Morphological Characterization and Genetic Variability among Bambara Groundnut (*Vigna subterranean* L.Verdc.) Accessions of Ghana

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Abstract

Bambara groundnut (*Vigna subterranean* L. Verdc.) is an indigenous African crop cultivated for the subterranean pod that is rich in protein. Yield of Bambara groundnut in Ghana is variable and unpredictable. The current study was undertaken to morphologically characterize and estimate the extent of genetic variability, heritability and genetic advance among 25 Bambara groundnut accessions collected from major growing areas in Ghana. The experiment was laid in a randomized complete block design with three replications. The accessions differed significantly ($p<0.01$) in number of days to emergence, 100 seeds weight, biological yield, harvest index, number of pods with two seeds per plant, number of pods per plant, economic yield and yield per plot. The genotypic coefficient of variation (GCV) values were near to phenotypic coefficient of variation (PCV) values for economic yield, harvest index, shelling percentage, number of pods with two seeds per plant, number of pods per plant, economic yield, percentage germination, number of days to emerge, and yield per plot, that indicates high contribution of genotypic effect for phenotypic expression of these characters. High heritability coupled with high genetic advance as percentage of the mean was obtained for economic yield, harvest index, number of pods with two seeds per plant, number of pods per plant, percentage germination, number of days to emergence, and yield per plot; reflecting the presence of additive gene action for the expression of these traits. The presence of genetic variability among accessions, heritability of the traits and the additive gene action for their expression shows the possibility to improve Bambara groundnut through selection.

Key words: Genetic Advance, Heritability, Selection, Variability

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INTRODUCTION

Bambara groundnut (*Vigna subterranean* L. Verdc.) is an indigenous African crop, cultivated primarily for the subterranean pods, rich in protein which helps to alleviate nutritional disorder in human and livestock (Massawe et al., 2002). Bambara groundnut has a number of production advantages in that it can yield on poor soils with little rainfall as well as produce substantial yields under better agronomic conditions (Anchirnah et al., 2001). It contributes soil nitrogen for other crops by fixing atmospheric nitrogen through symbiosis with *Rhizobium* bacteria and therefore it is beneficial in crop rotations and intercropping (Karikari et al., 1999).

In Ghana, the crop is mostly grown in the coastal savannah, transition and guinea savannah agro – ecologies, where rainfall is low as compared to the high rainfall areas of the country (Berchie et al., 2010). West Africa as a whole produces 45% – 50% of the annual world production of Bambara groundnut estimated at 330,000 tons although most countries including Ghana do not collect accurate statistics on internal production, and marketing of the crop (Obeng-Aseidu et al., 2000). Bambara groundnut has been characterized by variable and unpredictable yields for reasons that have not been identified due to limited research carried out on the crop (Massawe et al., 2002). Although there has been an increase in the number of scientific reports on Bambara groundnut in Ghana (Adu-Dapaah and Sangwan, 2004; Berchie et al., 2010; and Obeng-Aseidu et al., 2000), few studies have been made on the genetic diversity of the accessions in Ghana.

Knowledge of the genetic variability available among accessions of Bambara groundnut is needed as a guide for breeders and other scientists working on the improvement of this underexploited legume crop. Therefore, the present study was conducted to morphologically characterize and assess genetic variability, heritability, and genetic advance of Bambara groundnut accessions collected from major growing regions of Ghana.

METHODOLOGY

Description of the Study Area and Accessions

The study was conducted on the multipurpose nursery of the College of Agriculture, University of Education (Ashanti Mampong campus) in Ghana. Ashanti Mampong is located at latitude 07° and 04° north and longitude of 01° and 2°41' west at an elevation of 1457.7 m above sea level. Twenty-five Bambara groundnut accessions (Table 1) were collected from the major growing areas in Ghana, that is the Northern, Upper East, Upper West, Ashanti and Brong Ahafo regions. The accessions were collected from farmers and traders at the major markets in the regions. The accessions were named using the first letter of the town, where they were collected and a number to differentiate them if there were more than one accession collected from that town.

Table 1: Collection area and description of 25 Bambara groundnut accessions, collected from the major growing areas in Ghana

