OPEN ACCESS J. Plant Breed. Genet. 07 (02) 2019. 41-53 DOI: 10.33687/pbg.007.02.2822

Available Online at ESci Journals

Journal of Plant Breeding and Genetics

ISSN: 2305-297X (Online), 2308-121X (Print)

http://www.escijournals.net/JPBG

SELECTION FOR YIELD IMPROVEMENT IN BAMBARA GROUNDNUT [*Vigna subterranea* (L.) VERDC.]

[a]Nwakuche C. Onwubiko, [b]Michael I. Uguru, [c]Grace O. Chimdi

[a] *Department of Crop Science and Technology, Federal University of Technology, Owerri, Nigeria.*

[b] *Department of Crop Science, University of Nigeria, Nsukka, Nigeria.*

[c] *Department of Agricultural Technology, Federal Polytechnic Bauchi, Nigeria.*

ABSTRACT

Selection as the most practical and economical way of improving yield in an extreme autogamous crop was carried out in a Randomized Complete Block Design (RCBD) with three replications, with thirty three accessions of Bambara groundnut {*Vigna subterranea* (L.) Verdc}. Qualitative characters displayed a reasonable range of variation except for eye pattern, seed shape, pod texture and growth habit. The result on the analysis of variance (ANOVA) showed significant differences (p<0.05) for all traits except for plant height, number of leaves per plant and seed length that were statistically insignificant. The principal component analysis result revealed that eight components (Eigen values ≥ 1) accounted for 78.36 % of the phenotypic variance, and quantitative traits revealed more phenotypic variation among the accessions Pearson's correlation coefficient showed that petiole length (r= 0.64), vigour index (r= 0.49), seed length (r=0.53), canopy width (r=0.38), and internode length (0.58). had a high positive correlation with seed yield. Ranking of the accessions based on significantly strong correlated traits with yield using the rank summation index (RSI) method, and the selection of the best top 5% of the entries identified accessions TVSU 1688 and 1638 with RSI scores of 31 and 43 respectively as the best high yielding Bambara groundnut lines. Correspondingly, accessions TVSU 1688 and 1638 had the highest mean seed yield per plant of 1150.5g and 720.8g respectively in the 3-year field evaluation; which further confirmed the precision of the ranking and selection result. Invariably these two accessions were inherently high yielding Bambara groundnut accessions.

Keywords: Bambara groundnut, selection, *Vigna subterranea*, yield.

INTRODUCTION

The potential yield of crops is diminished by biotic and abiotic stress, therefore constant crop improvement is indispensable for sufficient and secure yields in crops both for now and in the future. The various methods used in crop breeding to improve crops can be categorized into four; selection of plants based on observed natural variations existing among native plants, or landraces or accessions, selection of plants with desirable traits after hybridization or controlled mating from different parents, selection of specific recombinants after monitoring the inheritance of within-genome variation, and the creation and introduction of novel variation into genomes through genetic engineering. Summarily, the core of plant breeding is the selection of better types among variants based on defined goals; like yield and quality of edible parts; ease of cultivation, harvest, and processing; tolerance to environmental stresses; and resistance against pests and diseases (Breseghello and Coelho, 2013).

Selection is one of the scientific methods of crop improvement. In fact, cultivated crops emerged from several cycles of both natural and artificial selection (Chahal and Gosal, 2002; Goussard, 2004; Uguru, 2005). Sometimes, selection of plants based on observed variants is the only readily available strategy for improvement of plants, especially for extreme inbreeders; autogamous crops with flowers that are cleistogamous in nature, as other breeding methods are either not feasible or practicable. However, this breeding method is not fascinating as it does not create variability

* Corresponding Author:

Email: nwakuche.onwubiko@futo.edu.ng

but only act on the natural existing variation. Furthermore, the efficiency of this breeding method depends on the amount of observable genetic variation existing in a population like, individual differences in viability, adaptability, resistance to diseases and pests, large fruit size and other selective values of the breeder; which usually is to select line(s) with good agronomic characters than others. Worse still, some of these traits are environment specific, making this crop improvement method unreliable.

Till date, Bambara groundnut is cultivated in the form of landraces. It is an extreme autogamous crop (Baudoin and Mergeai, 2001) with cleistogamous flowers (Cobble and Steele, 1976; Tindall, 1983). Several workers reported that successful hybridization between lines of Bambara groundnut through conventional breeding has not been achieved (Marandu and Ntundu, 1995; Ntundu, 1997; Massawe *et al.,* 2005; Uguru and Agwatu 2006). According to kone *et al* (2007) the improvement of Bambara groundnut through convictional breeding method is slow and difficult due to the long generation time and preponderant homozygous nature of the crop. Similarly, Goli *et al* (1995) observed that geotropic pod development of the crop makes its improvement through artificial hybridization difficult. Hence, the readily available improvement strategy therefore is to apply selection on the already existing variations. However, in order to arrive at a conclusion with a high precision for such an important trait as yield, it is important that many accessions especially those collected from different eco-geographic regions be used in the study. This would be significant in not only capturing variability for a specific trait (like yield) but also in selecting the right parent from a wide range of collections for yield improvement in Bambara groundnut. Therefore, this study was specifically set up to improve yield in Bambara groundnut through selection.

MATERIALS AND METHODS

Field characterization and evaluation of 33 accessions of Bambara groundnut (Table 1) collected from the gene bank of International Institute of Tropical Agriculture (IITA) Ibadan were carried out between 2014 to 2016, under wet cropping season at the Teaching and Research Farm of the Department of Crop Science and Technology, Federal University of Technology, Owerri (lat. 5^0 N, long. 7^0 E and at altitude of 55m above sea level). The farm is in the humid tropical agroecological zone with a mean annual rainfall range of 2250 mm to 2500 mm, and a mean daily temperature range of 27^0C to 28^0C (Owerri meteorological station).

