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Characterization of Bambara Groundnut Landraces and Their Evaluation by Farmers in the Upper West Region of Ghana

Huudu Bampuori Abu[1]* and Samuel Saaka Jeduah Buah[2]

[1] Regional Agricultural Development Unit, Ministry of Food and Agriculture (MOFA), P.O. Box 21, Wa, Ghana

[2] Savanna Agricultural Research Institute (SARI), Wa Station, P.O. Box 494, Wa, Ghana

The Bambara groundnut (*Vigna subterranea* [L.] Verdc.) has a large number of landraces throughout Africa, where small-scale farmers have preserved its genetic diversity on their farms. In 2004, we surveyed farmers in the Upper West Region of Ghana to determine their strategies for managing crops and for maintaining varieties of neglected Bambara groundnut landraces. We collected 22 landraces from the region, and conducted field experiments in 2005 and 2006 to evaluate their phenotypic variability with respect to agronomic and morphological traits. Important characters correlated with grain yield that could be used for selection and improvement of Bambara groundnut varieties were the 100-seed weight (the most important character influencing grain yield; $r=0.95$) and shelling percentage ($r=0.86$). There were negative correlations between grain yield and canopy spread ($r=-0.62$) and between grain yield and days to maturity ($r=-0.37$), providing evidence that spreading landraces have a longer vegetative phase, take longer to mature, and therefore suffer declines in yield due to the low soil moisture levels in the savannah zone. Late flowering also has a detrimental effect on seed yield of the Bambara groundnut in the savannah zone ($r=-0.39$). Landraces have local names based on their maturity period, growth habit, and seed coat colour or on their use. Some of the neglected landraces are common to more than one ethnic group. Local farmers largely prefer fast-cooking, early varieties of Bambara groundnut with large, cream-coloured seeds. Further improvement of Bambara groundnut must take these selection criteria and farmer preferences into account.

Key words: *Vigna subterranea,* landrace, variability, agro-biodiversity, farmer preference

Introduction

The Bambara groundnut (*Vigna subterranea* [L.] Verdc.), an indigenous African legume, plays an important socio-economic role in the semi-arid regions of Africa. The edible seeds are a rich source of protein and, along with other local sources of protein, help enhance the nutritional status of farm families in the region. It is the third most important pulse, after peanut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*), grown by farmers on smallholdings in Ghana. *Vigna subterranea* is a drought-tolerant crop that can be grown in marginal, low-input environments. Although the crop produces a nutritious food and is cultivated throughout Africa, it remains largely neglected by the scientific community. Nevertheless, empirical evidence and fragmentary research results suggest that it is a crop with great potential.

Vigna subterranea is grown by subsistence farmers in Africa under traditional low-input agricultural systems mainly for home consumption. However, recent events have seen an increase in its importance and a shift in status from a subsistence crop to a cash crop. In previous studies, simple correlation analysis indicated that the number of leaves, pods, and stems per plant, shelling percentage, shell thickness, and 100-seed weight are all correlated

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* Corresponding author: Regional Agricultural Development Unit, Ministry of Food and Agriculture (MOFA), P.O. Box 21, Wa, Ghana.

E-mail: abuhuudu@yahoo.com

with grain yield, and these characters have been used by plant breeders to select for grain yield (Karikari, 1972; Tanimu and Aliyu, 1990; Goli *et al.,* 1997; Ouedraogo *et al.,* 2008). To help ensure acceptance and eventual adoption of improved crop varieties by low-resource farmers, farmer participation in the breeding Process is necessary (Mekbib, 2006; Gyawali *et al.,* 2007).

Most farmers in Ghana grow landraces of Bambara groundnut; therefore yields, usually under low-input farming systems, are low and unpredictable. The low yields have been associated with poor germination percentage and variable germination rates, which often lead to poor crop establishment (Linnemann and Azam-Ali, 1993). Nonetheless, there is also evidence that the crop can produce high yields (up to 3 t/ha), suggesting that there is high yield potential that can be exploited in breeding programmes. In Ghana, grain yields of 714 to 1100 kg/ha have been reported for local landraces (Karikari and Lavoe, 1977). Baudoin and Mergeai (2001) also reported that the average yield of dry seeds ranges between 300 and 800 kg/ha in traditional farming compared to 3000 kg/ha for commercial farming. This is comparable to the yields of 300 kg/ha reported for landraces in Tanzania (Collinson *et al.,* 2000). Farmers grow several local landraces differing in size, hardiness, leaf shape, and seed coat colour. Some indigenous landraces which were once widely cultivated are now grown only in some restricted areas. Landraces currently abandoned by farmers were once more popular and are today neglected for a variety of agronomic, economic, social, and cultural factors.

The Northern Savannah Biodiversity Conservation Project (NSBCP), realizing the significance of conserving agricultural biodiversity and its importance in ensuring food security and developing a sustainable agriculture, initiated a programme with subsistence farmers in northern Ghana in the early 2000s to create awareness about the rapid loss of useful local Bambara groundnut landraces and the concept of conservation of agricultural biodiversity.