S/N	Name	Source	Region	Description
1	B1	Bawku	Upper East	Dark brown with red mottling and white eyes
2	B2	Bawku	Upper East	Plain red with white eyes
3	B3	Bawku	Upper East	Cream with dark black stripes and white eyes surrounded with black colour
4	B4	Bawku	Upper East	Cream with white eyes surrounded by red colour
5	B5	Bawku	Upper East	Cream with white eyes surrounded by pale blue colour.
6	B6	Bawku	Upper East	Plain brown with white eyes
7	N1	Navorongo	Upper East	Cream with white eyes surrounded by pale blue colour.
8	E1	Ejura	Ashanti	Brown with white eyes surrounded by black eyes
9	E2	Ejura	Ashanti	Brown with black mottling and white eyes
10	E3	Ejura	Ashanti	Cream with black mottling and white eyes with thin black colour surrounding it
11	E4	Ejura	Ashanti	Coffee with white eyes
12	A1	Attebubu	BrongAhafo	Cream with red mottling and white eyes surrounded by thin red colour
13	T1	Tatale	Northern	Cream with red mottling and white eyes with thin red colour.
14	A3	Attebubu	BrongAhafo	Cream with white eyes surrounded by black colour.
15	A2	Attebubu	BrongAhafo	Cream with red mottling and white eyes surrounded by pale blue colour.
16	N2	Navorongo	Upper East	Brown with red mottling and white eyes surrounded by dark red colour.
17	N3	Navorongo	Upper East	Plain coffee with white eyes
18	W1	Wa	Upper West	Dark red with white eyes
19	N5	Navorongo	Upper East	Cream with black eyes
20	N4	Navorongo	Upper East	Light coffee with white eyes surrounded by black colour
21	T2	Tatale	Northern	Cream with white eyes surrounded by black colour
22	T3	Tatale	Northern	Plain brown with white eyes
23	T4	Tatale	Northern	Light coffee with white eyes surrounded by black colour
24	T5	Tatale	Northern	Completely cream with white eyes
25	W2	Wa	Upper West	Completely black with white eyes

Experimental Design and Field Management

The research was conducted from September to December 2014 using randomized complete block design with three replications. A planting distance of 50 cm between rows and 25 cm within rows, with one seed per hill and 30 plants per plot was used. The total plot size was 3.75m^2 (2.5m x1.5m), with five rows in a plot and six plants per row. The planting area was ploughed and harrowed. Hand weeding was carried on as and when the weeds appear. All the plots were watered with equal amount of water, whenever there was no rain for four consecutive days starting from the first day of emergence. The crops were harvested, when the leaves begun to turn yellow which is a sign of pod maturity.

Data Collection and Analysis

Data on traits, viz. percentage germination, number of days to emergence, days to 50% flowering, number of stems per plant, hundred seeds weight (g), biological yield (g), harvest index, shelling percentage, number of pods with two seeds per plant, number of pods per plant, economic yield and yield/ plot (kg) were recorded based on the International Plant Genetic Resources Institute Descriptors for Bambara groundnut (IPGRI 2000).

The values were determined as follows: Days to Emergence as the number of days from planting to the day when 50% of the seedlings emerged on a plot; Percentage Emergence as the number of seeds that germinated on a plot from the time of sowing to two weeks after sowing were counted and expressed as a percentage of the total number of seeds that were sown; Days To 50% Flowering as the number of days from emergence to the day when 50% of the plants flowered on a plot; number of stems per plant as the average number of stems per plant from three randomly picked plants at the time of harvesting; number of pods with two seeds per plant as the number of pods with two seeds from each of the three selected plants and an average number estimated, 100 seed weight (g) as the weight of 100 seeds selected at random from each plot and weighed with an electronic scale; shelling percentage calculated as; $100 \times \frac{\text{weight of seeds (g)}}{\text{weight of pods (g)}}$ for the pods of three selected plants for each plot; yield per plot (g) as the weight of all shelled seeds from a plot by using an electronic scale; Economic yield (g) after harvest, shelled seeds from three selected plants from each plot were oven dried at 80^0C to constant mass and weighed with an electronic scale; biological yield (g) after harvest, three selected fresh plants from each plot including the pods were oven dried at 80^0C to constant mass and weighed with an electronic scale; harvest index (%) was calculated as the ratio of the economic yield to the biological yield expressed as a percentage.

The data collected for each of these characters were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) software version 9.2 (SAS, 2008). Means were separated with Duncan multiple range testing (DMRT) at 5% probability levels.

Estimation of Variance Components

The variability present between accessions was estimated from grand mean to each character, phenotypic and genotypic variance and coefficient of variation. The genotypic and phenotypic variances were determined from mean square values of the ANOVA for each trait according to Prasad et al. (1981), as follows:

σ^2e =MSe,

$\sigma^2 g = \frac{MSg - MSe}{r}$

$\sigma^2 p = \sigma^2 g$ +MSe/r

Where σ^2e is environmental variance, σ^2g is genotypic variance, σ^2p is phenotypic variance, MSe is mean square of error, MSg is mean square of genotype, and r is number of replications. Genotypic Coefficient of Variability, Phenotypic Coefficient of Variability, Broad sense heritability and genetic advance, and genetic advance as the percent of the mean were computed using the variance components (Burton 1952; Johnson et al. 1955; and Kumar et al. 1985). The formulae are as follows:

