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Preliminary Investigation on Some Agronomic and Morphological Variations of Within and Between Bambara Groundnut Landraces

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ABSTRACT

Bambara groundnut [*Vigna subterranea* (L.) Verdc.] is an indigenous legume crop in Africa. It has comparable value to other legumes for food and nutritional security in the continent. However, small-scale farmers continue cultivating unimproved landrace varieties over the production areas in sub-Saharan Africa. Bambara groundnut landraces exist as heterogeneous mixtures of seeds, which typically contain a few to several seed morpho-types that may embrace wide genetic diversity. In this study, the agro-morphological variations of 213 Bambara groundnut landraces were evaluated to determine the presence of within- and between-landraces of pod and seed morphology, out of which only 49 were used to access their genetic variability using 9 agronomic traits while 158 landraces were used to determine leaf morphology. Most of the landraces displayed pointed, round and yellowish pod colour, with grooved and oval seed shapes. For leaf morphology, 49.4% had round leaves, while 21.5% had elliptical leaves, with 55.7% landraces being heterogeneous possessing more than one leaf shape. Significant differences (P< 0.05) were detected for seed traits and leaf morphology including seed height, canopy spread and terminal width. Leaf morphology could be a useful marker for strategic breeding and genetic conservation of Bambara groundnut.

Keywords: Bambara groundnut, Genetic diversity, Landraces, Leaf morphology, Partially balanced design.

INTRODUCTION

Bambara groundnut [*Vigna subterranea* (L.) Verdc.; Syn: *Voandzeia subterranea* (L.) Thouars.] is an African grain legume widely grown in arid and semi-arid (Mwale *et al.,* 2007) where rainfall is scarse. Based on the most recent characterization data (Goli *et al.,* 1997), it was established that West Africa is believed to be the centre of diversity of the crop especially regions around Yola (Nigeria) and Garoua (Cameroun). Bambara groundnut is also grown in Sri-Lanka, Malaysia, Philippines, India and Brazil (Goli *et al.,* 1997; Mwale *et al.,* 2007). The crop is mainly grown by subsistence farmers under traditional agricultural systems, mostly for home consumption (Abu and Buah, 2011). Bambara groundnut is an under-utilized legume crop and grows as landrace varieties with unpredictable and low yields.

Bambara groundnut has multiple advantages comparable with that of other legumes such as cowpea, dry bean, and groundnut. The seed of Bambara groundnut is rich in protein and this complements the cereal based diets of most rural communities in Africa (Ntundu *et al.,* 2004; Olukolu *et*

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al., 2012). Chemical analyses of the seed revealed that about 32.7% of essential amino acids comprise of lysine, histidine, arginine, leucine and isoleucine, while 66.1-70.8% were non-essential amino acids including methionine, glycine, cysteine, tyrosine and proline (Minka and Bruneteau, 2000; Amarteifio *et al.,* 2010). In its fresh form, the seed is consumed as vegetable, while dry seed can be processed to flour to prepare various kinds of foods including Moi-Moi (a form of steamed-paste) in Nigeria (Okpuzor *et al.,* 2009). Dry seeds are also used as animal feed (Ntundu *et al.,* 2006).

The crop is tolerant to drought, adapts to severe environments and has the ability to produce some yield where other legumes may not grow well. It also suffers attack from few pests and diseases (Azam-Ali *et al.,* 2001; Sesay *et al.,* 2008). Bambara groundnut has the ability to fix atmospheric nitrogen into the soil through symbiotic activity with *Rhizobium* sp., which is highly beneficial when grown in rotation with cereal crops (Ncube and Twomlow, 2007; Hillocks *et al.,* 2012). Although yield of Bambara groundnut is unpredictable (Massawe *et al.,* 2002), the crop has the genetic potential to produce up to 3,000 kg ha^{-1} (Collinson *et al.,* 2000). Seed yield between 700 to 1,000 kg ha^{-1} has been reported in Ghana on famers' field (Abu and Buah, 2011), in which farmers were observed to plant mixed seeds (landraces) as an approach to at least make some harvest in times of weather uncertainty (Brink *et al.,* 2000). Despite its values Bambara groundnut has not received sufficient research attention. As a result there is no coordinated effort for agronomic improvement of the crop through breeding (Ntundu *et al.,* 2004). More research resources have been devoted to cereal crops such as maize, millet and sorghum, and to other legumes, especially groundnut, dry bean and cowpea (Drabo *et al.,* 1995). The lack of genetic variability and the absence of suitable ideotypes that are adapted to specific cropping systems are additional constraints limiting seed yields (Sprent *et al.,* 2010). Therefore, genetic enhancement and breeding is needed through the utilization of available germplasm.