The objective of this study was to document available indigenous knowledge on Bambara groundnut landraces that had previously been used by the local people but that are gradually being neglected. The study also aimed to investigate farmers' existing production practices, perceptions of neglected landraces, and preferences and criteria for their selection of landraces to meet different needs. The study also determined the variability between the neglected landraces and determined correlations between yield and agronomic traits to aid breeders in utilizing these traits in breeding programmes.

Materials and methods

Study area

Bambara groundnut is widely grown in northern Ghana, which comprises the Northern, Upper West, and Upper East administrative regions. Northern Ghana occupies about 40% of the total area of Ghana (239,000 km^2). The Upper West Region where this study was conducted covers an area of 18,480 km^2 representing about 8% of the total land area of Ghana and is located in the north-western corner of Ghana stretching from 9°35′N to 11° 00′N and from 01°25′E to 02°50′E (Fig. 1). The region falls within the Guinea savannah vegetation zone with Sudan savannah characteristics towards the extreme north-western fringes. Temperatures are generally high, between 26℃ and 30℃, with little variation throughout the year. It experiences distinct dry and wet seasons; the characteristic unimodal rainfall pattern starts in April or May and ends in September or October and ranges from 900 to 1100 mm. The topography is generally flat with elevations varying from 200 m above sea level along the Black Volta River to 350 m above sea level along the ridge that stretches from Wa in the south to the Burkina Faso border in the north. Soils in the study area vary from shallow sandy loams having medium to course quartz stones and ironpan boulders on the surface (Dystric Leptosol) to deep, poorly drained alluvial clays (Vertic Cambisol) in valley bottoms. The texture of the soils is mainly loamy sand and sandy loam.

Inventory survey and observation nursery

The study was carried out in two phases. In Phase 1, surveys on neglected landraces were conducted in 2004 in the Upper West Region of Ghana, using focused group discussions, matrix ranking, and individual interviews. Different participatory rural appraisal tools were used as was deemed appropriate. The communities within the district were selected on the basis of the importance of Bambara groundnut and for their range of agro-

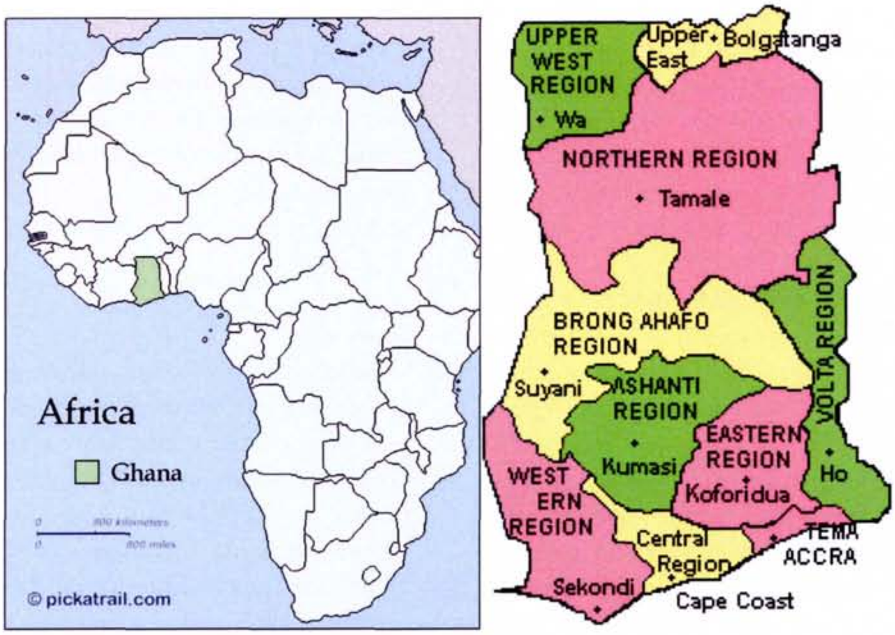

Fig. 1. Map of Africa showing Ghana and its administrative regions.

ecological and socio-economic conditions, and ethnic and cultural multiplicity. Additionally, the research team was guided by some prior knowledge of the distribution and importance of Bambara groundnut diversity in those communities.

We randomly selected 120 farmers from a compilation of farmers in the region who were believed to possess the most indigenous knowledge about the Bambara groundnut. We were helped in this respect by agricultural extension workers and village chiefs who were more familiar with the farmers in the various communities. The farmer sample consisted of 97% men and 3% women, ranging in age from 35 to 82 years. The mean age of farmers who were still growing the neglected landraces on less than 0.4 ha per variety was 60 years. Information about the landraces that had previously been used by the local people but which were gradually being neglected was collected randomly through individual, household, and group interviews, with some of the interviews being conducted in the field. In addition, information on the source of varieties, the names and their meanings, and current status and any possible threats was obtained from the farmers. Where possible, small samples of seed of the neglected landraces were obtained from farmers in areas where they were still grown.

