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Divergence in African Yam Bean Accessions, Promote Utilization

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Abstract

Sphenostylis stenocarpa (African yam bean) is an underutilized legume with significant nutritional benefits that could enhance security of food and nutrition in Nigeria. Despite its potential, limited knowledge of the available germplasm and their diverse traits has restricted its optimal use. This study assessed 10 accessions of African yam bean using morphological descriptors. Quantitative traits such as terminal leaf length and width, petiole length, peduncle length (cm), number of leaves, pod weight and pod length showed significant variation among the accessions. Cluster analysis (Ward's method) grouped the accessions into three clusters, primarily differentiated by traits like flowering duration, maturity period, petiole length, terminal leaf width, and pod length. Principal Component Analysis (PCA) revealed that these traits were the main contributors to variability in the first principal component. Genetic correlation analysis demonstrated significant interrelationships among the 15 measured traits, suggesting that selecting one trait could indirectly improve others in breeding programs. This study provides critical insights into genetic diversity present in the African yam bean gene pool, offering valuable information for its genetic enhancement and breeding with the aim to addressing food and nutritional security issues in sub-Saharan Africa.

Keywords: Quantitative Characters, African Yam Bean, Flowering, Cluster Analysis

Introduction

Sphenostylis stenocarpa commonly known as the African yam bean, is an extremely nutritious legume that produces both seeds and tubers in tropical regions of Africa. It is a member of the Fabaceae family, one of the most economically significant families among dicotyledons, this crop is of tropical African origin'. The seeds are notable for their high protein content, approximately 37%, and around 64% carbohydrates [1, 2]. The tubers, on the other hand, contain about 16% protein and approximately 68% carbohydrates [3].

The crop's leaves, seeds and tubers are versatile in culinary applications. Seeds can be prepared by roasting, boiling, or processing into paste and are also used as seasoning [4]. Tubers are typically roasted or boiled, and the leaves are prepared as vegetables. Despite its high nutritional potential, the crop remains underutilized [5], primarily cultivated by smallholder farmers. However, its adoption is hindered by challenges such as prolonged

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cooking times and a lengthy maturity period of approximately 9 to 10 months [6]. Furthermore, limited attention from scientists, crop improvement experts, and donors has constrained its utilization. Notably, no varieties of African yam bean have been officially registered or released in Nigeria.

Given its potential and associated challenges, exploring genetic diversity within the African yam bean species is critical. Identifying variations can enable the development of improved or new varieties [7] to address the demands of a growing population. Rising global food security challenges, driven by population growth, decreased cultivable land, induced by urbanization and climate change, highlight the need to conserve and utilize plant genetic resources to enhance food and nutritional security [8].

Understanding phenotypic diversity within germplasm collections is essential for effective management and breeding programs. Assessing differences in performance among genetic materials is crucial for superior accessions selection and integrating them into crop improvement initiatives to enhance economically significant traits. Adewale *et al.* [9], have observed that seed coat color and pattern are key traits used for classifying African yam bean, though phenotypic descriptions often lack sufficient genetic data.

'Both phenotypic traits and molecular markers have been utilized to assess variation in crop germplasm' [7, 10, 11]. 'The National Centre for Genetic Resources and Biotechnology (NACGRAB) in Ibadan, Nigeria, maintains a significant collection of African yam bean germplasm, some of which are cultivated locally by farmers. This study aims to evaluate phenotypic variation in 10 African yam bean accessions conserved at the NACGRAB genebank and other national agricultural research institutions in Nigeria to identify unique accessions for breeding programs and the improvement of varieties.

Materials and Methods

Ten accessions of *Sphenostylis stenocarpa* were sourced from the genebank at the National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria. The accessions were evaluated at the NACGRAB experimental field using a randomized complete block design (RCBD) with three replicates. Each accession was cultivated in a two-row plot, with each row measuring 5 meters in length and spaced 1 meter apart within and between rows. Fertilizer application was carried out as required, and plots were kept weed-free through manual weeding. Two weeks after planting, the plants were staked to support climbing.

Data Collection

Quantitative morphological traits were measured to assess variation among the accessions. Data collection was carried out from ten plants per plot at 50% flowering. The traits recorded include: Vegetative traits: Number of leaves/plant (NOL), internode length (IL), petiole length (PetL), terminal leaf width (TLW), terminal leaf length (TLL) and peduncle length (PeL). Reproductive traits: pod width (PW), pod length (PL), Number of pods/peduncle (PP), number of locules/pod (LP), number of seeds/pod (SP), hundred seed weight (HSW), and weight/seed (WS). Additionally, days (50%) to flowering (DF) and maturity (DM) were assessed.

