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Yield Components and Yield Stability Performance of Some Nigerian Accessions of Bambara Groundnut [*Vigna subterranea* (L.) Verdc.] in Six Environments

Opeyemi T. Osundare[1, 2, 3], Benjamin O. Akinyele[1], Alexander C. Odiyi[1],
Olaniyi A. Oyatomi[2], Michael T. Abberton[2]

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ABSTRACT

Background: Bambara groundnut accessions over the years had been unstable in its yield potentials with contrasting yield inferences, factors not limited to variety, soil types and nutrients, climate change, time had been bottlenecks for scientist to breakthrough in stability research. Field experiments were conducted in three years at two locations to assess and identify accessions with stable yield and determine the relationship between yield and yield components.

Methods: Seeds of 100 accessions of Bambara groundnut of Nigerian origin were obtained from the genebank of the Genetic Resources Center, IITA in 2017. Randomized complete block design (RCBD) was used in the evaluation for three years in two locations. PROC ANOVA procedure on the statistical analytical system (SAS, 9.4) was used to determine significant differences and stability equation was used to identify yield stable index.

Result: Correlation showed that seven yield contributing traits had positive and significant correlation with yield per hectare. Yield stability analysis indicated nine of the selected accessions were stable in the expression of its yield potentials in the environments and years. This study showed that selection for high yielding and stable accessions could be useful for further utilization of genetic resources in achieving food security.

Key words: Bambara groundnut, Locations, Years, Yield component, Yield stability.

INTRODUCTION

Bambara groundnut [*Vigna subterranea* (L.) Verdc.] is an herbaceous, intermediate, annual, self-pollinating crop belonging to the family Leguminosae, subfamily Papilionoideae and genus *Vigna* Osundare *et al.* (2018). The crop is an important legume in Africa after cowpea [*Vigna unguiculata* (L.) Walp.] (Atoyebi *et al*., 2017) and it is popular in Africa because of its resistance to drought and, its ability to produce reasonable yield on poor soils (Mayes *et al*., 2019). Bambara groundnut has the potential to improve nutrition, boost food security, foster rural development and support sustainable land use (Berchie *et al*., 2010). Bambara groundnut varied widely depending on accessions and environmental conditions. Shareef *et al*., 2013; Berchie *et al*., 2010; Mwale *et al*., 2004 also reported reasonable yield of Bambara groundnut accessions with minimal input, low rainfall and poor soil fertility. Mayes, *et al*., 2019; Chai *et al*., 2017 further reiterated that Bambara groundnut are drought resistant compared to other crops but that yields are highly affected by water stress and even moderate water stress can cause high yield losses.

Yield evaluation of Bambara groundnut accessions over the years had been unstable and the inconsistency in such yield is caused by, but not limited to variety, soil nutrients, climate change, time and biodiversity. These factors had been bottlenecks for scientist to break through in stability research. Yates and Cochran, (1938) reported that agricultural experiments on the same, or group of factors, are usually carried out in a number of places and from year to year, due to differences in soil, agronomic practices, climatic conditions and other variations in the environment.

Selection for biologically diverse accessions of Bambara groundnut that are high yielding and maintain stable yield in recent weather changes and hence, better performing is a better attempt to ensuring food security. This work assessed and identified Bambara groundnut accessions with stable yield and determined the relationship between yield and yield components.

[1]Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria.
[2]Genetic Resources Center, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.
[3]Department of Crop Science and Horticulture, Federal University Oye-Ekiti, PMB 373, Ekiti State, Nigeria.

Corresponding Author: Opeyemi T. Osundare, Department of Crop, Soil and Pest management, Federal University of Technology, Akure, Nigeria. Email: opeyemi.osundare@fuoye.edu.ng

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MATERIALS AND METHODS

The trials were carried out at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and its research station, located at the Institute of Agricultural Research and Training (IAR and T) Ikenne, Nigeria for three years (2017/2018, 2018/2019 and 2019/2020). Ibadan is located on coordinate's 7.38°N and 3.94°E and it is situated at 181 meters above sea level. The average annual temperature is 26.5°C and about 1311 mm of precipitation falls annually with 81% mean relative humidity. Ikenne is on coordinate's 6.87°N and 3.71°E and 235.2 meters above sea level, has an annual rainfall of 1200 mm, 65% mean relative humidity and 21.4°C mean temperature.