$\text{PCV} = \frac{\sqrt{\sigma 2p}}{\bar{x}} * 100$

$\text{GCV} = \frac{\sqrt{\sigma 2g}}{\bar{x}} * 100$

$H = \sigma^2 g/\sigma^2 p * 100$

$GA = KH * \sigma p$

$\text{GAM (\%)} = GA/\bar{x} * 100$

Where PCV is phenotypic coefficient of variation, σ^2p is phenotypic variance, GCV is genotypic coefficient of variation, σ^2g is genotypic variance, H is Heritability in the broad sense, and $\bar{x}$ is grand mean of the character under study, GA is genetic advance, K is the selection differential (K = 2.06 at 5% selection intensity), σP is the phenotypic standard deviation of the character, and GAM (%) is the genetic advance as percentage of the mean.

RESULTS AND DISCUSSION

Analysis of Variance

The genotype mean squares for traits viz. germination percentage, number of days to emerge, hundred seeds weight, biological yield, harvest index, number of pods with two seeds per plant, number of pods per plant, economic yield, and yield per plot were highly significant (Table 2).

Table 2. Analysis of variance for different quantitative characters in Bambara groundnut

Traits	Genotype mean square (df 24)
Germination percentage	901.1 **
Number of days to emerge	0.72 **
Number of days to 50 % flowering	14.24 ns
Number of stems per plant	2.69 ns
Hundred seeds weight	190.96 **
Biological yield	205.06 **
Harvest index	188.04 **
Shelling percentage	6.71 ns
Number of pods with two seeds per plant	7.59 **
Number of pods per plant	83.51 **
Economic yield per plot	29.42 **
Yield per plot	1353.7 **

** Significant at $p<0.01$.

The observed high significant difference in the traits between the genotypes reflected the existence of large variability among tested genotypes and this variability can be further utilized in the Bambara groundnut improvement program. An efficient genetic improvement of a crop cultivar depends on the availability and knowledge of genetic variability in the agro-morphological characteristics. Where there is no more usable variability, in most crop plants as the result of continuous selection, use of induced variation has become an option (Vuledzani *et al*., 2015). However, in crop plants like Bambara groundnut, where no much selection has been made and variation has not been depleted, use of available variation in the accessions could be good resource for plant breeders to improve the crop.

Range and Mean Values of Agro-morphological Characters

Wide range of variability was observed between genotypes for the traits studied (Table 3). Accessions N4 and B6 had the highest germination (99%), followed by accession B3 (97%), while accession T5 had the lowest germination (20%). Accessions with low germination percentage had delayed seedling emergence. Days to emergence ranged from 5.3 to 12.3 among the tested accessions. Similar results with significant differences in germination and emergence were reported by Berchie *et al*. (2010), in which case they demonstrated the importance of priming Bambara groundnut seeds to break the seed coat to achieve uniform emergence. This shows that the variation in germination and subsequent emergence in Bambara groundnut is related to the inherent variation in seed coat hardness between accessions. Where the difference in seedling emergence between accessions is significant, either use of seed priming or using accessions known to have less hardness in seed coat might result in early emergence to attain uniform emergence and subsequent field establishment.

Genotype B3 attained maximum number of pods with two seeds (5.0), and yield per plot (104 g). Genotype B1 had maximum value in number of pods per plant (25.6), harvest index (47.5%) and economic yield (15 g). The highest values in 100 seed weight (63.12 g) were observed in genotype T5. The significant variations among the accessions for the majority of the morphological traits of economic importance is a sign of the presence of high degree of usable genetic variation giving room for selection of superior ones.

Table 3. Estimates of range and mean for Agro-morphological traits for accessions of Bambara groundnut in Ghana

Traits	**Unit**	**Mean**	**Range**
Germination	percent	80.99	20.00 -99.00
Days to emerge Days	days	8.10	5.33-12.33
Days to 50 % flowering	days	34.20	30.00-37.33
Stems per plant	number	8.50	7.00-10.30
Hundred seeds weight	gram	47.08	36.10-68.9
Biological yield	gram	8.58	4.33-15.33
Harvest index	percent	23.52	15.09-47.39
Shelling percentage	percent	68.08	50.80-84.3
Pods with 2 seeds per plant	number	2.17	00.00-5.00
Number of pods per plant	number	16.70	7.00-27.00
Economic yield per plot	gram	8.58	4.33-15.33
Yield per plot	gram	55.99	16.76-104.00

Estimation of Variance Components

Variables recorded viz. genotypic variance (σ^2g) ranged between 0.06 and 721.0; phenotypic variance (σ^2ph) 0.28-73.22; environmental variance (σ^2e) 0.89-451.2; phenotypic coefficients of variation (PCV) 11.16-78.62; and genotypic coefficients of variation (GCV) 0.89-66.18 (Table 4). The PCV values were higher than the GCV values for all the parameters indicating environmental influence on the expression of the traits (Jonah *et al*., 2013). However, GCV values were near to PCV values for the characters like economic yield, harvest index, shelling percentage, number of pods with two seeds per plant, number of pods per plant, percentage germination, and number of days to emerge, indicating high contribution of genotypic effect for phenotypic expression of these characters.