Data Analysis

The agronomic data collected were analyzed using Analysis of Variance (ANOVA) with SAS software version 9.4 (SAS Institute, 2011). Descriptive statistics were also calculated. Where significant differences were observed (5%), Fisher's Least Significant Difference (LSD) test was applied to compare means. Clustering analysis (using PAST software version 4.13) was performed to group accessions based on phenotypic similarities and calculate similarity coefficients.

Results

Significant variation was observed across all the measured traits (Table 1). The accessions NG/AO/11/08/028 and NG/AO/11/08/096 recorded the highest number of locules per pod (29), while the accessions AYB23, AYB 45C ST, and NG/EO/APR/09/007 had the lowest (18).

For agronomic traits, the internode length was between 9.9 cm and 13.9 cm, (average being 11.84 cm). Petiole length was between 4.9 cm and 6.5 cm, the average value being 5.61 cm. Number of leaves/plant ranged from 24 to 32, with an average of 27.8. Terminal leaf length was between 5 cm and 7.1 cm, (mean = 5.89 cm). Seed traits also displayed notable variability. Number of pods/peduncle was between 1 and 3, (average of 2). Pod length ranged from 21.7 cm to 25 cm, (mean = 23 cm). The number of seeds/pod ranged from 15 to 19, (average = 16.7). The weight of 100 seeds was between 18.9 g and 24.8 g, (average = 22.41 g).

The analysis of genetic correlation revealed significant relationships among the 15 traits studied. The correlations of these genotypic traits are presented in Figure 1. The dendrogram illustrating the genetic relationships among the traits grouped the 10 accessions into three distinct clusters (Figure 2). Accessions in Group 1 reached 50% flowering 88 days after planting.

The eigenvalues from the correlation matrix of the PCA, based on the 15 phenotypic traits, revealed that the first three principal components with eigenvalues greater than 1.0 explained 77.7% of the total variance (Table 3). Of the total variance (PC1), 34.89% showed a strong positive association with traits such as the terminal leaf length, number of leaves/plant, internode length, petiole length, terminal leaf width, locules per pod, 100-seed weight, seeds/pod, and weight/seed. Conversely, it was negatively associated with traits like days to 50% flowering, peduncle length, pod weight and days to maturity. The second principal component (PC2) and the third principal component (PC3) contributed 26.92% and 15.9% respectively, of the total variance.

Discussion

Traits such as terminal leaf width, terminal leaf length, and the number of leaves/plant proved effective in differentiating between accessions. Variability evaluation of plant genetic diversity is key in plant breeding and crop improvement programs. Developing new high yielding *Sphenostylis stenocarpa* variety is dependent on the present of variability in the available germplasm and this is crucial in contributing to nutritional and food security in Nigeria. Assessment of divergence based on qualitative and quantitative morphological characteristics in *Sphenostylis stenocarpa*, among the accessions evaluated, showed a significant variation, as observed for all traits. This implies the distinctiveness of the accessions studied. Aremu and Ibirinde [12] reported the level of divergence revealed by numbers of leaves/plant, terminal leave width and terminal leave length were adequate to distinguish between one accession and the other.

The significant correlations observed among traits were negatively or positively associated with the first and second PCA, indicating their critical role in explaining the variation among African yam bean accessions. These traits are therefore essential for effective characterization of the crop.

The hierarchical clustering grouped the accessions into three distinct clusters, demonstrating sufficient genetic divergence to justify germplasm selection. Accessions within the same group showed closer genetic relatedness compared to those in different groups [13]. The clustering pattern, based on genetic relationships among traits, confirmed the effectiveness of Ward's clustering method in delineating genetic diversity. Similar studies on phenotypic characteristics of underutilized legumes, including African yam bean [12], Lima bean [14], Pintoi peanut [15], and winged bean [16], also attributed relationships among traits to genetic linkage.

To facilitate efficient selection of parental lines, accessions with high average values from different clusters may be selected [17]. It is assumed that hybridization between genetically distinct accessions will produce desirable segregants. Consequently, accessions from diverse clusters with superior trait values may be chosen for breeding programs as parental lines with the aim of improving African yam bean.