Previous reports indicated the presence of within and between landrace variability (Massawe *et al.,* 2002; Massawe *et al.,* 2003) that can be exploited in breeding. Well-characterized germplasm is essential for strategic conservation and genetic enhancement through pre-breeding and breeding techniques. Bambara groundnut has varied regional names such as Jugo beans or *Indlubu* (South Africa), *Gurjiya* or *Kwaruru* in Hausa (Northern Nigeria) (http://en.wikipedia.org/wiki/*Vigna subterraneal*/) and in Swahili, it is known as *Njugumawe* (Hillocks *et al.,* 2012). Bambara groundnut landraces are usually named in relation to the site of their collection, such as the markets where they were purchased, or their seed coat colours, neither of which reflect their origin (Massawe *et al.,* 2002). Thus one landrace may be grown in several growing regions with many names. Thus far no improved varieties have been released following a well-designed breeding of the crop. Farmers typically practice a crude form of mass selection and retain their own seed from season to season, often with mixed seed morpho-types. Some distinguishable features of the landrace varieties grown by farmers include seed morphology, which may be round or oval in shape. These traits can be utilized to initiate selection and phenotypic evaluation through field characterization that would further be used for breeding and systematic conservation. Selection of desirable genotypes increases their use in breeding program to improve selection response on agro-morphological traits. The integration of under-utilized species such as Bambara groundnut landraces in the agro-biodiversity research and conservation would assist in mitigating climate changes and ensuing global food security (Jaenicke, 2011). For improved productivity of a crop species, genotypes possessing uniform growth and reproduction are selected, bred and released for large scale production (Rauf *et al.,* 2010). Characterization of Bambara groundnut landraces as a source of desirable genes is a primary step towards the conservation of biodiversity and for effective breeding (Ghalmi *et al.,* 2010).

In this study the agronomic variation of Bambara groundnut landraces were evaluated to determine the genetic variability present within- and between-landraces using 49 landraces, while pod and seed were evaluated for morphological traits using 213 landraces. In addition, 158 landraces were evaluated for leaf morphology alone. All the seeds were initially selected from a diversity of Bambara groundnut landraces using seed morphological features including seed coat colour and pattern, seed eye colour and pattern, and hilum colour and pattern.

MATERIALS AND METHODS

Study Site

The study was carried out in the field at the Ukulinga Research and Training Farm of the University of KwaZulu-Natal (UKZN), and in the controlled environment facility of UKZN Pietermaritzburg campus, South Africa. The experiments were conducted from October, 2011 to May, 2012. The field site is situated on a latitude 30^{o} 24' S, longitude 29^{o} 24' E, and 800 m above sea level (Information was provided by the University weather station).

Plant Material, Experimental Design, Field Management, and Data Collection

Forty nine genotypes of the Bambara groundnut landraces were used for the field experiment. The landraces were evaluated using a partially balanced lattice design with two replications (Table 1). The genotypes were randomized within seven incomplete blocks over the two replications. The experimental plot comprised of a single row measuring 2.2 m long, with inter- and intra-row spacing of 0.4m x 1.0m, respectively. This spacing was referred to be sufficient to allow the crop to express its potential in the field. Each row represents a plot, due to lack of sufficient seeds.

In addition, a total of 158 landraces whose seeds were small in number were grown in the field in a non-replicated trial using single rows for each landrace and were used for the assessment of leaf morphology. Ten plants were tagged for all and data collections. Sowing was done on flat bed, with one seed sown per stand. Missing stands were replaced within two weeks after sowing. All relevant agronomic practices were carried out to maintain a healthy crop. The entire selected landraces represent a 'Mini core collection' of landraces from six geographical zones of sub-Saharan Africa including one seed company (Table 1).

Data on quantitative agronomic and seed traits were collected. Data on the quantitative traits from the replicated trial were generated using ten tagged plants in each row within the seven incomplete blocks over the two replicates as well as from the non-replicated trial. Because of the within and between variations, few quantitative data were measured to allow single plant selection for further yield evaluation. The quantitative data include number of days to 1st Seedling Emergence (SEM) and number of days From Planting to 50% Seedling Emergence (FPEM). These were taken as number of days from sowing to seedling emergence. Other measurements were taken using a measuring ruler expressed in centimeter (cm), including Plant Height (PHT) as distance from the ground level to longest terminal leaf of the plant. Canopy Spread (CNS) was taken as the widest ends of the plant, while Terminal Leaf Length (TLL) and Terminal Leaf Width (TLW) were measured as the distance from the leaf tip to the point the leaf by the leaf blade ends on the leaf stalk and the widest ends across the leaf blade, respectively. Seed Length (SDL) (measured as the longest ends of the seed), Seed Width (SDW) (measured as the distance between the sides of the seed