Method 1

Planting was done in August of 2014 2015 and 2016 under wet cropping season on a portion of land measuring 40 m x 20 m, which was cleared, ploughed and marked out into 3 blocks with a space of 1 meter between blocks. Two seeds were sown which were later thinned down to one on ridges spaced 100 cm apart. The intra plant spacing was 20 cm. Poultry manure was applied at 15 t/ha as observed by Duruigbo (2004). Standard cultural practices like supply, thinning, weeding at 3 and 7 weeks after planting (WAP) and earthing up at 9 WAP were adopted for optimum crop growth and development (Ntundu *et al.,* 2006).

The experimental design was randomized complete block design (RCBD) with three replications. Treatments were evaluated for Bambara groundnut descriptor list for 9 qualitative and 18 quantitative morphological characters (Table 1) as described by the International Bambara Groundnut Network (BAMNET), (IPGRI, IITA, BAMNET. 2000).

Descriptive statistical analyses were carried out on qualitative morphological data, while the data collected from evaluation of quantitative morphological traits were subjected to analysis of variance (ANOVA) following the procedure of RCBD (GENSTAT 5.0 Release 4.23DE, Discovery Edition 3,). Detection of differences among treatment means for significance was done using Fisher's Least Significant difference (F-LSD) at 5% probability level.

Method 2

Correlation coefficients among the morphological traits: Pearson's correlation coefficients was computed for all pairs of traits to determine characters that vary in the same or opposite directions with yield. Characters that were positively correlated with yield were used to perform rank summation index (RSI), to guide select high yielding Bambara groundnut accession(s) from the population. Goli *et al* (1995) reported that correlation is a useful guide, especially for plant breeders who may want to associate a set of traits in their selection programmes. In fact, the analysis of correlations among measurable characters is of great value to plant breeders in selecting delicate characters. Moreover, correlations between pairs of characters are reliably significant, when the absolute values of the coefficient are greater than 0.20.

Table 1. Morphological traits and descriptor list used for the study.

GTH	Growth Habit	1=bunch type, 2= semi-bunch type, 3=spreading type
TLS	Terminate leaflet shape	1=round, 2=oval, 3=Lanceolate, 4=elliptic
TLC	Terminal leaflet colour	1=green, 2=red, 3=purple
POS	Pop shape	1=No point, 2=ending one point round one side 3= Pointed one side with a hook, 4=pointed each side
POC	Pod colour	1= yellowish brown, 2=brown, 3=reddish brown, 4= Purple, 5=black
POT	Pod texture	smooth, 2= little grooves, 3= much grooved 4= much folded
SDS	Seed shape	1= round, 2= oval
VGI	Vigour index	1=stunted, 9= vigorous plants.
PTL	Petiole length	(mm)
PTS	Plant spread	(cm)
PHT	Plant height	(cm)
LP	Number of leaves per plant	(-)
NSP	Number of stems per plant	(-)
POL	Pod length	(mm)
PDW	Pod width	(mm)
NPP	Number of pods per plant	(-)
SNP	Seed number per pod	(-)
SWT	100-seed weight	(g)
SDL	Seed length	(mm)
SDW	Seed width	(mm)
TLL	Terminal leaflet length	(mm)
TLW	Terminal leaflet width	(mm)
INL	Internode length	(mm)
NNS	Number of nodes per stem	(-)
POL	Pod length	(mm)
POW	Pod width	(mm)
SYD	Seed yield	(g/m^2)

Selection method for crop improvement: A Rank Summation Index (RSI) method of Mulumba and Mock (1978) was used in this study to rank the accessions for their overall performance with respect to characters that were positively correlated with yield; in this way accession(s) with high yielding ability were identified and selected. To obtain the RSI, accessions were first ranked with mean values of traits that were positively correlated with yield (in this case, 1 = best and thirty 33= poorest), thereafter traits ranks were summed to generate overall performance of each accessions. Thus the lower the RSI score of any accession the better its yielding ability, and based on this result selection was made among the accessions as proposed by Ajala *et al* (1995). Top 5% of the entries of the population were selected as high yielding accession(s) of Bambara groundnut.

RESULTS

Morphological traits: Nine (9) qualitative morphological traits as outlined in descriptor for Bambara groundnut developed by the International Bambara Groundnut Network (IPGRI, IITA, BAMNET, 2000) were used to characterize the thirty three accessions. The results as displayed in figure 1 below showed that these qualitative morphological descriptors showed a varying degree of differentiation among the Bambara groundnut accessions evaluated. In fact a reasonable number of the qualitative characters showed high variability among the accessions studied. Summarily, ground colour of eye, displayed a wide range of variation more than other qualitative morphological characters (Figure 4.1 below). Apparently, 12.1% of the accessions had brown triangular ground colour of eye, 18.2% showed grey butterfly-like eye, and 9.1% grey triangular eye. Furthermore, 3% of the accessions each had dark red butterfly and light brown types of ground colour of eye, and 54.5% had the type described as others. On the other hand, the eye pattern of the accessions was the morphological trait that had the least qualitative variability. It resolved the collections evaluated into only 2 classes; eye as thin lines and no eye. While 72.7% had eye as thin lines, 27.7% had no eye.