A total of 22 landraces that are gradually being neglected in the region were chosen by these 120 farmers on the basis of seed coat colour, seed yield, seed size, seed shape, maturity dates, growth habit, or known history of pest resistance. Table 1 gives a full list of Bambara groundnut landraces chosen by farmers in the region together with the corresponding seed coat colours. Seeds of these 22 neglected landraces were obtained from farmers in the region after harvesting in March 2004. Collection was based on names given by farmers and not on any biochemical, genetic, or molecular analyses. Characterization was done using standard descriptors for Bambara groundnut (IPGRI/IITA/BAMNET, 2000). The landraces were sown for seed multiplication and preliminary grain yield evaluation. These attributes together with consumer preferences and special interests were used (in Phase 2) to select candidate landraces for further field studies. Through farmer networks, local farmers who still had seed of the neglected landraces were encouraged and supported financially by the NSBCP to continue *in situ* conservation of the endangered indigenous cultivars. The farmers multiplied the seed of the indigenous landraces and provided seed for local communities.

In Phase 2, participatory variety selection was applied to select diversified Bambara groundnut landraces that possessed farmer-preferred plant and

Table 1. Bambara groundnut landraces used in the 2005 and 2006 field study at Poyentanga, Upper West Region, Ghana

Entry No.	Local Name	Seed coat colour	Community	District
1	*Bagkaragiyile*	Cream	Ko	Lawra
2	*Bankabile*	Mottled	Kumassal	Lawra
3	*Bankarubile*	Mottled	Sagu	Wa
4	*Dapialikamu*	Black	Tanchara	Lawra
5	*Kontonsibii*	Cream	Bujan	Sissala East
6	*Mouli*	Red	Nimoro	Sissala East
7	*Siigbilkpanchuore*	Mottled	Lawra	Lawra
8	*Siigbilpulale*	Cream	Wa	Wa
9	*Siigbilzie*	Red	Jang	Nadowli
10	*Siimikorigyele*	Mottled	Lawra	Lawra
11	*Siimisogla*	Black	Billaw	Jirapa/Lambussie
12	*Simbikpong*	Cream	Jonga	Wa
13	*Simbinagtiri*	Cream	Gudayiri	Wa
14	*Simitakara*	Light red	Lawra	Lawra
15	*Simmie*	Cream	Pulima	Sissala West
16	*Simpulun*	Cream	Karni	Jirapa/Lambussie
17	*Singblikali*	Mottled	Tanchara	Lawra
18	*Sinkalisiwea*	Cream	Pulima	Sissala West
19	*Sinkon*	Cream	Taffiasi	Sissala East
20	*Sinkongo*	Light red	Pulima	Sissala West
21	*Sinkpone*	Cream	Tampala	Lawra
22	*Sumbibile*	Cream	Kumassal	Lawra

grain traits. The 22 landraces selected by farmers in Phase 1 were sown during the 2005 and 2006 cropping seasons in a nursery established in the NSBCP garden at Poyentanga near Wa (10°04′N, 02°30′W; 323 m above sea level). Land preparation involved uniform cultivation to make a fine seed bed. The experimental design was a randomized complete block replicated three times in which the Bambara groundnut landraces were assigned at random to the plots. Individual plot sizes were 1.5 ×6 m with a 0.5 m border in-between each experimental plot. Two seeds were sown per stand at a spacing of 0.30 m between rows and an interplant spacing of 0.30 m. Seedlings were thinned to one per stand 7 days after emergence. Planting was done on 10 July 2005 and 17 July 2006. No insecticide or mineral fertilizer was applied. The field was kept weed-free by hand hoeing throughout the period of the experiment.

Parameters measured were days from sowing to emergence and to 50% flowering (when half of the plants in a plot were flowering), canopy spread at pod initiation, 100-seed weight, shelling percentage (calculated as a ratio of dry weight of hulled seed to total unshelled pod dry weight multiplied by 100), grain yield, and days from sowing to physiological maturity. Data of the quantitative characters for the two seasons were combined after Bartlett's test (Sokal and Rohlf, 1969) showed homogeneity of error variances and were analyzed using the SAS Statistical Analysis Software for Windows ver. 9.1 (SAS Institute Inc., Cary, NC, USA). Where significant differences were found among the landraces for a particular parameter, mean separation was done using Fisher's LSD values (Steel and Torrie, 1986). A correlation matrix of agronomic characteristics and grain yield was also established. Descriptive statistics were also used to summarize data collected by farmers.

The performance of the landraces in the nursery was assessed both visually and quantitatively by a group of farmers including the NSBCP-supported farmers. The farmers assessed and made their own selection of desired lines at a field day held when the plants reached physiological maturity. Farmers were invited to see the landraces and to "vote" for the ones they liked. The farmers walked through the trial and recorded the numbers of all of the plots containing the landraces they liked. Farmers were also asked to give their quality criteria for a maximum of 10 varieties, through pair-wise comparisons of landraces, explaining which criteria contributed to their preference for a given landrace. The pair-wise comparison enabled us to obtain farmers' criteria for their preferences. These preference criteria reflected farmers' priorities with regard to objectives of production, crop management, processing, consumption, and marketing. Organoleptic qualities such as taste and cooking time of the landraces were obtained from farmers who grew and utilized the landraces. At various stages of plant growth during each cropping season, field visits were made to fields of the farmers who were supported financially by NSBCP to continue *in situ* conservation of the landraces. These visits allowed us to observe farmers' production practices as well as the growth and development of the landraces under typical farming conditions.