Table 1. List of the Bambara groundnut landraces used for some agronomic and seed traits assessment and their origin used in the study.[a]

S/No.	Accessions	Origin	Entry status	S/No.	Accessions	Origin	Entry status
1	211-31	CAPS	2011 Entry	26	211-75	CAPS	2011 Entry
2	211-45	CAPS	2011 Entry	27	211-76	CAPS	2011 Entry
3	211-46	CAPS	2011 Entry	28	211-77	CAPS	2011 Entry
4	211-47	CAPS	2011 Entry	29	211-79	CAPS	2011 Entry
5	211-48	CAPS	2011 Entry	30	211-80	CAPS	2011 Entry
6	211-52	CAPS	2011 Entry	31	211-82	CAPS	2011 Entry
7	211-53	CAPS	2011 Entry	32	211-83	CAPS	2011 Entry
8	211-55	CAPS	2011 Entry	33	211-84	CAPS	2011 Entry
9	211-56	CAPS	2011 Entry	34	211-85	CAPS	2011 Entry
10	211-57	CAPS	2011 Entry	35	211-86	CAPS	2011 Entry
11	211-58	CAPS	2011 Entry	36	25-1	ZM	ZM 5425
12	211-59	CAPS	2011 Entry	37	32-1	ZM	ZM 3236
13	211-60	CAPS	2011 Entry	38	42-2	ZM	ZM 2042
14	211-61	CAPS	2011 Entry	39	89-1	ZM	ZM 5689
15	211-62	CAPS	2011 Entry	40	KB 08	ARC	KUBU 08
16	211-63	CAPS	2011 Entry	41	KN 211-6	KNG	2011 Entry
17	211-64	CAPS	2011 Entry	42	KN 211-7	KNG	2011 Entry
18	211-65	CAPS	2011 Entry	43	KN 211K	KNG	2011 Entry
19	211-66	CAPS	2011 Entry	44	M08-1	ZIM	ZIM 108
20	211-67	CAPS	2011 Entry	45	M09-3	ZIM	ZIM 109
21	211-68	CAPS	2011 Entry	46	SB 19-3-1	ARC	SB 19-3-1
22	211-69	CAPS	2011 Entry	47	TV-14	IITA (Ghana)	TVSu 1466
23	211-71	CAPS	2011 Entry	48	TV-39	IITA (Sudan)	TVSu 390
24	211-72	CAPS	2011 Entry	49	TV-93	IITA (Kenya)	TVSu 793
25	211-74	CAPS	2011 Entry				

[a] Legend on seed sources: CAPS= Capstone Seed Company, Howick, South Africa; ZIM= Department of Research and Specialist Services, Zimbabwe; ZAM= The National Plant Genetic Resources Centre, Zambia; ARC= Agricultural Research Council, Republic of South Africa; PMB= Farmer collection from Pietermaritzburg in South Africa; KNG= Farmers' collection from Kano, Nigeria; IITA= International Institute of Tropical Agriculture, Ibadan in Nigeria.

with the seed eye facing up), and Seed Height (SHT) (measured as the distance from the dorsal side to the point of seed eye of the seed) were determined using a Digital Vernier Calipers (cm) on ten randomly selected, but well developed and uniform seeds. SDL and SDW were measured as the height of the longest and the widest sides of the seed respectively, while SHT was taken as the height between the hilum and the dorsal end of the seed. Means and ranks were computed. The recorded qualitative data included pod shape and colour, seed shape, seed coat colour and presence and absence of a seed eye determined by visual assessment, and seed texture was determined visually and most frequently by hand feeling. Leaf morphology was evaluated through visual observation. All data recorded were according to descriptors for Bambara groundnut (IPGRI/IITA/BAMNET, 2000) with some modifications; and records were averaged.

Data Analysis

All the quantitative traits over the two replications were computed for all landraces over the seven incomplete blocks and subjected to Analysis Of Variance (ANOVA) based on the lattice procedure, using Agrobase (Agrobase, 2005) and the SAS statistical program (SAS, 2002).

Treatments' means were separated by the Least Significant Differences (LSD) at 5% probability. Descriptive statistics was employed to analyze qualitative data using percentages (%).