Table 1: Mean performance of the evaluated African yam bean accessions

	NOL	IL (cm)	PetL	DF	DM	TLL (cm)	TLW	PeL (cm)	PP	PL (cm)	PW (g)	SP	LP	HSW (g)	WS(g)
AYB 23	25	11.2	5.2	90	140.3	5.5	1.9	20.7	3	22.2	8.3	16	18	24.80	0.248
AYB 23 ST	29	9.9	5.2	92	140.7	5.6	1.9	19.8	2	22.2	12.8	18	20	23.60	0.236
AYB 45C ST	28	10.9	5.9	95	146.3	5.5	1.9	17.8	2	21.8	12.7	16	18	22.30	0.223
AYB 61	30	11.0	6.4	90	139.7	5.3	1.8	24.2	3	21.2	5.6	17	19	24.80	0.248
AYB 91 LT	28	12.2	5.5	90	139.7	5.2	1.9	21.9	2	24.4	7.2	19	20	22.50	0.225
NG/AA/SEP/09/168	27	12.6	4.4	99	149.3	7.1	1.6	21.2	1	21.8	12.1	17	19	21.00	0.210
NG/AO/11/08/028	32	12.3	6.4	88	137.7	6.8	2.3	15.0	2	25.1	12.1	17	29	24.60	0.246
NG/AO/11/08/096	24	13.9	6.5	88	138.3	6	2	21.9	2	24.7	10.4	16	29	18.90	0.189
NG/AO/11/08/111	27	13.3	5.7	90	140.0	6.9	2.3	20.6	2	25	7.9	15	19	20.40	0.204
NG/EO/APR/09/007	28	11.1	4.9	98	149.3	5	1.3	23.1	1	21.7	12	16	18	21.20	0.212
Grand Mean	27.80	11.84	5.61	92.00	142.13	5.89	1.89	20.62	2.00	23.01	10.11	16.70	20.90	22.41	0.224
Standard deviation	2.23	1.19	0.68	3.84	4.41	0.74	0.29	2.55	0.69	1.52	2.54	1.15	4.19	1.97	0.020
Standard Error (±)	0.26	0.39	0.05	0.26	1.07	0.05	0.03	0.09	0.26	0.05	0.05	0.26	0.26	0.28	0.001
Mean square (Accession)	15.9**	4.5**	1.5**	147.3**	58.7**	1.8**	0.3**	20.9**	1.3**	7.4**	20.8**	4.0**	56.3**	12.5**	0.001**
CV (%)	1.14	1.31	1.13	0.34	0.93	1.07	1.67	0.54	15.81	0.27	0.63	1.89	1.51	0.05	0.282

NOL = number of leaves per plant; IL = Internode length; PetL = petiole length; DF = days to 50% flowering; DM = days to maturity; TLL= terminal leave length; TLW = terminal leaf width; PeL = peduncle length; PP = number of pods per peduncle; PL = pod length; PW = pod width; SP = number of seed per pod; LP = number of locules per pod; HSW = hundred seed weight; WS = weight per seed.