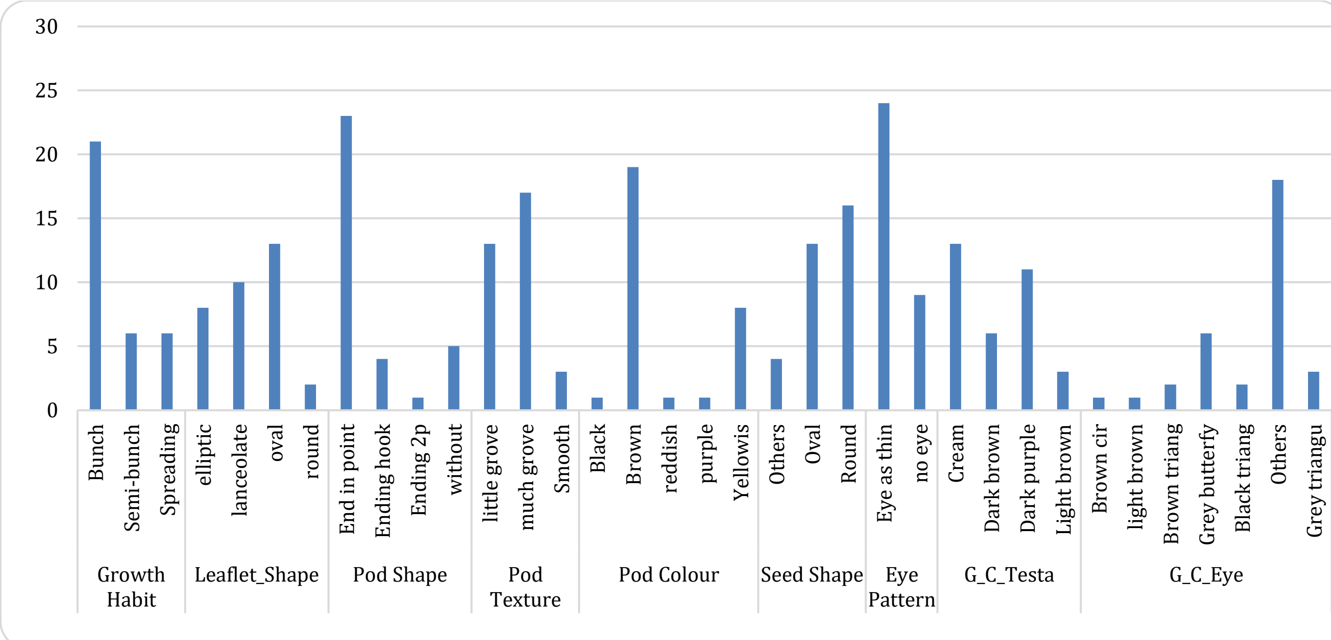

Figure 1. Distribution of qualitative morphological features among thirty-three accessions of Bambara groundnut.
Key
G_C_Testa = Ground colour of testa
G_C_Eye = Ground colour of eye.

Quantitative morphological variability: Table 2 below revealed the result of the analysis of variance (ANOVA) on the 17 quantitative traits of the Bambara groundnut accessions. There were significant differences (p<0.05) for all the traits except for plant height, number of leaves per plant and seed length that were statistically insignificant. Furthermore, the summary of the basic statistic; means, standard deviation, variances and coefficient of variation which were used to measure variation displayed by the quantitative characters across the lines evaluated are shown in Table 3. The result showed that quantitative traits exhibited different levels of variability across the accessions. Seed yield displayed the highest level of variation with a coefficient of variation of 70%. Moderate level of variation of 45% was recorded for number of leaves, while seed yield had the least (7%) level of variation.

Table 2. Analysis of variance (ANOVA) for quantitative morphological features of thirty-three accessions of Bambara groundnut used in the study.

Trait	Sum of Squares	Df	Mean Square	F	Sig.
Vigour index	177.838	32	5.557	7.537	0.000
Plant height	699.354	32	21.855	1.339	0.158
Canopy width	3949.838	32	123.432	2.509	0.001
No of leaves per plant	142112.970	32	4441.030	0.740	0.824
Terminal leaflet length	3033.576	32	94.799	1.834	0.019
Terminal leaflet width	940.036	32	29.376	7.447	0.000
Petiole length	44946.970	32	1404.593	18.665	0.000
No of stem per plant	155.682	32	4.865	17.313	0.000
No of branches per plant	336.721	32	10.523	66.395	0.000
No of nodes per stem	184.903	32	5.778	37.859	0.000

Internodes length	994.700	32	31.084	103.059	0.000
Pod length	907.370	32	28.355	119.302	0.000
Pod width	87.838	32	2.745	2.157	0.004
Seed length	68.848	32	2.152	1.555	0.066
Seed width	59.274	32	1.852	8.289	0.000
Seed yield	4010653.723	32	125332.929	45.557	0.000
Seed weight	24448.103	32	764.003	8.260	0.000

D.f. = degree of freedom

Table 3. Basic statistics of morphological characters of the thirty-three accessions of Bambara groundnut used for the study.

Character	Min.	Max	Mean	Standard deviation	Variance	C.V.	Number of observations
Vigour index	4	10	7.32	1.50	2.27	20	33
Plant height	16	27	21.84	4.07	16.62	17	33
Canopy width	37	81	52.63	8.44	71.30	16	33
Number of leaves	117	368	266.27	71.13	5060.60	45	33
Terminal leaflet length	27	80	56.81	8.02	64.32	14	33
Terminal leaflet width	19	36.7	24.81	3.54	12.53	14	33
Petiole length	90	200	136.81	22.07	487.09	16	33
Number of stems	5.8	12.6	8.47	1.32	1.75	15	33
Number of branches	6	15.9	8.90	1.90	3.62	21	33
Number of nodes	5.90	12.7	8.60	1.41	2.01	17	33
Internode length	10.90	22.63	16.96	3.11	9.71	18	33
Pod length	18.50	32.80	22.95	3.13	9.80	13	33
Pod width	10	16	13.56	1.31	1.74	9	33
Seed length	11	17	13.28	1.26	1.59	9	33
Seed width	8.62	14.20	11.32	0.89	0.80	7	33
Seed yield	69.20	1150.5	289.12	204.28	41730.3	70	33
Seed weight	45.60	130	83.25	17.61	310.11	21	33

C.V. = coefficient of variation

Principal Component Analysis: Result of the principal component analysis (PCA) of the twenty three morphological features (qualitative and quantitative that showed significant differences) of the evaluated Bambara groundnut accessions is presented in Table 4. All the twenty three traits were grouped under eight components (Eigen values ≥ 1) which accounted for 78.36 % of the phenotypic variance among the accessions. In fact, the first 8 principal components (PCs) accounted for 23.97%, 13.68%, 9.80%, 8.61%, 6.35%, 6.08%, 5.44% and 4.43%, of the observed morphological variations among the accessions in that order. The important traits responsible for the observed variability among the accessions, and had the highest loadings in the eight principal components in this study were terminal leaflet length, terminal leaflet width, petiole length, eye pattern, pod width, seed width, leaflet shape, number of branches, number of nodes, ground colour of eye, number of leaves, number of stems, internode length, seed yield, seed shape, pod texture, pod length, and plant height. These traits were mostly quantitative morphological characters.