Results and Discussion

Genetic diversity in Bambara groundnut landraces

Landraces still dominate the area under Bambara groundnut production in Ghana, which is an indication that there has been very little attempt at Bambara groundnut improvement in Ghana over the years. Many of the landraces maintained and used by smallholding farmers meet several different needs and represent a valuable resource for them. The landraces have adapted to hostile environments and are popular among farmers for their stability of yields under different environmental conditions. Nevertheless, some of them are steadily being neglected in the region.

Some of the endangered landraces collected in the region are common to more than one ethnic group. In general, the landraces collected have names based on their maturity period, growth habit, seed coat colour, or use. Such informal methods of classification may lead to a single landrace having more than one name as a consequence of seed introductions to or from other places or the undocumented historical movement of people and their crops across locations. Thus, there may be duplications within the 22 landraces collected. In general, names of landraces like *Siimisogla* (black Bambara groundnut) and *Siigbilzie* (red Bambara groundnut) describe the seed coat colour. *Sumbibile* describes an early-maturing landrace with small seed size, whereas *Simbikpong* describes a late-maturing landrace. Moreover, it was evident that farmers sometimes used collective names for landraces. For example *Simbinagtiri* is used to describe any landrace with a spreading/trailing growth habit. Additionally, the high variation in seed coat colour (Fig. 2) that exists in the collection is probably a result of human selection. The variation available within landraces is of great value to a breeding programme for stressful environments and low-input farming systems.

Farmers maintain diversity at one or more levels by planting a mixture of seeds of different landraces together in the same plot. The practice of sowing mixtures of seeds is a strategy farmers use to secure crop production where rainfall is low, soil is poor, and crop production is difficult to control (Brink *et al.,* 2000). However, the predominant seed coat colour of Bambara groundnut landraces identified in the region is cream; and landraces with this seed coat colour are popular because of their suitability for marketability and preference for home consumption. Cream-seeded landraces tend to produce seed with homogeneous attributes, and at the time of sowing and harvest, farmers avoid mixing seeds which possess a cream seed coat colour with those

Fig. 2. Seed morphological variability in Bambara groundnut germplasm.

Table 2. Main reasons cited for growing local Bambara groundnut varieties

Reason for growing Bambara groundnut	Frequency ($n=120$)	Percent
Mainly for food	98	82
Mainly for cash	5	4
For both food and cash	17	14

Source: Field survey data, January 2004.

of other seed coat colours. The agronomic characterization of the landraces evaluated indicates that there are significant differences with regard to morphological, physiological, and agronomic traits. Also days to maturity, 100-seed weight, shelling percentage, canopy spread, and grain yield are among the important traits that vary significantly among the landraces.

Main purpose of Bambara groundnut cultivation

Bambara groundnuts are grown for their edible seeds which are used as a nutritious pulse. The seeds are eaten fresh in the unripe state or, because the dried seeds are very hard, as a pulse after soaking and boiling. The dried seeds are sometimes roasted and ground into flour. The majority of farmers mentioned that Bambara groundnut seeds require a long cooking time. Data from the survey showed that Bambara groundnuts are sown either in mixed cultivation with other crops or in pure stands. Pure stand Bambara groundnut is by far the most frequent cropping pattern practiced by more than 50% of Bambara groundnut farmers in the survey area. The present farming practices are based on indigenous knowledge passed down from generation to generation, and these practices along with the seed are gradually disappearing. The crop is cultivated primarily for home consumption, with excess quantities sold in local markets. A total of 98 (82%) of farmers indicated that they cultivate these landraces on a small scale for home consumption only, and about 4% cultivate them for the market only (Table 2). A total of 17 (14%) of farmers produce the landraces mainly for household subsistence but sell relatively small quantities as a last resort in times of dire need.

Maintenance of biodiversity

In the survey, the majority of Bambara groundnut farmers in the region were no longer cultivating the neglected landraces on a large scale. The crop has become less important in many parts of the region because of the expansion of cowpea and peanut production. The latter crops are supported by seed supply systems, production and post-harvest technologies, and agricultural extension services. The indications are that indigenous Bambara groundnut genetic material is being eroded. Measures must therefore be taken to conserve existing landraces.

Table 3. Main reasons cited for loss of indigenous Bambara groundnut varieties

Reasons for loss	Percent (%)
Low productivity	58
Varietal growth characteristics	12
Moisture stress	16
Poor soils	11
Food quality problems	3
Total number of farmers	120

Source: Field survey data, January 2004.

Among the farmers interviewed, about 46% still grow the endangered landraces in very small plots annually. Farmers cited low productivity (58%), moisture stress (16%), varietal growth characteristics (12%), and poor soils (11%) as the main reasons for increasingly neglecting Bambara groundnut landraces (Table 3). The majority (89%) of farmers perceive that declining soil fertility coupled with unpredictable climatic conditions make the cultivation of late-maturing varieties very risky. Under such circumstances, only early-maturing crop varieties can be grown. Such a situation could gradually lead to a loss in biodiversity.

