College of Agriculture and Natural Resources of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. He is also a member of the National Variety Release and RegistrationCommittee.

Dr. I. D. K. Atokple

is currently heading the GM Cowpea Research at CSIR-SARI. He had worked as the substantive Sorghum and Cowpea breeder of the Institute before assuming his current role.