Seeds of one hundred accessions of Bambara groundnut were obtained from the genebank of the Genetic Resources Center (GRC), International Institute of Tropical Agriculture, Ibadan, Nigeria in 2017 and used for the field experiments. Total block size was 1,050 m^2 (21 m × 50 m) and each plot was 1 m × 2.5 m. Inter and intra row spacing was 1.00 m and 0.25 m. The experiments were laid out in a randomized complete block design (RCBD) with three replications. Each plot contained 10 plants.

Twenty nine quantitative traits were collected using the descriptor for Bambara groundnut (IPGRI/IITA/BAMNET, 2000). Data on the traits from the replicated trials were generated using five tagged plants (at the middle of the row).

Traits in the three replications of the locations and in the three years across locations were computed for all accessions and subjected to analysis of variance (ANOVA), using the PROC ANOVA procedure on statistical analytical system (SAS, version 9.4). Treatments means were separated by Duncan multiple range test (DRMT) with significant differences at 1% and 5% levels of probability. Pearson correlation was carried out using the PROC CORR procedure to indicate the association of yield components and yield in the observed years.

The established variance of the field trial observations were used to calculate yield stability index for locations (E) and in years (Y) for each accession. Population mean was calculated and used as mean yield for each accession.

Yield stability (S_i^2) index were classified and denoted as $S_i^2 \geq 1$ (have above average sensitivity to location mean yield changes and are expected to be more productive in yielding sites and seasons). S_i^2 index ≤ 1 (are stable and are relatively insensitive to location mean yield and may be well suited to producing reliable yields in low yielding sites and seasons). $S_i^2 = 1$ (have a responsiveness close to the group mean) according to Tahir *et al*., (2015); Mutava *et al*., (2011) and Shukla, (1972).

S_i^2 was calculated using Type 1 or static stability concept for stability analysis as:

$$\frac{\Sigma(RiJ - mj)^2}{(e - 1)}$$ (Becker and Leon, 1988; Lin *et al*., 1986)

Where,

RiJ = Observed genotype yield response in the environments.

mj = Genotype mean yield across environments.

e = Number of environments.

This concept was adopted to ensure the consistency both in time and in space, *i.e.* across environments belonging to the same or different sites, where a stable accession tends to maintain constant yield across environments.

RESULTS AND DISCUSSION

Yield stability

Table 1 showed stability analysis for locations (E) and years (Y). It revealed 9 out of the selected 100 accessions were stable (≤1 stability index) in the expression of their yield potential. In the three years (Y) and locations (E) of the experiments, accessions TVSu-1241, TVSu-1242, TVSu-2102, TVSu-2106, TVSu-579, TVSu-644, TVSu-667, TVSu-83 and TVSu-838 had less than one (≤1) stability index,

Table 1: Stability analysis of 100 accessions of Bambara groundnut in 6 environments (2 locations for 3 years).

	Stability coefficients (≤1=stable and ≥1=unstable)					
Accession	Geno. yield	Mean yield	Σ(Rij-mj)	$\Sigma(Rij\text{-}mj)^2$	Stability index (E)	Stability index (Y)
TVSu-1241	39.516	39.08	0.436	0.190	0.03	0.09
TVSu-1242	39.302	39.08	0.222	0.049	0.00	0.02
TVSu-2102	38.563	39.08	-0.517	0.267	0.05	0.13
TVSu-2106	39.785	39.08	0.705	0.497	0.09	0.24
TVSu-268	37.217	39.08	-1.863	3.470	0.69	1.73
TVSu-273	37.48	39.08	-1.60	2.560	0.51	1.28
TVSu-351	37.283	39.08	-1.797	3.229	0.64	1.61
TVSu-363	37.125	39.08	-1.955	3.822	0.76	1.91
TVSu-366	40.694	39.08	1.614	2.604	0.52	1.30
TVSu-579	38.689	39.08	-0.391	0.152	0.03	0.07
TVSu-644	39.645	39.08	0.565	0.319	0.06	0.15
TVSu-667	37.034	39.08	-2.046	4.186	0.83	0.12
TVSu-83	39.681	39.08	0.601	0.361	0.07	0.18
TVSu-838	39.44	39.08	0.36	0.129	0.02	0.06

(Environment=E and Year=Y).