Farmers' perception about diminishing rainfall may be due to the distribution of rainfall rather than the total amount of rainfall received. Soils in the region have a sandy texture and low soil organic matter and therefore have low moisture retention capacity. However, the mean annual rainfall in the region (about 1000 mm) is normally sufficient for Bambara groundnut production despite intermittent drought in some years.

For 92% of the farmers, the advent of high-yielding, early-maturing cowpea and peanut varieties has resulted in the underutilization of late-maturing landraces and those with low yield potential. Many (84%) of the farmers perceived their soils to be of adequate fertility for Bambara groundnut production and therefore do not use any fertilizers in the production of the crop. Farmers were very clear in their perception that local Bambara groundnut cultivars are not responsive to fertilizer additions and would produce some grain even without fertilizer additions. Even so, because inorganic fertilizers are scarce and expensive, most farmers on smallholdings in Ghana rarely use them on food crops. Subsistence farming in the region is thus characterized by low external input, low crop yield, food insecurity, soil nutrient depletion, and environmental degradation (Rhodes, 1995). It is clear that Bambara groundnut landraces have been grown continuously in unfavourable and stressful environments in the northern savannah zone of Ghana without agronomic inputs such as fertilizers, irrigation, or pest and disease control. The ability of the landraces to survive in the most resource-poor environments is a clear demonstration of how well adapted they are to stressful conditions.

The study revealed that despite the low yield potential of Bambara groundnut landraces compared to improved early-maturing varieties of peanut and cowpea, conscious efforts are still made by a few farmers to grow them annually in very small plots, in an attempt to maintain biodiversity, probably because of the socio-cultural and nutritional roles those particular landraces play in their communities.

Farmers' Bambara groundnut selection practices

Bambara groundnuts are grown from seed. Farmers either save their own seed for the next season or buy from the market, and the mixing of seeds of similar or different seed coat colour results in a completely different population which may be heterogeneous. The very fact that individuals within a population vary in their yield performance, depending on the vagaries of each season, means that the overall genetic composition of a landrace changes each year when farmers grow crops from their own saved seeds. In fact, farmers confirmed that the seed of some landraces (e.g., *Siigbilpanchoure*) changes from one season to another, and this can be explained by the fact that some genotypes are not fixed and there is segregation in progeny (Karikari *et al.,* 1997). Moreover, seed sown by farmers is mixed, and farming conditions (rainfall, temperature, humidity, and physical and chemical properties of soil) of each year can favour one or more genotypes at the expense of others. Only favoured genotypes will produce seed. So the composition of seed will change from season to season according to previous environmental conditions. Almost no farmers had ever bought seed and therefore used their own seed saved from previous crop harvest. Other sources of seed were neighbours, relatives, and friends.

Farmers control seed quality by sorting and selecting at physiological maturity. This method is cheap and relies on indigenous knowledge of seed production, quality control, and processing. Farmers base their seed selection criteria on seed size, maturity, and seed health. Farmers mostly select well-matured, good-looking, larger seeds that are free from disease and which also look exactly like what they had planted. The high heritability of 100-seed weight indicates that significant increases in yield can be obtained by selection for this trait within genotypes (Karikari, 2000; Adenji *et al.,* 2008). Farmers are aware of this relationship, and the surveys indicated that farmers in the region select large seeds for planting. The majority of farmers (86%) selected seed of the neglected landraces based on multiple criteria during harvesting. Seed selection is mostly done by men (82%), but in some cases both men and women did the selection (15%). Very few women alone (2%) selected seed for planting.

Farmers generally selected genotypes appropriate for distinct agro-ecological systems. For example, early-maturing landraces were mostly found in the more arid and degraded north-western parts of the region (i.e., Lawra district). Intermediate- and late-maturing landraces were mostly grown in the wetter southern parts, especially in Wa Municipal. Many farmers (74%) were uncertain about the origin of the local landraces. According to the farmers, the landraces have been reverently handed

Table 4. Bambara groundnut characteristics preferred by farmers in the Upper West Region, Ghana

Characteristic	Percent (%)
Fast cooking	42
Early maturing	21
Large seeds	17
Cream/white seed	11
High yields	6
Sweet taste	3
Total number of farmers	120

Source: Field survey data, January 2004.

down from generation to generation.

Overall, the most important traits and selection criteria for landraces as identified by growers and consumers during the surveys were early maturity, high yield, large seeds, sweet taste, fast cooking, and cream-coloured seeds (Table 4). Fast cooking was the most frequently indicated preference criteria by both men and women, followed by early maturity and large seeds. This implied that most farmers in the region considered the reduced cooking time an important characteristic, and perhaps more so than any other criterion. Nevertheless, Dzietror and Bortei-Doku (1992) reported that in the coastal savannah area of Ghana, where Bambara groundnut seeds are boiled for food, cream-coloured seeds without any eye pattern are preferred for consumption because they are tastier, and Brink *et al.* (1996) similarly observed that cream-coloured seeds are preferred in Botswana. Cream-coloured seeds tend to have lower tannin contents than the darker seeds (Ofori *et al.,* 2001). In the northern savannah, however, where the seed is milled into flour for use in stews and soups, seed colour is not a major concern for consumers (Ofori *et al.,* 2001). Thus, landraces grown by farmers in these two regions differ primarily in seed colour, with cream-seeded landraces dominating in southern Ghana and northern growers preferring large seeds of any colour.