Correlation Coefficients among the morphological traits: Pearson's correlation coefficient result to determine the degree to which quantitative characters are associated with yield is shown in Table 5. Petiole length was strongly correlated with seed yield (r= 0.64). Other traits that had significant positive correlation with seed yield were vigour index (r= 0.49), seed length (r=0.53), canopy width (r=0.38), and internode length (0.58). However, plant height (r= 0.12) and number of leaves (r= 0.48) had positive correlation with yield but they were not significant. On the contrary, number of branches per plant (r= -0.09), number of nodes per plant (r= -0.13), terminal leaflet length (r= -0.18), terminal leaflet width (r= -0.25), pod length (r= -0.11), pod width (r= -0.27) and seed width (r= -0.09) were negatively and non-significantly correlated with seed yield.

Selection for high yield based on RSI rankings: Table 6 showed the result on the identification and selection of accession(s) with high yielding ability, based on the rankings of Bambara groundnut accessions with characters that were significantly correlated with yield namely; petiole length, vigour index, seed length, canopy width, and internode length. Accessions TVSU 1688 and TVSU 1638 were the top best 5% of the entries of the population. They recorded the lowest Rank Summation Index (RSI) score of 31 and 43 respectively. On the other hand, accession TVSU 1555 recorded the highest RSI score of 148 and invariably was identified as the least in seed yield among the lines evaluated.

Table 4. Principal component analysis for quantitative and qualitative morphological features of thirty-three accessions of Bambara groundnut used for the study.

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
Eigen Value	5.513	3.147	2.256	1.981	1.461	1.399	1.251	1.020
Percentage Variation %	23.971	13.683	9.808	8.615	6.353	6.082	5.441	4.436
Cumulative %	23.971	37.654	47.462	56.077	62.430	68.512	73.954	78.389
Plant Height	0.273	-0.155	-0.183	0.079	0.120	-0.045	0.304	0.178
No of Leaves Per Plant	-0.159	0.145	-0.317	0.368	0.029	-0.113	-0.140	-0.005
Terminal Leaflet Length	0.332	0.035	0.223	0.039	-0.071	0.093	0.202	-0.019
Terminal Leaflet Width	0.313	0.017	0.169	0.087	-0.057	-0.202	0.307	0.039
Petiole Length	0.300	-0.059	-0.023	0.296	-0.021	0.025	0.071	0.426
No of Stem Per Plant	0.068	0.089	0.159	0.318	0.515	-0.355	-0.094	0.048
No of Branches Per Plant	-0.247	0.120	0.374	0.219	-0.043	0.165	0.061	0.070
No of Nodes Per Stem	-0.252	0.247	0.311	0.139	0.000	0.065	0.096	0.129
Internode Length	0.028	0.021	0.003	0.336	0.083	0.522	0.122	-0.151
Pod Length	0.249	0.281	0.050	-0.035	-0.060	0.336	-0.074	-0.071
Pod Width	-0.011	0.454	-0.139	-0.071	0.037	-0.202	0.131	0.117
Seed Width	-0.031	0.385	-0.317	-0.138	0.101	0.141	0.129	0.257
Seed Yield	-0.043	-0.221	-0.186	0.071	0.494	0.392	-0.064	0.213
Seed Weight	0.138	0.316	-0.173	0.100	0.179	-0.035	0.173	-0.217
Growth Habit	0.286	0.079	0.211	-0.039	0.005	0.015	-0.216	0.171
Leaflet Shape	0.079	0.392	0.133	-0.143	0.092	-0.132	0.098	-0.072
Pod Shape	0.281	0.105	0.090	-0.123	0.017	0.197	-0.339	0.310
Pod Texture	-0.177	-0.093	0.277	0.007	0.264	0.108	0.487	-0.137
Pod Color	0.053	-0.041	-0.057	-0.586	0.216	0.153	0.245	-0.025
Seed Shape	0.240	-0.088	-0.113	0.013	0.373	-0.117	-0.172	-0.435
Eye Pattern	0.336	-0.111	0.180	0.045	-0.108	-0.005	-0.041	-0.260
Ground Color of Testa	0.046	0.282	-0.039	0.085	-0.059	0.263	-0.197	-0.381
Ground Color of Eye	-0.116	0.056	0.376	-0.224	0.364	-0.045	-0.316	0.089

Table 5. Pearson's correlation coefficient of quantitative characters of thirty-three accessions of Bambara groundnut.

	Vigour index	*Plant height*	*Canopy width*	*No of leaves per plant*	*Terminal leaflet length*	*Terminal leaflet width*	*Petiole length*	*No of stem per plant*	*No of branches per plant*	*No of nodes per stem*	*Internode length*	*Pod length*	*Pod width*	*Seed length*	*Seed width*	*Seed yield*
Vigour index																
Plant height	.425*															
Canopy width	-.113	-.165														
No of leaves per plant	-.106	-.352*	.096													
Terminal leaflet length	-.011	.453**	-.301	-.425*												
Terminal leaflet width	.171	.443**	-.391*	-.289	.625**											
Petiole length	.449**	.225	.331	-.172	-.166	-.148										
No of stem per plant	.310	.097	-.047	.173	.107	.281	-.065									
No of branches per plant	-.082	-.454**	-.190	.204	-.179	-.273	-.320	.070								
No of nodes per stem	-.036	.482**	-.220	.281	-.227	-.257	-.355*	.111	.872**							
Internode length	.429*	.290	.427*	-.328	-.074	-.126	.924**	-.022	-.308	-.331						
Pod length	-.199	.063	-.168	-.139	.452**	.417*	-.346*	.021	-.094	-.070	-.314					
Pod width	-.053	-.207	-.009	.172	-.077	.109	-.280	.123	-.023	.298	-.228	.263				
Seed length	.361*	.258	.470**	-.326	-.074	-.145	.911**	-.007	-.318	-.343	.994**	-.316	-.220			
Seed width	.073	.056	.148	.088	-.129	-.272	-.037	-.097	-.112	.074	.015	.147	.552**	.012		
Seed weight	.057	.191	-.100	.136	.213	.213	-.050	.244	-.127	-.024	-.067	.361*	.438*	-.056	.355*	
Seed yield	.486**	.123	.380*	.048	-.188	-.255	.635**	.091	-.097	-.133	.580**	-.112	-.277	.531**	-.009	1