Table 2: Correlation coefficients of 28 quantitative traits observed on 100 accessions of Bambara groundnut in three years.

	Traits association													
	PH cm	TLL mm	TLW mm	NTLvs	Pet L mm	PlanSpr	IntL mm	BL mm	PdclL mm	ND to FF	DtoM	NFpP	NPdspP	YKgpHa
PHcm	1													
TLL mm	0.52**	1												
TLW mm	0.47**	0.68**	1											
NTLvs	0.46**	0.16**	0.05ns	1										
Pet L mm	0.93**	0.39**	0.35**	0.54**	1									
PlanSpr	0.66**	0.33**	0.36**	0.25**	0.62**	1								
IntL mm	0.18**	0.07ns	0.23**	0.02ns	0.24**	0.21**	1							
BL mm	0.10**	0.00ns	0.10**	-0.04ns	0.06ns	0.16**	0.07ns	1						
PdclL mm	0.04ns	0.01ns	0.09**	-0.02ns	0.01ns	0.08ns	0.14**	0.02ns	1					
NDtoFF	-0.50**	-0.16**	-0.13**	-0.41**	-0.58**	-0.43**	-0.37**	-0.01ns	-0.04ns	1				
Dto50%F	-0.50**	-0.16**	-0.13**	-0.41**	-0.58**	-0.43**	-0.37**	-0.01ns	-0.04ns	1.00**	1			
DtoM	0.77**	0.34**	0.23**	0.55**	0.81**	0.65**	0.04ns	0.05ns	0.00ns	-0.55ns	-0.55**	1		
NFpP	0.04ns	0.08ns	0.08ns	0.05ns	0.03ns	-0.01ns	0.01ns	0.05ns	0.05ns	-0.01ns	-0.01**	0.02ns	1	
NPdspP	0.00ns	0.05ns	0.03ns	0.08ns	-0.01ns	-0.14**	-0.12**	-0.09**	0.07ns	0.13**	0.13**	-0.01ns	0.00ns	1
YKgpHa	0.06ns	0.19**	0.16**	0.08ns	0.01ns	-0.10**	-0.11**	-0.08ns	0.06ns	0.09**	0.09**	-0.01ns	0.02ns0.81**	1

*Significant @ $P \leq 0.05$, ** significant @ $P \leq 0.01$, ns = Not significant.

Legend: PH=Plant height, TLL=Terminal leaflet length, TLW=Terminal leaflet width, NTLvs=Number of trifoliate leaves, PetL=Petiole.
length, Plan Spr=Plant spread, IntL=Internode length, BL= Banner length, NDtoFF=Number of days to first flowering.
PdclL=Peduncle length, NDtoM=Number of days to maturity, NFpP=Number of flower per peduncle.
NDto50%F=Number of days to 50% Flowering, NPdspP=Number of pods per plot, YKgpHa=Yield in kilogramme per ha.

Table 2: Cont.: Correlation coefficients of 28 quantitative traits observed on 100 accessions of Bambara groundnut in three years.