Assessment of local landraces in the observation nursery

The variability in the means of various parameters measured in the landraces is shown in Table 5. Days from sowing to emergence varied from 14 to 27. About 64% of the landraces took 21 days or longer to emerge. The landrace *Siimikorigyele,* which had small, mottled seeds, took the longest to emerge. Landraces with large seed sizes tended to emerge faster. In the low-rainfall semi-arid regions, rapid seedling emergence would be advantageous because this reduces the period over which seedlings are susceptible to soil moisture stress, and the quicker the roots develop the more likely the seedling is able to withstand drought (Karikari, 2000).

Days to flowering followed a trend similar to the emergence pattern. Days to flowering ranged from 51 to 68. The landraces *Dapialikamu* and *Siigbilpulale* were the earliest to flower, while *Siimikorigyele* took the longest to flower. Canopy spread ranged from 22 to 47 cm. The landraces *Simbinagtiri* and *Bankarubile* had wider canopies whose spread was over 40 cm. These two spreading varieties had low petiole/internode ratios (<6.0). Landraces with high petiole/internode ratios (>8.0) were mostly the cream-coloured landraces and they tended to be bunchy and upright and so were more exposed to sunlight than those with low petiole/internode ratios which tended to creep. Landraces with a bunching habit are easier to harvest. The landraces *Kontonsibii, Mouli,* and *Simpulun* had the least canopy spread and therefore belong to the bunching type. The spreading landraces usually have larger and more leaves than the bunching or non-spreading varieties, and also have larger seeds, but tend to have an indeterminate flowering habit (Ofori, 1996). Spreading Bambara groundnut landraces are sometimes used in mixed cropping situations where they serve as cover crops and help suppress weed growth and prevent soil moisture loss; while the bunching and semi-bunching types are often used in pure stands where optimum grain yield can be achieved with greater plant populations.

Performance of the landraces in this study showed that there were significant differences in 100-seed weight (Table 5) which may serve as a criterion for selection for seed size and grain yield. The landraces with cream-coloured seeds produced significantly larger seeds, probably due to the fact that cream-coloured seeds are preferred for home consumption, as these are claimed to be tastier (Brink *et al.,* 1996); consequently, such seeds have been favoured by farmers when selecting for seed size,

Table 5. Mean quantitative characters of 22 Bambara groundnut landraces evaluated in 2005 and 2006 at Poyentanga, Upper West Region, Ghana

Landrace	Grain yield (kg/ha)	100-seed weight (g)	Shelling percentage (%)	Days to emergence	Days to flowering	Days to maturity	Canopy spread (cm)	Petiole/internode ratio
Bagkaragiyile	245	41	49	23	66	119	32	6.1
Bankabile	533	55	55	16	55	96	28	7.5
Bankarubile	331	45	53	15	52	104	41	5.6
Dapialikamu	470	54	55	14	51	101	32	6.7
Kontonsibii	594	69	65	24	65	119	22	9.0
Mouli	509	53	63	23	65	120	22	8.6
Siigbilkpanchuore	512	54	53	23	66	105	28	6.8
Siigbilpulale	557	56	52	15	51	106	31	6.5
Siigbilzie	430	49	49	22	65	114	33	6.3
Siimikorigyele	407	20	49	27	68	107	37	6.6
Siimisogla	421	49	59	16	53	96	32	6.5
Simbikpong	534	56	60	19	63	117	32	6.7
Simbinagtiri	317	45	50	23	65	115	47	5.4
Simitakara	367	50	47	23	65	119	30	5.7
Simmie	418	51	59	23	65	121	32	6.7
Simpulun	893	73	74	18	52	96	22	8.8
Singblikali	333	43	51	22	65	149	26	8.2
Sinkalisiwea	763	49	72	21	56	109	26	8.3
Sinkon	342	48	53	23	65	120	31	7.2
Sinkongo	458	47	55	19	53	102	34	6.1
Sinkpone	611	59	67	21	64	120	27	6.2
Sumbibile	258	37	46	21	64	117	35	6.1
LSD (0.05)	52	4	3	2	3	10	2	0.2
CV%	5.4	3.4	2.6	3.3	2.0	4.3	2.1	1.3

and seed sizes of these landraces have improved over time.

Shelling percentage which is the ratio of dry weight of hulled seed to total unshelled pod dry weight multiplied by 100 is a reflection of the pod filling efficiency and this was found to be significantly related to seed size. The low shelling percentage in the large-seeded, early-maturing landraces was due to the fact that the seed accounted for a high proportion of total pod mass. High shelling percentage values for *Simpulun* is probably an indication of effective pod filling. Grain yield ranged from 245 to 893 kg/ha, with an overall mean of 467 kg/ha (Table 5). Grain yield was significantly greater in *Simpulun* and *Sinkalisiwea* than in *Bagkaragiyile* or *Sumbibile*. *Bagkaragiyile* produced the least grain. The landraces matured between 96 and 149 days, with a mean maturity period of 112 days. The maturity periods indicated earliness (mean of 96 days) for *Bankarbile, Siimisogla,* and *Simpulun* and lateness for *Sinkon, Mouli, Simmie* and *Sinkpone*. *Singblikali* was very late, maturing in 149 days.