RESULTS AND DISCUSSION

There were significant (P< 0.05) variations in some of the agronomic traits including days to 1st seedling emergence, days to 50% seedling emergence and canopy spread, among the Bambara groundnut landraces (Table 2). Terminal leaf width were highly (P< 0.001) significant, and there was no significant variation for plant height and terminal leaf length. Among the three seed traits evaluated, seed length was (P< 0.01) significant, whereas seed height showed significance at *P*< 0.05, there was no variation among the genotypes. The extent of variations observed calls for plant selection that can further be evaluated for the confirmation of homogeneity. Also, significant (P< 0.05) differences were detected for all the aforementioned traits between the replicates, probably due to variations of heterogeneity in the soils of the experimental field.

Mean values for number of days after planting (DAP) to 1st and 50% seedlings emergence ranged from 9 to 13.5 for landraces KN 21-7 and 211-13, and 11 to 22 DAP for landraces 42-2 and 211-37, respectively (Table 3). This corroborates with reports of characterization of Bambara groundnut landrace in Burkina Faso (Ouedraogo *et al.,* 2008) who reported germination of 83.0% at 14 Days After Planting (DAP), while a range of 14 to 27 DAP and a mean of 21 DAP for 64.0% germination were reported by Abu and Buah (2011). The mean plant height ranged from 19.7 to 27.9 cm for landraces TV-14 and 211-86, while canopy spread was 28.4 to 52.0 cm for landraces 211-48 and 211-86, respectively. Canopy spread with a range of 22.0 to 47.0 cm was reported in Ghana (Abu and Buah, 2011). Mean terminal leaf length

Table 2. Summary statistics of mean square and significant differences of some agronomic and seed traits among 49 Bambara groundnut landraces tested using the partially unbalanced lattice design with seven incomplete blocks and two replications.

		SEM [a]		FPEM [b]		PHT [c]		CNS [d]		TLL [e]		TLW [f]	
Source of variation	*Df*	*MS*	*F*-value	*MS*	*F*-value	*MS*	*F*-value	*MS*	*F*-value	*MS*	*F*-value	*MS*	*F*-value
Replication	1	8.582	5.21*	32.0	6.96*	63.362	15.33*	415.955	17.87*	2.984	12.64*	0.444	8.04*
Genotype (Unadjusted)	48	2.125		8.751		5.926		43.969		0.342		0.217	
Block (Adjusted)	12	0.410		2.905		1.329		7.390		0.936		0.020	
RCBD (Residual)	48	1.957		5.021		4.835		27.242		0.276		0.064	
Genotype (Adjusted)	48	2.125	1.09*	8.751	1.74*	5.926	1.23 NS	43.969	1.61*	0.342	1.24 NS	0.217	3.39**
		SDL [g]		SDW [h]		SDH [i]							
Source of variation	*Df* [j]	*MS*	*F*-value	*MS*	*F*-value	*MS*	*F*-value						
Replication	1	2.880	7.23*	0.059	0.12 NS	1.569	6.64*						
Genotype (Unadjusted)	48	1.516		0.733		0.565							
Block (Adjusted)	12	0.120		0.106		0.064							
RCBD (Residual)	48	0.468		0.599		0.279							
Genotype (Adjusted)	48	1.516	3.24**	0.733	1.22 NS	0.565	2.02*						

[a] Days to 1st Seedling Emergence; [b] Days to 50% Seedling Emergence; [c] Plant Height; [d] Canopy Spread; [e] Terminal Leaf Length; [f] Terminal Leaf Width; [g] Seed Length; [h] Seed Width; [i] Seed Height; [j] Degree of Freedom; MS: Mean Square, NS: Not Significant. *Significant difference at the 0.05 probability level; **Significant difference at the 0.001 probability level.

Table 3. Mean response and ranks of some agronomic and seed traits among 49 Bambara groundnut landraces.