*. Correlation is significant at the 0.05 level.

**. Correlation is significant at the 0.01 level.

Table 6. Accessions, their traits means, ranks, and Rank Summation Index of the Bambara groundnut collections used for the study.

Accessions	Petiole length	rsi	Vigour index	rsi	Seed length	rsi	Canopy width	rsi	Internode length	rsi	RSI
1688	100.00	1	6.00	5	12.33	6	43	2	16.93	17	31
1638	103.33	2	6.33	10	12.66	10	41.33	1	17.3	20	43
1604	108.33	3	5.00	2	14	26	44	3	15.36	11	45
1639	130.00	15	6.00	7	12.66	9	49.33	11	12.73	4	46
1503	126.67	11	7.33	15	12.33	4	51.33	15	12.16	2	47
1625	136.67	18	5.67	4	13.66	21	49	10	11.03	1	54
1584	130.00	13	8.00	23	12	3	48.66	9	15	9	57
1627	123.33	9	5.33	3	13.66	22	45	4	18.23	23	61
1559	155.00	28	4.67	1	13	15	48.66	8	15.66	13	65
1697	133.33	16	6.67	14	13.33	19	52	18	12.4	3	70
1605	126.67	12	6.33	8	12.33	5	51.33	16	21.33	31	72
1509	160.00	29	8.00	22	13	12	48.66	7	14.4	7	77
1513	115.00	4	8.67	29	13	14	46.66	5	20.4	26	78
1766	123.33	10	8.00	24	13	16	53.33	22	14.36	6	78
1788	133.33	17	6.33	11	14	29	47.66	6	17	18	81
1512	143.33	25	7.67	18	12.66	8	58.33	28	14.53	8	87
1713	140.00	22	9.00	30	12.66	11	52	19	13.13	5	87
1591	130.00	14	7.33	16	14	25	54.33	24	15.13	10	89
1819	136.67	20	7.33	17	12.33	7	51	14	22.43	32	90
1614	123.33	8	6.33	9	14	27	55.33	25	18.2	22	91
1917	170.00	30	8.00	20	12	1	50.33	12	21.3	30	93
1510	140.00	23	6.33	12	13	17	56	27	15.66	14	95
1610	116.67	5	8.67	28	13	13	52.66	20	21.16	29	96
1504	140.00	21	6.67	13	13.66	20	54	23	17.26	19	97
1620	143.33	24	8.00	21	12	2	55.66	26	18.4	24	103
1631	121.67	6	7.67	19	15	33	60.66	30	16.36	15	104
1483	146.67	26	8.33	26	13.33	18	51	13	17.43	21	105
1563	123.33	7	8.33	25	14.66	31	52	17	21.1	28	108
1702	136.67	19	6.00	6	13.66	23	60	29	22.63	33	110
1769	150.00	27	8.33	27	14	28	53	21	18.86	25	128
1552	175.00	31	9.67	31	14.33	30	64.66	31	16.76	16	139
1554	180.00	32	10.00	33	15	32	70	33	15.56	12	142
1555	193.33	33	9.67	32	14	24	66	32	20.43	27	148

Result on Agronomic traits field evaluation: The summary of the mean result on the 3 year field evaluation of agronomic characters of the Bambara groundnut accessions evaluated is presented on Table 7. Nine accessions had early emergence of 7 days after planting (DAP), while seven accessions recorded 50% emergence at 8 DAP. The number of accessions that had two seed per pod were 18, which represented approximately 55% of the distribution. Two accessions TVSU 1555 and 1917 flowered earlier than others at 35 DAP. On yield, accession TVSU 1688 recorded the highest mean seed yield per plant of 1150.5g. The second and third best high yielding accessions were TVSU 1638 and 1788 with a mean seed yield per plant of 720,8g and 616.2g respectively. On the contrary, accession TVSU 1819 had the least seed yield per plant of 69.2g. The highest plant height of 27 cm was observed for Accessions TVSU 1483 and 1917, while the least plant height of 16.2 cm was for TVSU 1788. Number of leaves per plant as shown on Table 7 showed that accessions TVSU 1688 and 1510 had the highest number of leaves of 387. Other accession whose mean number of leaves per plant was above 300 leaves were TVSU 1504 (380 leaves), 1509 (370 leaves), 1555 (368 leaves), 1638 (367 leaves) and 1697 (330 leaves). Accession TVSU 1766 recorded the highest mean internode length of 22.63 cm while TVSU 1512 had the least mean internode length of 10.09 cm.