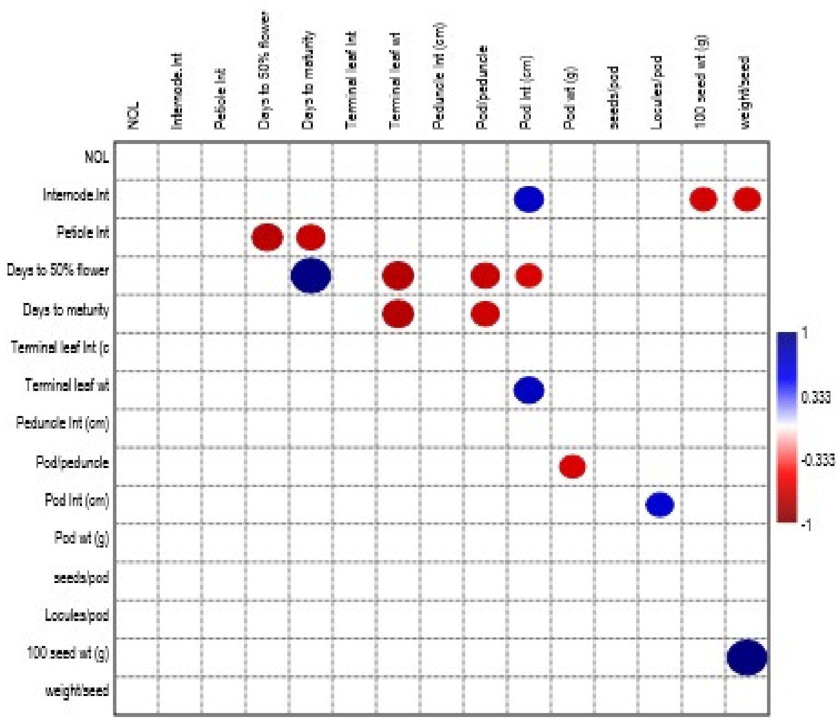

Figure 1: Correlations of morphological traits of 10 African yam bean accessions

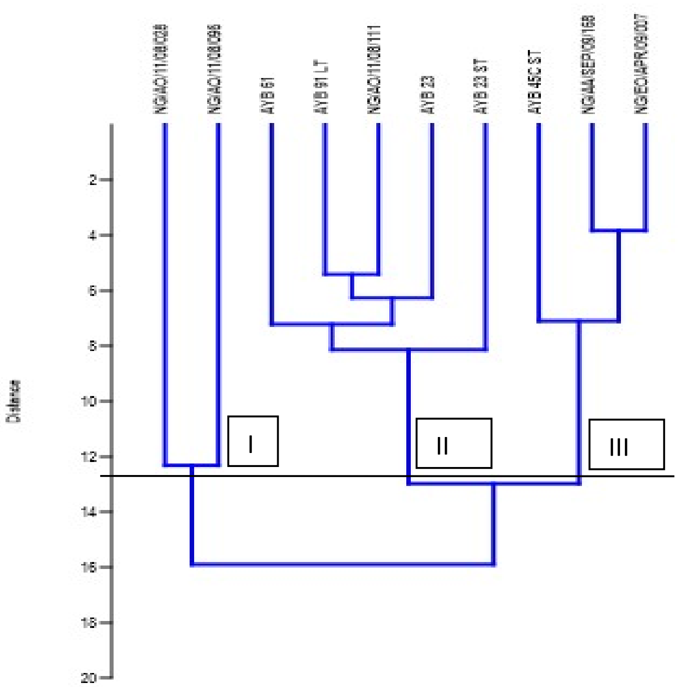

Figure 2: Dendrogram of the 10 African yam bean accessions following Ward's cluster analysis based on the Euclidean distance.

Table 2. Mean performance per cluster of 10 African yam bean accessions

Characters	I	II	III
	NG/AO/11/08/028, NG/AO/11/08/096	AYB 23, AYB 23 ST, AYB 61, AYB 91 LT, NG/AO/11/08/111	AYB 45C ST, NG/AA/SEP/09/168, NG/EO/APR/09/007
Leaves/plant	28.00±5.66	28.00±1.93	27.67±0.58
Internode length (cm)	13.10±1.13	11.52±1,29	11.53±0,93
Petiole length (cm)	6.45±0.07	5.60±0.49	5.07±0.76
Days to 50% flower	88.00±.0/.0	90.40±0.89	97.33±2.08
Days to maturity	138.00±0.542	140.02±0.43	148.30±1.73
Terminal leaf length(cm)	6.40±0.56	5.70±0.69	5.87±1.09
Terminal leaf width (cm)	2.15±9.21	1.96±0.19	1.60±0.30
Peduncle length (cm)	18.45±4.88	21.44±1.71	20.70±2.68
Pod/peduncle	2.00±0.0	2.40±0.55	1.33±0.58
Pod length (cm)	24.90±0.28	23.00±1.62	21.77±0.06
Pod weight (g)	11.25±1.20	8.36±2.69	12.27±0.38
seeds/pod	16.50±0,71	17.00±1.58	16.33±0.58
Locules/pod	29.00±0.0	19.20±0.84	18.33±0.58
100 seed weight (g)	21.75±4.03	23.22±1.84	21.50±-0.7
weight/seed	0.22±0.014	0.23±0.02	0.22±0.007

Table 3. Factor scores of observed characters, eigenvalues, and percentages of variances accounted for by the first three principal components of 10 African yam bean Accessions.

Characters	**PC 1**	**PC 2**	**PC 3**
Number of leaves/plants	0.066352	0.24973	0.4033
Internode length (cm)	0.18266	-0.40581	-0.12739
Petiole length (cm)	0.35029	0.030667	-0.06878
Days to 50% flower	-0.41537	-0.07034	0.142
Days to maturity	-0.40889	-0.09185	0.11511
Terminal leaf length (cm)	0.12174	-0.28277	0.27898
Terminal leaf width	0.39256	-0.05205	0.11529
Peduncle lent (cm)	-0.17397	0.017407	-0.53495
Pod/peduncle	0.25273	0.30297	-0.26732
Pod length (cm)	0.32953	-0.25063	0.059134
Weight/Pod (g)	-0.15712	-0.14688	0.48856
seeds/pod	0.005312	0.21792	0.11665
Locules/pod	0.2998	-0.18527	0.1782
100 seed weight (g)	0.082336	0.45698	0.15276
weight/seed	0.082336	0.45698	0.15276
Eigen value	5.23342	4.03805	2.38997
Percentage variance (%)	34.889	26.92	15.933
Percentage Cumulation variance (%)	34.89	61.81	77.743

Authors' Contribution(s)

Nwosu, D.J. Conceptualization, Supervision, experiment planning, Data analysis. **Afolayan G., and Nwosu, D.J**. Results interpretation, writing original draft, Reviewing, and Editing. **Adetunji D.A., Hanafi S. S**.: Carried out the experiments and Data collection. **Afolayan G., Nwosu, D.J.** and **Amao J. O.**: Writing-Reviewing and Editing. **Fashola O. O** Literature review and editing, **Oladimeji B.K, Abbas S., Muhammad A.A**: Technical Expertise, Guidance, Reviewing and Editing.

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