S/No.	Landraces	DTEM [a] Mean	DTEM [a] Rank	FPEM [b] Mean	FPEM [b] Rank	PHT [c] Mean	PHT [c] Rank	CNS [d] Mean	CNS [d] Rank	TLL [e] Mean	TLL [e] Rank	TLW [f] Mean	TLW [f] Rank	SDL [g] Mean	SDL [g] Rank	SDW [h] Mean	SDW [h] Rank	SDH [i] Mean	SDH [i] Rank
1	211-31	13.5	1	20.0	2	22.8	29	41.8	22	6.4	45	2.5	38	11.35	13	9.8	5	9.1	6
2	211-45	12.5	4	16.5	14	24.15	12	44.15	10	7.45	3	3.1	4	11.35	15	9.55	9	9.05	7
3	211-46	11.0	28	15.5	21	23.8	17	40.2	30	7.15	10	2.8	14	10.2	38	8.6	34	8.1	41
4	211-47	12.5	5	22.0	1	23.6	19	43.6	13	7.5	2	3.0	7	10.45	34	8.7	29	8.35	35
5	211-48	10.0	44	15.0	24	19.7	48	28.4	49	6.65	30	2.7	17	10.6	31	8.5	41	8.4	33
6	211-52	11.0	26	15.0	27	23.55	20	36.8	44	7.05	14	2.6	33	11.6	7	8.65	30	8.65	21
7	211-53	9.0	48	12.0	48	23.9	14	47.35	6	7.35	4	2.25	45	11.4	12	9.05	21	9.05	8
8	211-55	10.0	45	16.5	10	22.7	33	42.55	19	6.95	18	2.35	40	10.5	32	8.5	39	8.1	40
9	211-56	11.0	22	13.5	38	22.4	35	41.2	24	6.55	41	2.55	37	11.55	8	9.75	6	9.55	2
10	211-57	11.5	19	14.5	30	24.15	11	43.6	12	7.1	12	2.65	30	9.7	45	8.85	26	8.4	29
11	211-58	9.5	47	13.5	37	21.9	37	39.9	34	6.6	38	2.6	32	11.35	14	8.9	24	8.65	20
12	211-59	10.5	30	15.5	20	25.15	6	43.15	14	6.75	26	3.25	2	10.5	33	8.55	35	8.0	42
13	211-60	10.5	31	15.0	23	25.7	3	41.8	21	7.25	7	2.9	8	10.15	40	7.95	45	8.25	36
14	211-61	10.5	33	13.5	39	20.6	47	42.6	18	6.7	29	2.7	19	10.7	27	8.1	44	8.95	12
15	211-62	11.0	23	14.5	28	23.25	24	39.0	37	6.75	28	2.7	18	10.75	25	8.95	22	8.75	15
16	211-63	10.5	37	13.5	41	23.2	26	40.0	32	6.55	39	2.9	9	11.7	5	9.2	16	8.95	10
17	211-64	10.0	39	13.5	42	20.65	46	38.7	39	6.6	37	2.7	24	10.9	22	9.15	18	8.7	18
18	211-65	10.0	43	16.5	12	21.3	44	42.9	17	6.3	46	2.15	46	10.3	37	8.7	28	8.5	27
19	211-66	11.0	24	16.0	16	23.95	13	49.45	3	6.9	19	2.8	15	12.05	4	9.45	11	8.95	9
20	211-67	12.0	9	15.5	19	23.4	21	40.0	33	6.6	35	2.35	39	9.6	46	9.1	19	7.65	46
21	211-68	12.0	12	13.5	43	22.75	30	36.65	45	6.6	36	2.3	42	10.65	29	8.5	37	8.15	37
22	211-69	11.5	15	15.0	22	23.3	23	38.3	41	6.65	32	2.6	36	10.15	39	8.5	40	7.9	43
23	211-71	12.0	10	13.0	46	27.4	2	48.75	5	6.6	34	2.35	41	10.05	42	8.55	36	8.15	38
24	211-72	10.5	36	16.5	13	21.45	43	41.8	20	7.8	1	1.9	47	10.6	30	9.15	17	8.4	31
25	211-74	11.0	25	14.0	35	22.1	36	40.9	26	6.8	25	2.85	11	10.8	24	9.25	15	8.4	30
26	211-75	10.0	42	13.5	40	24.6	9	42.95	16	7.25	8	3.35	1	11.45	11	8.6	32	8.7	17
27	211-76	10.0	40	15.0	25	24.8	8	40.9	27	6.85	24	2.85	10	9.75	44	7.85	48	7.65	47
29	211-79	10.5	32	16.0	15	23.25	25	46.5	7	5.3	49	3.05	6	10.95	20	9.8	4	8.5	28
30	211-80	11.0	21	15.5	18	23.3	22	43.8	11	6.85	23	2.7	23	11.25	16	8.85	25	8.85	14
31	211-82	10.5	34	18.5	4	22.75	32	41.2	25	6.75	27	2.65	31	10.65	28	8.5	38	8.4	32
32	211-83	12.5	6	14.0	33	23.1	27	39.8	35	6.9	21	2.75	16	9.6	47	7.9	47	7.8	44
33	211-84	11.5	18	17.0	9	23.1	28	40.6	29	6.9	22	2.65	29	11.5	9	9.35	12	8.95	11
34	211-85	10.0	46	17.0	8	23.8	18	44.2	9	7.0	17	2.85	13	10.7	26	9.25	14	8.6	24
35	211-86	11.0	29	14.5	29	27.9	1	52.0	1	7.1	11	1.8	49	8.9	48	7.55	49	7.45	48
36	25-1	12.5	7	17.5	6	24.2	10	50.3	2	6.5	42	2.7	27	11.5	10	8.8	27	8.75	16
37	32-1	11.0	20	18.0	5	23.9	15	49.25	4	7.3	6	3.15	3	11.15	18	9.35	13	8.65	23
38	42-2	10.0	41	11.0	49	25.5	4	38.7	38	6.5	43	2.6	35	10.95	21	9.95	2	8.85	13