DISCUSSION

Assessment of diversity on qualitative morphological characters showed a substantial level of variation among the Bambara groundnut accessions evaluated. The range of variation displayed by some qualitative morphological traits were broad enough to discriminate between one accession and the other. Out of the nine qualitative morphological descriptors used in this study, the highest variability was observed for ground colour of eye. The accessions were resolved into six groups, in which 12.1% exhibited brown triangular ground colour of eye, 54.5% revealed the type classified as others, 18.2% showed grey butterfly-like eye, and 9.1% displayed grey triangular eye. Furthermore 3% of the accessions each showed dark red butterfly and light brown types of ground colour of eye. pod colour was another qualitative morphological character that displayed a wide range of variation among the accessions. It differentiated the Bambara groundnut lines into five groups. Brown colour of pod constituted 57.6% of the distribution, while yellowish brown and black pod colours recorded 24.3% and 12.1% respectively. The least, 3% was for accessions with purple and reddish pod colour each. Other qualitative morphological features that showed some variation among the Bambara groundnut accessions were leaflet shape, pod shape and ground colour of eye. These results have some implication in breeding and selection programmes for crop improvement in Bambara groundnut. It has been reported that selection is effective only when significant genetic variability exits in high frequency among the genotypes (Hahn,1997; Adebisi *et al*., 2001). Several other works have reported substantial level of variation in qualitative morphological characters in Bambara groundnut (Mohammed, 2014; Siise and Massawe, 2013; Abu and Buah, 2011).

Contrarily, the least qualitative morphological variability was observed for eye pattern that discriminated the accessions into only two classes. The accessions that recorded eye as thin lines constituted 72.7% of the distribution, while the eye pattern displayed by 27.3% was no eye. Other qualitative characters that also showed low variability were growth habit, pod texture, and seed shape. Invariably these qualitative morphological characters did not exhibit a reasonable distinguishable identity among the evaluated Bambara groundnut collections. This result suggests the level of relatedness among the accession evaluated, which is an expected natural occurrence. This implies that more descriptors be used in the characterization of the accessions to delimit them into distinct groups (Kok *et al*.,1989), as was done in this study. In addition, the similarity these accessions of Bambara groundnut exhibited over these traits despite the wide geographical area of their collections suggests that the crop has not developed significant variation for these morphological qualitative traits. Being an extreme inbreeder, natural crossing and selection of accessions over several generations that would have enabled evolution of diverse type was suppressed (Appa Rao *et al*., 1996). Moreover, this situation may have been compounded by duplicates maintained as separate accessions with different identification number over a broadly different environment, thereby reducing the actual variation.

Table 7. Mean result on field evaluation of agronomic traits.

Accessions	Days to emergence	50% emergence	Number of leaves	Number of branches	Plant height	Days to flowering	Number of seeds per pod	Number of nodes	Internode length	Pod length	Yield
1483	8	8	244	9.7	27	37	1	8.4	16.93	22.3	188.5
1503	8	10	335	8.3	21.2	39	1	10.8	17.3	20.1	318
1504	7	9	380	11.7	22	37	1	9	15.36	18.5	157.8
1509	8	8	370	9.8	20	39	2	10.8	12.73	23.2	264.7
1510	8	9	387	8	20	38	1	6.8	12.16	21.5	383.2
1512	8	10	144.4	9.3	22	41	2	9.3	10.09	23.8	187.4
1513	8	9	249	15.9	18.1	38	2	7.3	15	22.3	381
1552	10	11	162	8.8	25	37	2	8.2	18.23	20	319.6
1554	10	10	251	7.2	25	42	1	9.1	15.66	19	235.3
1555	10	10	368	6.7	25.2	35	1	7.1	12.4	20	331.9
1559	7	9	266	7.2	23	40	2	9.3	21.33	21.4	273.8
1563	9	10	241.2	8.1	22	37	2	12.7	14.4	21.4	193.4
1584	7	9	215	9.8	23	37	2	8.2	20.4	32.8	115.9
1591	7	8	187.4	8	24	36	2	6.9	14.36	29.8	197.2
1604	8	9	259	8.4	18	37	2	6.6	17	27.7	243.4
1605	8	8	247.6	7.6	19.1	37	1	7.2	14.53	19.3	474.3
1610	7	10	300	9.3	19	41	1	7.7	13.13	23.3	115.5
1614	7	9	117.2	10.7	21	41	2	8	15.13	24.5	272.2
1620	8	9	282	8.2	23	38	1	7.3	22.43	22.2	227.9
1625	7	8	289	7	20	38	1	8	18.2	23.1	198.4
1627	8	9	220	13.3	17	37	2	7.6	21.3	23	231.2
1631	8	10	285	9.4	18	37	1	10.4	15.66	22.7	141
1638	7	8	367	10	22	37	2	10.4	21.16	25.9	720.8
1639	9	10	271.2	10.2	20	38	1	8.1	17.26	23.8	102.1
1688	9	10	387	12.5	26	37	2	11.9	18.4	22.9	1150.5
1697	8	9	330	6	26	37	2	8.3	16.36	23.8	107.4
1702	7	8	258	7.1	20.4	37	2	6.8	17.43	24.3	306.6
1713	10	10	31.43	7.2	24	39	2	9.9	21.1	23.9	476.3
1766	9	10	228	10	22	37	1	9	22.63	24.5	148.5
1769	8	9	295	6.8	24	37	1	8.4	18.86	22.5	233.9
1788	10	11	249	7.4	16.2	36	2	11.1	16.76	21.8	616.2
1819	8	9	169	6.6	22	40	2	7.6	15.56	21.3	69.2
1917	9	10	122	8.6	27	35	1	5.9	20.43	20.9	158