Table 6 shows the descriptive statistics and Pearson's correlation coefficients of agronomic parameters and yield in Bambara groundnut landraces. Correlation analysis indicated that the yield-related components demonstrating significant positive correlation with grain yields are 100-seed weight ($r=0.95$), shelling percentage ($r=0.86$), and petiole/internode ratio ($r=0.63$). These characters could be used for selection in a breeding programme. Similarly, Karikari (2000) also reported a significant positive correlation between seed size and

Table 6. Descriptive statistics and Pearson's correlation coefficients of agronomic parameters and yield in Bambara groundnut landraces evaluated in 2005 and 2006 at Poyentanga, Upper West Region, Ghana

Variable	No. of observations	Mean	Standard Deviation	Minimum	Maximum	CV%	Pearson's correlation coefficient (*r*) with grain yield
Days to emergence	66	20	3.49	14	27	3.3	−0.49
Days to flowering	66	61	6.21	50	68	2.0	−0.39
Days to maturity	66	112	12.56	90	150	4.3	−0.37
Canopy spread (cm)	66	31	5.98	21	48	2.1	−0.62
Petiole/internode ratio	66	7	1.04	5	9	1.3	0.63
100-seed weight (g)	66	52	8.12	36	74	3.4	0.95
Shelling percentage	66	56	7.87	44	74	2.6	0.86
Grain yield (kg/ha)	66	467	153.13	234	899	5.4	

yield in Bambara groundnuts. In contrast, Misangu *et al.* (2007) reported that 100-seed weight had a non-significant correlation with seed yield as a result of component compensation. They observed that a consistent negative relationship between pod number and seed size compensated for and sacrificed the relationship between seed size and yield. Different environments and genotypes used might have contributed to the different responses because various factors, including genetic factors and competition for ambient resources, contribute to negative relationships among plant components.

In this study, the negative correlations between grain yield and canopy spread and grain yield and days to maturity provide evidence that spreading landraces have a longer vegetative stage, take longer to mature, and suffer yield declines due to low soil moisture content in the savannah zone. The results also suggest that late flowering has a detrimental effect on seed yield of Bambara groundnut in the savannah zone. In areas with marginal rains, earlier flowering confers an advantage of forming more pods and seeds and consequently higher yields.

Conclusion

Farmer knowledge regarding local landraces constitutes an important element in the knowledge and management of genetic resources. Owing to the absence of improved Bambara groundnut varieties, farmers continue to grow their own landraces and are the major custodians of germplasm. Most local landraces are selected by farmers on the basis of fast cooking time, stable grain yields, early maturity, and pest and drought tolerance. Further improvement of Bambara groundnut must take these selection criteria into account. Due to the increasing use of land for other food crops, the number of landraces continues to dwindle to the disadvantage of the Bambara groundnut.

Of the 22 Bambara groundnut landraces examined in this study, the 100-seed weight and shelling percentage were found to be significantly correlated to grain yields. However, 100-seed weight was found to be the most important character to be considered during selection and breeding of Bambara groundnuts in Ghana. Traits such as 100-seed weight may serve as a criterion for indirect selection for grain yield, although a more exhaustive and critical analysis of these correlations is needed. Negative correlations between grain yield and canopy spread and grain yield and days to maturity provide evidence that spreading landraces take longer to mature and may suffer declines in yield due to reduced moisture in the savannah zone.

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References

Adenji, O.T., Peter, J.M. and Bake, I., 2008. Variation and interrelationships for pod and seed yield characters in Bambara groundnut (*Vigna subterranea* [L.] Verdc.) in Adamawa state, Nigeria. *African Journal of Agricultural Research* 3: 617-621. [online]. Available from: http://www.academicjournals.org/ajar/PDF/pdf%202008/sep/Adeniji%20et%20al.pdf [Accessed 2 June 2010]

Baudoin, J.P. and Mergeai, G., 2001. Bambara groundnut (*Vigna subterranea* (L.) Verdc.). In: Roman H.R. (Ed.), *Crop Production in Tropical Africa.* A DGIC Publication, CIP Royal Library Brussels, Belgium, pp. 313-317.

Brink, M., Collinson, S.T. and Wigglesworth, D.J., 1996. Characteristics of Bambara groundnut cultivation in Botswana. In: Azam-Ali, S., N., Sesay, A., Collinson, S.T. (Eds), *Proceedings of the International Bambara Groundnut Symposium* held at the University of Nottingham, U.K., 23-25 July 1996. pp. 133-142.