[a] Days to 1[st] Seedling Emergence; [b] Days to 50% Seedling Emergence; [c] Plant Height; [d] Canopy Spread; [e] Terminal Leaf Length; [f] Terminal Leaf Width; [g] Seed Length; [h] Seed Width; [i] Seed Height.

Table3 continued….

Continued. of Table 3.

S/No.	Landraces	DTEM [a] Mean	DTEM [a] Rank	FPEM [b] Mean	FPEM [b] Rank	PHT [c] Mean	PHT [c] Rank	CNS [d] Mean	CNS [d] Rank	TLL [e] Mean	TLL [e] Rank	TLW [f] Mean	TLW [f] Rank	SDL [g] Mean	SDL [g] Rank	SDW [h] Mean	SDW [h] Rank	SDH [i] Mean	SDH [i] Rank
39	89-1	11.5	17	14.0	34	21.55	42	44.65	8	6.45	44	2.85	12	11.25	17	10.1	1	9.15	5
29	211-79	10.5	32	16.0	15	23.25	25	46.5	7	5.3	49	3.05	6	10.95	20	9.8	4	8.5	28
40	KB 08	13.0	2	17.0	7	20.65	45	43.15	15	7.05	13	2.7	25	8.6	49	8.1	43	7.35	49
41	KN 211-6	12.0	8	15.0	26	21.65	39	31.25	47	6.3	47	2.3	43	9.8	43	8.4	42	8.1	39
42	KN 211-7	9.0	49	13.0	44	23.8	16	40.0	31	7.0	16	1.8	48	10.4	35	9.05	20	8.5	26
43	KN 211K	12.0	11	14.5	32	21.55	41	30.05	48	6.65	31	2.7	22	11.7	6	9.6	8	9.2	4
44	M08-1	11.5	14	14.0	36	22.75	31	37.6	43	6.65	33	2.65	28	10.85	23	8.9	23	8.65	22
45	M09-3	10.5	35	14.5	31	21.85	38	38.3	40	6.9	20	2.7	26	10.1	41	7.95	46	7.7	45
46	SB 19-3-1	13.0	3	15.5	17	22.45	34	41.55	23	7.25	9	2.6	34	10.4	36	8.65	31	8.35	34
47	TV-14	11.0	27	13.0	45	19.65	49	35.15	46	6.05	48	2.3	44	11.0	19	8.6	33	8.55	25
48	TV-39	10.5	38	12.5	47	25.05	7	38.2	42	7.3	5	2.7	20	12.6	2	9.5	10	9.3	3
49	TV-93	12.0	13	19.5	3	25.4	5	39.3	36	6.55	40	3.05	5	13.1	1	9.85	3	9.95	1
	Mean	11.07		15.22		23.16		41.30		6.82		2.65		10.80		8.90		8.52	
	R^2 (%)	54.1		65.2		60.0		65.9		59.4		77.9		77.1		55.1		68.2	
	CV (%)	12.6		14.7		9.5		12.6		7.7		9.6		6.3		8.7		6.2	
	LDS (0.05)	2.35		3.76		3.69		8.75		0.88		0.42		1.15		1.30		0.89	

[a] Days to 1st Seedling Emergence; [b] Days to 50% Seedling Emergence; [c] Plant Height; [d] Canopy Spread; [e] Terminal Leaf Length; [f] Terminal Leaf Width; [g] Seed Length; [h] Seed Width; [i] Seed Height.

measured from 5.3 to 7.8 cm for landraces 211-79 and 211-72, while mean terminal leaf width was 1.8 to 3.35 cm for landraces 211-86 and 211-75, respectively. Seed length was measured at 8.6 to 13.1 mm for landraces KB 08 and TV-39, respectively while 7.6 to 10.1 mm was observed for landraces 211-86 and 89-1, respectively. Mean seed height ranged from 7.4 to 10.0 mm for landraces KB 08 and TV-93, respectively. Significant ($P< 0.05$) differences have been reported for some quantitative agronomic and seed traits, such as plant spread, plant height, seed length and seed width (Ntundu *et al.,* 2006). Shegro *et al*. (2013) opined that cultivar and environment influence morphological dimensions among Bambara groundnut landraces.