Analysis of variance result on the twenty one quantitative (agronomic) characters showed that significant differences ($p<0.05$) were observed for most of the characters in the three years. Comparatively quantitative characters revealed more variation than qualitative character as can be seen further in the principal component analysis (PCA) result. Eight out of twenty three morphological features (qualitative and quantitative that showed statistical significant differences) that accounted for 78.36 % of the phenotypic variance observed among the accessions were all quantitative traits. In fact the first four components accounted for 23.97%, 13.68%, 9.80%, and 8.61% in that order of the observed morphological variations among the accessions, and the traits with major loadings in these components were terminal leaflet length, terminal leaflet width, petiole length, pod width, seed width, seed weight, terminal leaflet shape, number of branches, number of nodes, ground colour of eye, number of leaves, number of stems, and internode length. Further investigation into this result clearly showed that all these traits with major loadings in the first four components of the PCA were quantitative except for terminal leaflet shape and ground colour of eye that were qualitative. Invariably quantitative characters were largely responsible for the observed wide differences that exit among the accession. Several other workers have reported similar result on Bambara groundnut (Hudu and Saaka, 2011; Ntundu *et al*., 2006; Siise and Massawe, 2013). The broad variability exhibited by the quantitative characters in the evaluated Bambara groundnut collections indicates that there can be opportunity for selection of superior progenies with respect to these traits when crosses are made from among the accessions. This is important in the improvement of the crop through conventional breeding method, especially for long term crop improvement where diverse genotypes are required as parental stocks (Ariyo and Odulaja,1991). In addition, this observed wide variation can also be an advantage in the improvement of the crop through selection which can only be achieved by imposing selection on the existing variations. Success in selection programmes for crop improvement depends on the available genetic diversity to achieve the anticipated goals (Padulosi, 1993; Aliero and Morakinyo, 2001).

Pearson's Correlation study between quantitative characters to determine pairs of traits that vary in the same or opposite directions with seed yield showed that petiole length recorded the highest significant positive correlation with seed yield, implying that increase in petiole length will contribute to increase in seed yield. Other traits that also recorded highly significant correlation with seed yield, and as such can be reliably significant in determining yield improvement in Bambara groundnut were vigour index, seed length, canopy width, and internode length. Previous works have reported in literature (Ouedrago *et al*., 2008; Ntundu *et al*., 2006; Goli *et al*., 1995) that these traits were significantly correlated with seed yield in Bambara groundnut. Invariably, these traits can be directly selected for yield improvement in Bambara groundnut. This result provides useful important information in breeding and selection for increase in seed yield in Bambara groundnut. Moreover, it was also used in ranking the accessions based on Rank Summation Index (RSI) method of Mulumba and Mock (1978), for the identification and selection of accession(s) with high yield potentials.

The summary of the result on the identification and selection of top best 5% of high yielding Bambara groundnut lines among the collections evaluated based on the selective index showed that accessions TVSU 1688 and TVSU 1638 recorded the lowest RSI scores of 31 and 43 respectively. They were invariably selected as the best top 5% high yielding lines. Correspondingly the agronomic field evaluation result of the accessions also showed that accessions TVSU 1688 and 1638 recorded the best performance on seed yield. TVSU 1688 and 1638 recorded the highest mean seed yield per plant of 1150.8g and 720.5g respectively. They were unvaryingly selected as the best high yielding accessions (best top 5%) among the 33 lines based on field evaluation result. Apparently, the result of the two methods (that is selective index and agronomic field evaluation) used in this study to identify high yielding accessions were in perfect agreement. The agronomic field evaluation result had confirmed the precision of the selective index result and vice versa. Invariably these two results have clearly shown that accessions TVSU 1688 and 1638 were inherently high yielding Bambara groundnut lines.

The precision of the result on identification and selection of accessions TSVU 1688 and 1638 as inherently high yielding accessions among the collections evaluated was furthermore supported by the result of the agronomic field trials. It showed that accessions TSVU 1688 and

1638 possessed good agronomic characters that has been reported to improve seed yield in Bambara groundnut (Goli *et al*.,1995; Ntundu *et al*., 2006; Ouedrago *et al*., 2008). In this study, these two accessions recorded high vigour index of 9 and 7 respectively and possessed long petioles and internode lengths. Plant height of these two accessions were relatively high- 26 and 22 cm respectively. Furthermore, they had high mean number of stems per plant of 11.9 and 10.4 respectively, and their mean number of branches per plant were 12.5 and 10 respectively. Similarly, they had high mean number of leaves per plant of 387 and 367 respectively. These outstanding agronomic characters of accessions TSVU 1688 and 1638 have been reported to have some implications on weed control, and optimum leaf exposure to radiation (Goli *et al*.,1995).

CONCLUSION

In the light of the above observations; the result of this study on yield improvement on *Vigna subterranea*, is exact, and have clearly shown that accessions TSVU1688 and 1638, were inherently high yielding lines of Bambara groundnut and as such can be grown for yield improvement in Bambara groundnut. The precision of these results is high and significant based on the simplicity and clarity of the methods used in arriving at the conclusion. Hence, this present study has clearly contributed to yield improvement in this agronomical and nutritionally important but neglected crop; Bambara groundnut.

ACKNOWLEDGEMENT

We wish to thank the staff of genetic resource unit of International Institute of Agriculture, Ibadan for providing us with seeds of the thirty three accessions of Bambara groundnut used for this study.

REFERENCES

Adebisi, M.A, Ariyo, J.O. and Kehinde, B.O. (2001). Variation and correlation in quantitative characteristics in Soybean. In the proceedings of the 35th Annual Conference of the Agricultural Society of Nigeria held at University of Agricultural Abeokuta, pp121-125.

Ajala, S. O., L. M. Smith II, and A. Odulaja (1995). Potential of Kenyan Local maize (Zea mays L) germplasm as a source of resistance to the spotted stem borer chilopartellus (Swinhoe). Trop. Agric. (Trinidad), 72 (4): 297 - 302.

Aliero, A.A. and Morakinyo, J.A. (2001). Characterization of *Digitaria exilis* (Keppa). Stapf and *D. iburua*Stapf accessions. Nigerian J. Genet. 16(2001):10-21.

Aliyu, S. and Massawe, F.J. (2013). Microsatellites based marker molecular analysis of Ghanaian Bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces alongside morphological characterization. Genet Resour Crop Evol 60:777–787.

Allard, R. W. (1960). Principles of plant breeding. John Wiley and Sons Inc. New York. Pp 458.

AppaRoa, S., Mengesha, M.H. and Reddy, K.H. (1996). Diversity of Pearl millet germplasm from Cameroon, Crop Evolution, 43:173.