	Traits association													
	YpP g	NSdpPd	PdL mm	PdW mm	SdL mm	SdW mm	ShThk mm	Sdwt g	Chfwt g	Shperc	Shdhv/P	100-sdwt g	Y/Plant g	YKgpHa
YpP g	1													
NSdpPd	-0.04ns	1												
PdL mm	0.09ns	0.19**	1											
PdW mm	0.03ns	-0.09ns	0.35**	1										
SdL mm	0.16**	-0.13ns	0.36**	0.65**	1									
SdW mm	0.05ns	-0.12ns	0.23**	0.58**	0.62**	1								
ShThk mm	0.00ns	-0.06ns	0.07ns	0.22**	0.18**	0.14**	1							
Sdwt g	0.28**	-0.01ns	-0.06ns	-0.08ns	-0.02ns	-0.01ns	-0.06ns	1						
Chfwt g	0.25**	-0.01ns	-0.02ns	-0.03ns	0.01ns	0.01ns	-0.01ns	0.80**	1					
Shperc	0.06ns	-0.04ns	0.05ns	0.00ns	0.05ns	0.01ns	0.07ns	-0.08ns	0.35**	1				
Shdhv/P	-0.06ns	0.04ns	-0.04ns	0.00ns	-0.04ns	-0.01ns	-0.06ns	0.09**	-0.36**	-0.97**	1			
100-sdwt g	0.13**	-0.10ns	0.19**	0.38**	0.44**	0.32**	0.08ns	0.02ns	0.06ns	0.00	0.00ns	1		
Y/Plant g	0.46**	-0.08ns	0.05ns	-0.09ns	0.04ns	-0.02ns	0.01ns	0.18**	0.21**	0.31**	-0.30**	-0.01ns	1	
YKgpHa	1.00**	-0.04ns	0.09ns	0.03ns	0.16**	0.05ns	0.00ns	0.28**	0.25**	0.06ns	-0.06ns	0.13**	0.47**	1

*Significant @ P≤0.05, ** Significant @ P≤0.01, ns=Not significant.

Legend: NPdspP=Number of pods per plot, YpP=Yield per plot, YpHa=Yield per hectare (Kg), NSdpPd=Number of seed per pod.

PdL=Pod length, PdW=Pod width, SdL=Seed length, SdW=Seed width, Shthk=Shell thickness, Sdwt=Seed weight per plot.

Chfwt=Chaff weight, Shperc=Shelling percentage, Shdhv/P=Shelled harvest per plot, 100sdwt=100 seed weight.

Y plant=Yield per plant.

Table 3: Mean performance of the accessions based on the expression of yield components in the two locations for three years.

Location	Traits	Mean	Years	Mean
Ikenne	Terminal leaflet length (mm)	64.34a	1	59.93c
Ibadan		63.10b	2	69.02a
			3	62.16b
Ikenne	Terminal leaflet width (mm)	27.43b	1	26.00c
Ibadan		28.12a	2	29.64a
			3	27.66b
Ikenne	Plant spread (cm)	35.24b	1	28.43c
Ibadan		39.89a	2	44.35a
			3	39.91b
Ikenne	Internodes length (mm)	13.49b	1	11.29c
Ibadan		13.84a	2	11.46b
			3	18.24a
Ikenne	Number of days to first flowering	36.78b	1	42.22a
Ibadan		37.44a	2	35.59b
			3	33.52c
Ikenne	Number of days to 50% flowering	38.78b	1	44.22a
Ibadan		39.44a	2	37.59b
			3	35.52c
Ikenne	Seed length (mm)	11.21a	1	10.67b
Ibadan		11.13a	2	11.44a
			3	11.38a
Ikenne	Yield per plant (g)	40.91a	1	50.34b
Ibadan		37.23b	2	53.76a
			3	13.80c
Ikenne	Number of pods per plot	195.02a	1	196.31a
Ibadan		163.40b	2	201.20a
			3	141.27b
Ikenne	Yield per plot (g)	199.21a	1	202.01a
Ibadan		165.80b	2	207.09a
			3	139.01b
Ikenne	Yield (kg/hectare)	793.25a	1	808.05a
Ibadan		663.20b	2	828.39a
			3	552.34b
Ikenne	Pod length (mm)	18.38a	1	17.96b
	Ibadan	18.22a	2	18.48a
			3	18.45a
Ikenne	Seed weight per plot (g)	131.94a	1	129.59a
Ibadan		108.43b	2	130.18a
			3	100.46b
Ikenne	Shelling percentage	33.25a	1	35.95b
Ibadan		33.89a	2	37.09a
			3	27.58c
Ikenne	Chaff weight (g)	48.08a	1	46.87a
Ibadan		39.85b	2	47.39a
		sss	3	37.57b
Ikenne	Shelled harvest (%)	66.67a	1	64.04b
Ibadan		65.99b	2	62.90c
			3	72.15a
Ikenne	100 seed weight (g)	68.28a	1	65.87b
Ibadan		68.12a	2	65.59b
			3	73.11a

which indicated that these accessions were stable and were relatively insensitive to locations mean yield in the years and suited to producing reliable yields in low yielding sites and seasons.