Table 4 showed the descriptive statistics of pod and seed morphology (shape) among 213 landraces, and that of leaf morphology among 158 Bambara groundnut landraces. There is scant information describing pod and seed morphology in Bambara groundnut landraces. In this study, 102 landraces with pointed and round pod shape were distinguished representing 47.9% as the highest, while 35 (16.4%) of the landraces had point and nook shape as the least, respectively (Table 4 and Figure 1). According to IPGRI/IITA/BAMNET (2000) none of the landraces which were studied and observed had pods without a point. Only four kinds of pod colour were observed among the 213 landraces (Figure 2). A total of 162 (76.1%) of the landraces were yellowish in colour being the highest, and only 10 (4.7%) of the landraces had reddish brown pod colour. Within the four descriptors for pod texture, 154 (72.3%) of the landraces had little grooved texture and < 1% of the landraces were more folded textured (Figure 3). Between the two descriptors used to describe seed shape, 169 of the landraces had oval shape and 44 were round, representing 79.3 and 21.7%, respectively. Description for the absence and presence of "seed eye" (Table 4 and Figure

Table 4. Pod and seed morphological traits among selected Bambara groundnut landraces and corresponding number and percentage of landraces.[a]

Traits	Description		Number of landraces bearing the trait	% Number of landraces bearing the respective trait
Pod shape	1.	Without point	0	0.0
	2.	Point + Round	102	47.9
	3.	Point + Nook	35	16.4
	4.	Point + Point	76	35.7
Pod colour	1.	Yellowish	162	76.1
	2.	Brown	28	13.2
	3.	Reddish brown	10	4.7
	4.	Purple	13	6.1
Pod texture	1.	Smooth	42	19.7
	2.	Little grooves	154	72.3
	3.	Much grooves	16	7.5
	4.	Much folded	1	0.5
Seed shape	1.	Round	44	20.7
	2.	Oval	169	79.3
Seed eye	1.	No eye	126	59.2
	2.	Present	87	40.9
Seed coat colour	1.	Black	11	5.2
	2.	Black/Purple	1	0.5
	3.	Brown	33	15.5
	4.	Brown speckle	5	2.5
	5.	Brown with spots	1	0.5
	6.	Cream	79	37.1
	7.	Cream with black stripe	1	0.5
	8.	Cream *RBF*[b] eye	2	0.9
	9.	Cream stripe	1	0.5
	Cream variegated		1	0.5
	Cream/Purple		1	0.5
	D/Brown		14	6.6
	D/Brown speckle		10	4.7
	14.	D/Brown with spots	1	0.5
	15.	L/Brown	33	15.5
	16.	L/Brown speckle	4	1.9
	17.	L/Brown with spots	1	0.5
	18.	Red	9	4.2
	19.	Tan	5	2.4
Terminal leaf shape[a]	1.	Round	78	49.4
	2.	Oval	24	15.2
	3.	Elliptic	34	21.5
	4.	Lanceolate	22	13.9

[a] Assessed among 158 landrace, [b] Red Butterfly (Figure 2-B).

4), showed about 59% had no seed eye and 41% had seed eye present.

Fifteen descriptors were employed to describe the various types of seed coat colour displayed by the Bambara groundnut landraces. Out of the 213 landraces studied, cream seed coat colour was dominated with 79 landraces, representing 37.1%. This was followed by brown and light brown seed coat colours with 33 landraces, representing 15.5% each. The least common seed coat colours were < 1%, displayed by only one landrace. Conversely, 158 landraces were used to define leaf morphology using four descriptors (Table 4 and Figure 5) wherein 78 landraces had

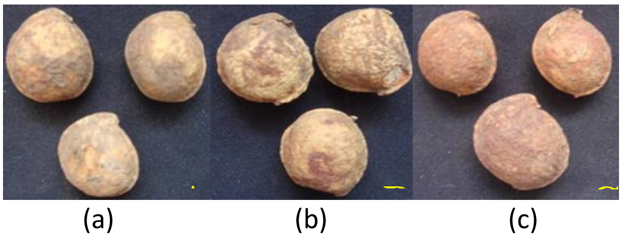

Figure 1. Bambara groundnut landraces assorted by pod shape: (a) Point+Round (M12-1)(Landrace name); (b) Point+Nook (211-34), and (c) Point+Point (TV 97-2).

Figure 2. Bambara groundnut landraces assorted by dry pod colour: (a) Yellowish (211-37) (Landrace name); (b) Purple (25-1); (c) Brown (011-28), and (d) Reddish brown (43-2).