Brink, M., Sibuga, K.P., Tarimo, A.J.P. and Ramolemana, G.M., 2000. Quantifying photothermal influence on reproductive development in Bambara groundnut (*Vigna subterranea* [L.] Verdc.)) models and their validation. *Field Crops Research* 66: 1-14. doi: 10.1016/S0378-4290(99)00075-1

Collinson, S.T., Sibuga, K.P., Tarimo, A.J.P. and Azam-Ali, S.N., 2000. Influence of sowing date on the growth and yield of bambara groundnut landraces in Tanzania. *Experimental Agriculture* 36: 1-13. doi: 10.1017/S0014479700361038

Dzietror, A. and Bortei-Doku, E., 1992. Survey of Bambara groundnut production in Ada, Ghana. *Paper presented at The 12th National Maize and Legume Workshop,* Kumasi, Ghana, 24-26 March 1992.

Goli, A.E., Begemann, F. and Ng, N.Q., 1997. Characterisation and evaluation of IITA's Bambara groundnut. In: Heller, J., Begemann, F., Mushonga, J. (Eds), *Bambara Groundnut* (Vigna subterranea *(L.) Verdc.). Promoting the Conservation and Use of Underutilized and Neglected Crops.* No. 9. pp. 101-118. IPGRI, Rome, Italy.

Gyawali, S., Sunwar, S., Subedi, M., Tripathi, M., Joshi, K. D. and Wilcombe, J.R., 2007. Collaborative breeding with farmers can be effective. *Field Crop Research.* 1001: 88-95.

IPGRI/IITA/BAMNET, 2000. *Descriptors for Bambara Groundnut.* International Plant Genetic Resources Institute, Rome Italy: International Institute of Tropical Agriculture, Ibadan, Nigeria; the International Bambara Groundnut Network, Germany, 57 pp.

Karikari, S.K., 1972. Correlation studies between yield and some agronomic characters in Bambara groundnut. *Ghana Journal of Agricultural Science* 5: 79-83.

Karikari, S.K., 2000. Variability between local and exotic Bambara groundnut landraces in Botswana. *African Crop Science Journal.* 8: 145-152. [online]. Available from: http://www.bioline.org.br/request?cs00015 [Accessed 2 June 2010]

Karikari, S.K. and Lavoe, S.K., 1977. Preliminary evaluation and utilization of fourteen cultivars of bambara groundnut. *Acta Hortic.,* 53: 195-199.

Karikari, S.K., Wigglesworth, D.J., Kwerepe, B.C., Balole, T.V., Bebolai, B. and Munthali, D.C., 1997. Country reports Botswana. In: Heller, J., Begemann, F. and Mushonga, J. (Eds), *Bambara Groundnut* (Vigna subterranea *(L.) Verdc.). Promoting the Conservation and Use of Underutilized and Neglected Crops.* No. 9. pp. 17-24. IPGRI, Rome, Italy.

Linnemann, A.R. and Azam-Ali, S.N., 1993. Bambara groundnut (*Vigna subterranea* (L) Verdc). In: Williams, J. T. (Ed.), *Underutilized Crop Series. No. 2. Vegetables and Pulses.* pp. 1-58. Chapman and Hall, London.

Mekbib, F., 2006. Farmer and formal breeding of sorghum (*Sorghum bicolor* (L) Moench) and the implications for integrated plant breeding. *Euphytica* 152: 163-176. doi: 10.1007/s10681-006-9191-7

Misangu, R.N., Azmio, A. and Reuben, S.O.W.M., 2007. Path coefficient analysis among components of yield in Bambara groundnut landraces under screen house conditions. *Journal of Agronomy* 6: 217-323 [online]. Available from: http://www.scialert.net/pdfs/ja/2007/317-323.pdf [Accessed 2 June 2010)

Ofori, I., 1996. Correlation and path-coefficient analysis of components of seed yield in Bambara groundnut (*Vigna subterranea*). *Euphytica* 91: 103-107.

Ofori, K., Kumaga, F.K. and Bimi, L.K., 2001. Variation in seed size, seed protein and tannin content of Bambara groundnut. *Tropical Science* 41: 41-44.

Ouedraogo, M., Ouedraogo, J.T., Tignere, J.B., Balma, D., Dabire, C.B. and Konate, G., 2008. Characterization and evaluation of accessions of Bambara groundnut from Burkina Faso. *Sciences and Nature* 5: 191-197.

Rhodes, E.R. (1995). Nutrient depletion by food crops in Ghana and soil organic nitrogen management. *Agric. Syst.* 48: 101-118. doi: 10.1016/0308-521X(95)93648-W

SAS Institute, 1990. *SAS/STAT User's Guide.* SAS Institute, Inc., Cary NC.

Sokal, R.R. and Rohlf, F.J., 1969. *Biometry. Principles and Practices of Statistics in Biological Research.* W. H. Freeman and Co., San Francisco. 320 pp.

Steel, R.G.D. and Torrie, J., 1986. *Principles and Procedures of Statistics. A Biometrical Approach.* McGraw-Hill Book Co., Auckland, 633 pp.

Tanimu, B.S. and Aliyu, L., 1990. Genotypic variability in Bambara groundnut cultivars at Samaru, Nigeria. In: Obigbeshan, I. O. (Ed.) *Proceedings of the 17th Annual Conference of Genetic Society of Nigeria.* Institute for Agricultural Research and Training. Obafemi Awolowo University, Nigeria, pp. 54-60.