This further indicated that yield stability of stable Bambara groundnut accessions might be genetic and less influenced by factors responsible for instability, hence, produce reliable yields with respective changing environmental factors overtime within given location. This was supported by Muniswamy *et al*. (2022) who reported yield stability in some genotypes of pigeon pea. Tahir *et al.* (2015) also reported yield stability in some genotypes of wheat; Clarke *et al*. (2011); Mutava *et al*. (2011); Annicchiarico (2002); Becker and Leon (1988); Lin *et al*. (1986) and Shukla (1972) reported on yield stability of crops. Accessions TVSu-268, TVSu-273, TVSu-351, TVSu-363 and TVSu-366 had less than one (≤1) stability index in the locations only, which indicated that these accessions had stable yield in the locations but unstable in the years of observation, which further reiterated that stability in locations does not ascertain stability in the years. This further indicated that accessions may be stable in environments within the year but considerable changes in the environmental factors in years may result to unexpected yield fluctuations. This was also supported by Becker and Leon (1988); Lin *et al*. (1986).

The instability observed on some of the accessions yield in the years was also confirmed by Toure *et al*. (2012) who reiterated that yield of Bambara groundnut varies widely, depending on the accession. Accessions with instability indexes had also been reported by Hammer *et al*. (2001) who reported that traits, expected seasonal conditions and agronomic management create diversity in crops. Mkandawire (2007) also reported that Bambara groundnut can grow and produce reasonable yield on laterite soils and made better use of the elements of weather including thermal duration or day length to produce more flower for higher yields.

Yield contributing traits

Correlation coefficients of yield and yield components were shown in (Table 2). Positive and significant correlation showed eight morphological traits were associated with plant height, which indicated that an increase in plant height might definitely lead to significant increase in the other, in other words, an increase in plant height might lead to an increase in internodes length or petiole length or plant spread, terminal leaflet length or width simultaneously. Similar positive and significant correlation was also reported by Bonny *et al*. (2019); Olukolu *et al*. (2012). Yield per plot also had positive and significant correlation with seed length, seed weight per plot, chaff weight, 100-seed weight, yield per plant and yield per hectare, similar results of positive association of traits were also reported by Kebede *et al*. (2001). This affirmed that selection based on these characters may be effective in improving yield.

Number of trifoliate leaves had negative and significant correlation with number of days to first flowering and number of days to 50% flowering, meaning that increasing days to flowering might lead to delay in crop yield harvest. Shelling percentage had negative and significant correlation with shelled harvest per plot. This indicated that an increase in shelling percentage decreases or reduces shelled harvest per plot in Bambara groundnut. This may be due to variation in shell thickness, seed weight per plot, seed length, seed width and yield per plant among the accessions.

Yield in locations and years

Table 3 showed means observed in the locations and years which showed variability and instability in the expression of traits in the production of Bambara groundnut. In the locations and years, number of days to first flowering, number of days to 50% flowering, seed length, yield per plant, number of pods per plot, yield per plot, yield per hectare, pod length, seed weight per plot, shelling percentage, chaff weight, shelled harvest and 100-seed weight showed varying mean responses in the locations and years. Massawe *et al*. (2005) reported that timing is an important factor in the production of Bambara groundnut.

CONCLUSION

Yield stability analysis showed that some accessions used in this study were stable in the expression of their yield potentials, irrespective of the location and year. This could be well suited in producing reliable yields, even in low yielding sites and seasons. This does not indicate that the accessions are high yielding but simply, the accessions exhibited their yield stability characteristics in varying environments. Nine accessions identified that adapted to the factors with unfailing, reliable and stable yield (TVSu-1241, TVSu-1242, TVSu-2102, TVSu-2106, TVSu-579, TVSu-644, TVSu-667, TVSu-83 and TVSu-838) should be recommended to farmers for stable yield and continuous utilization of genetic resources.

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Conflict of interest

The authors declare that we have no conflict of interest.

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