Figure 3. Bambara groundnut landraces assorted by dry pod texture: (a) Smooth (211-68) (Landrace name); (b) Little grooves (M09-3); (c) Much grooves (N211-12), and (d) Much folded (N211-1).

Figure 4. Description of the presence and absence of eye and its pattern on the seeds of some Bambara groundnut landraces: (a) Cream with black-broad eye (211-45) (Landrace name); (b) Cream with red-butterfly eye (211-75); (c) Cream with black thin eye (TV-96); (d) Red with plain eye (M 08-3); (e) Light-brown with black spots and plain eye (211-84), and (f) Dark-brown with plain eye (211-86).

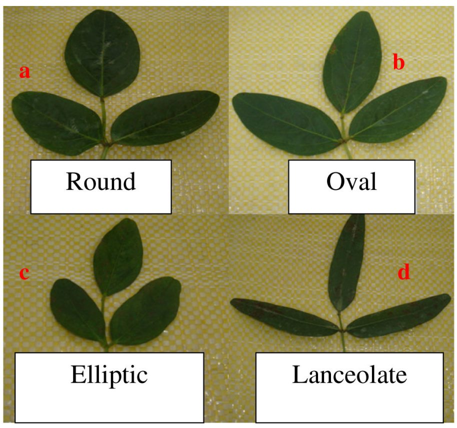

Figure 5. Description of leaf morphology of some Bambara groundnut landraces: (a) Round (211-55) (Landrace name); (b) Oval (211-68); (c) Elliptic (M09-3), and (d) Lanceolate (211-49).

a round leaf shape (49.4%); elliptic leaves were observed among 34 landraces (21.5%). Twenty four accessions showed oval leaves shape (15.0%); and 22 landraces had lanceolate shapes (14%). The findings in this study suffice it for Plant Breeders to use these landraces directly in scientific breeding projects of Bambara groundnut for its genetic enhancement especially for yield improvement and resistance or tolerance.

CONCLUSIONS

The findings in this study established the presence of sufficient within- and between-variations for some agronomic and morphological traits among the Bambara groundnut landraces studied for scientific breeding to be undertaken. This owes to the existence of several morpho-types within the landraces. The need remains for systematic selection of desirable agronomic traits such as maturity, pod and seed yields, seed quality and drought tolerance as well pests and diseases resistance and their use in breeding of the Bambara groundnut to boost its production and productivity.

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بررسی مقدماتی روی برخی تغییرات زراعی و مورفولوژیک درون و بین نژادهای بومی بادام زمینی بامبارا

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چکیده

بادام زمینی Bambara (*Vigna subterranea* [L.] Verdc.) یکی از حبوبات بومی آفریقا می باشد. این گیاه به لحاظ غذایی و امنیت تغذیه ارزش قابل ملاحظه ای در برابر سایر حبوبات در این قاره دارد. با این حال ، کشاورزان خرد هنوز به کشت واریته های اصلاح نشده ی بادام زمینی در مناطق جنوب صحرای آفریقا ادامه می دهند. گونه های بومی بادام زمینی Bambara مخلوط ناهمگنی از بذرها می باشند که عموما شامل کمی تا تعداد زیادی از گونه های متفاوت مورفولوژیکی بذرها با تنوع ژنتیکی گسترده هستند. در این پژوهش ۲۱۳ گونه بومی بادام زمینی برای تعیین وجود تفاوت های زراعی-مورفولوژیکی درونی یا بین گونه ای غلاف و بذر مورد مطالعه قرار گرفتند که تنوع ژنتیکی ۴۹ گونه ازآنها توسط بررسی ۹ مشخصه ی زراعی و ۱۵۸ گونه ی دیگر از طریق تعیین مورفولوژی برگ بررسی شدند. غلاف اکثر گونه ها به شکل گرد و زرد رنگ و خال دار بوده و بذر آنها بیضی شکل و شیاردار بود. در مورد مورفولوژی برگ ها ، ۴۹/۴ ٪ برگ های گرد و ۲۱/۵ ٪ برگ های بیضوی و همچنین ۵۵/۷ ٪ گونه های ناهمگن بیش از یک شکل برگ داشتند.تفاوت های معنی داری ($P<0.05$) در مشخصات بذر و مورفولوژی برگ ها مانند طول بذر، پهنای تاج (canopy) و عرض ترمینال (terminal) مشاهد شدند. مورفولوژی برگ می تواند یک نشانگر مفید برای پرورش استراتژیک و حفاظت ژنتیکی بادام زمینی بامبارا می باشد.