According to Rosmaina *et al*. (2016), PCV and GCV values greater than 20% are regarded as high and values between 10% and 20% to be medium, whereas values less than 10% are considered to be low. Accordingly, high PCV and GCV were recorded for economic yield, harvest index, shelling percentage, number of pods with two seeds per plant, number of pods per plant, percentage germination, number of days to emerge and yield per plot, while traits with moderate PCV and GCV were hundred seeds weight, and biological yield. High values of PCV and GCV indicated the existence of substantial variability for such characters and selection may be effective based on these characters.

Table 4. Estimation of component of variances: genotypic (σ^2g), environmental (σ^2e), and phenotypic (σ^2p); phenotypic (PCV) and genotypic (GCV) coefficient of variation, broad sense heritability (H) and genetic advance as percentage of mean (GAM%) in the agro-morphologic traits of 25 accessions of Bambara groundnut in Ghana

Traits	**σ^2g**	**σ^2e**	**σ^2p**	**GCV (%)**	**PCV (%)**	**H (%)**	**GAM (%)**
Hundred seed weight (g)	46.73	63.72	16.93	14.52	16.92	73.43	25.60
Economic yield (g)	162.20	235.43	73.22	48.34	78.62	68.94	95.65
Biological yield (g)	48.75	68.44	19.66	18.69	22.23	71.30	32.46
Harvest index	42.23	62.77	20.53	27.65	33.72	67.34	46.62
Shelling percentage	721.0	2237	22.36	34.37	60.45	0.032	0.41
Number of pods with two seeds/ plant	2.05	2.56	0.48	66.18	73.34	81.20	90.5
Number of pods / plant	19.2	27.8	8.7	26.33	31.65	68.94	44.98
Percentage germination	265.7	300.4	34.76	20.12	21.39	88.46	38.93
Number of days to emergence	2.93	3.24	0.28	21.32	22.31	91.30	41.96
Number of days to 50 percent flowering	0.18	4.92	4.75	6.47	22.23	3.58	0.478
Number of stems /plant	0.06	0.89	0.89	0.89	11.16	0.63	0.15
Yield per plot	329.9	451.2	121.3	33.25	38.64	73.22	58.25

Heritability and genetic advance

Heritability values ranged between 0.03% for shelling percentage and 91.30% for days to emergence. The genetic advance as a percentage of the mean also ranged from 0.15 for number of stems per plant to 95.7% for economic yield (Table 4). The response of a character to selection is more reliable, when heritability estimates and genetic advance are combined (Ibrahim and Hussein, 2006). Traits such as economic yield, harvest index, pods with two seeds, number of pods per plant, days to emergence and yield per plot recorded higher heritability values of 68.9%, 67.3%, 81.2%, 68.9%, 91.3%, and 73.2%, respectively, which is accompanied by high genetic advance as percentage of the mean of 95.65, 46.62, 90.5, 44.98, 41.96, and 58.25, respectively. This can be considered as a favourable attribute and an indication of additive gene effect (Percy and Turcotte, 1991). Where additive genes are less affected by environment, phenotypic selection for these traits will be effective (Rao and Patil, 1996).

High heritability values accompanied by low genetic advance were observed for hundred seed weight

(73.43% and 25.60%), biological yield (71.30% and 32.46%), and percentage germination (88.46% and 38.93%). In contrast, low heritability values accompanied by low genetic advance were observed for shelling percentage (0.032% and 0.41%), days to 50% flowering (3.58% and 0.478%) and number of stem /plant (6.63% and 0.15%). This indicates that in the latter case the traits are being exhibited due to favourable environmental influence rather than genotypic. Selection for such traits may not be rewarding due to the presence of high levels of dominance gene effect hence limited scope of selection (Rao and Patil, 1996).

CONCLUSION

From the results of this study it can be concluded that Bambara groundnut accessions significantly differed in important agro-morphological traits viz. percent germination, number of days to emergence, 100 seeds weight, number of pods with two seeds per plant, number of pods per plant, harvest index and economic yield. Most of these traits viz. days to emergence, number of pods per plant, number of pods with two seeds per plant, harvest index, economic yield, and yield per plot exhibited high heritability and high genetic gain as percentage of the mean reflecting the presence of additive gene action for the expression of these traits, hence improving these characters could be achieved through selection.

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