Ariyo, O.J and Oduaja, A (1991). Numerical analysis variation among accession of Okra (*Abelimoschus esculentus* (L.) Moench, Malvacea. Annals of botany.

Baudoin, J.P and Mergeai, G. (2001). Grain legumes: Bambara groundnut (*Vigna Subterreneae* (L.) Verdc) in crop production in Tropcal Africa, Roman H.

Breseghello, F. and Coelho, A.S.G. (2013). Traditional and Modern Plant Breeding Methods with Examples in Rice (*Oryzasativa* L.), J. Agric. Food Chem. 61, 8277–8286.

Chahal, G.S., and Gosal, S. S. (2002). Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches, Alpha Science Int'l Ltd. 604 pp.

Cobley, L.S. and Steel, W.M. (1976). Introduction to botany of tropical crops, 2nd edition, Logman, London.

Doku, E.V. (1995). Ghana In: Heller, J. Begemann, F., and Mushonga, J. (Eds.), pp 11-18. Bambara Groundnut (Vigna subterranea L. Verdc.). Promoting the Conservation and Use of underutilised and Neglected Crops. 9. Proceeding of Workshop on Conservation and Improvement of Bambara Groundnuts (Vigna subterranea L. Verdc.), 14-16 November 1995, Harare, Zimbabwe

Duruigbo, C.J. (2004). The effect of yam set weights and poultry manure rates on the growth and yield of yam/maize/cassava relay mixtures. Ph.D. Thesis submitted to Dept. of Crop Science and Technology, Federal University of Technology. Owerri 172pp.

GENSTAT (2003) GENSTAT 5.0 Release 4.23DE, Discovery Edition 3, Lawes Agricultural Trust, Rothamsted Experimental Station.

Goli, A.E., Begemann, F., Ng, N.Q. (1995) Characterization of IITA's Bambara groundnut collection. In: Proceedings of the workshop, conservation and improvement of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) 14–16 November, 1995, Harare Zimbabwe

Goussard, P.G. (2004) Improving grape vine material through selection. Department of Viticulture. Stellenbosch University. Lecture notes.

Hahn, S.K. (1997). Sweet potato, in: Ecophysiology of Tropical Crops, eds Alvim, R.T. and T.T. Kozlowski, Academic Press New York, pp237-248.

Hudu BA, Saaka SJB (2011) Characterization of Bambara groundnut landraces and their evaluation by farmers in the upper West Region of Ghana. J Dev Sustain Agric 6:64–74

IPGR/IITA/BAMNET (2000). Descriptors for Bambara groundnut (*Vigna subterranea*) International Plant Genetic Resources Institute, Rome, Italy; International Institute of Tropical Agriculture, Ibadan, Nigeria; The International Bambara Groundnut Network, Germany. ISBN 92-9043-461-9

Kok, P.D., Robetese, J.P. and E.N. Vanwick,1989. Systematic study of Digitaria section Digitaria (poaceae) in south Africa. South Africa J, Bot., 55(2):14111-153.

Kone, M., Patat-Ochatt, E.M., Conreux, C.,and Samgwan, R.S.S.J. (2007). Invitro morph genesis from cotyledon and epicotyls explants and flow cytometary distinction between landrace of Bambara groundnut (*Vigna subterranea* (L.) Verdc) an under-utilized grain legume. Plant Cell Tiss Organ Cult. 88:61-75.

Marandu, W.Y.F., and Ntundu, W.H. (1995). The Status of Under-utilised Crops in Tanzania: In Genetic Resources and Utilization of Under-utilized Crops in Southern and Eastern Africa. Proceeding of Regional Workshop held at Nelspruit, South Africa. K. Anthony, N. Haq and B. Cilliers (eds). Dynamic Ad CC, Nelspruit, pp. 116–129

Massawe, F. J., Mwale, S.S; Azam-Ali, S.N. and Roberts, J.A. (2005). Breeding in Bambara groundnut (*Vigna subterranea* (L.) Verdc): strategic considerations. Africa Journal of Biotechnology Vol.4 (6): 177-179.

Mulumba, N.N. and J. J. Mock, (1978). Improvement of yield potential of the Eto Blanco maize (Zea mays L.) population by breeding for plant traits. Egyptian J. Genet. Cytol. 7: 40 - 51.

Ntundu, W.H. (1997) Tanzania Country Report Bambara groundnut (*Vigna subterranean* (L.) Verdc.) In Heller J; Begamann, F. and Mushonga, J. (eds). Promoting the conservation and use of underutilized and neglected crop of Proc. Of the workshop on conservation and improvement of Bambara groundnut, Nov 14-16, Harare, Zimbabwe, pp53-58.

Ntundu, W.H., Shillah, S.A., Marandu, W.Y.F., and Christiansen, J.L. (2006) Morphological diversity of Bambara groundnut (Vigna subterranea (L.) Verdc.) landraces in Tanzania. Genet Resour Crop Evol 53:367–378

Ouedrago, M.O., Jeremy, T.O., Jean Baptiste, T., Didier, B., Clementine, B.D., Gnissa, K. (2008) Characterization and evaluation of accessions of Bambara groundnut (*Vigna subterranea* (L.) Verd court) from Burkina Faso. Sci Nat 5(2):191–197

Padulosi, S. (1993). Genetic diversity, taxonomy and eco-geographical survey of the wild relatives of Cowpea (Vigna unguiculate (L) Walp), Ph.D. thesis, University of Catholique de Louvain-la-Neuve, Belgium.

Tindall, H.D. (1983). Vegetables in the Tropics. English Language Book Society, Tropical crops - 5thirty three pages.

Uguru, M.I. (1996). Crop production: tools, techniques and practice. Fulladu publishing company. 153pp.

Uguru, M.I. (2005). Crop genetics and breeding (revised ed), Epharate press, Nsukka 113pp

Uguru, M.I. and Agwatu, U.K. (2006). Cytogenetic studies on Bambara groundnut (*Vigna subterranean* (L.) Verdc) J. Genet. & Breed. 60:00-00.