doi:10.14720/aas.2017.109.3.02 Original research article / izvirni znanstveni članek

Bivariate analysis of the genetic variability among some accessions of African Yam Bean (*Sphenostylis stenocarpa* (Hochst ex A. Rich)Harms)

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Received March 24, 2017; accepted December 08, 2017.
Delo je prispelo 24. marca 2017, sprejeto 08. decembra 2017.

ABSTRACT

Variability is an important factor to consider in crop improvement programmes. This study was conducted in two years to assess genetic variability and determine relationship between seed yield, its components and tuber production characters among twelve accessions of African yam bean. Data collected were subjected to combined analysis of variance (ANOVA), Principal Component Analysis (PCA), hierarchical and K-means clustering analyses. Results obtained revealed that genotype by year (G × Y) interaction had significant effects on some of variables measured (days to first flowering, days to 50 % flowering, number of pod per plant, pod length, seed yield and tuber yield per plant) in this study.The first five principal components (PC) with Eigen values greater than 1.0 accounted for about 66.70 % of the total variation, where PC1 and PC 2 accounted for 39.48 % of variation and were associated with seed and tuber yield variables. Three heterotic groups were clearly delineated among genotypes with accessions AY03 and AY10 identified for high seed yield and tuber yield respectively. Non-significant relationship that existed between tuber and seed yield per plant of these accessions was recommended for further test in various agro-ecologies for their suitability, adaptability and possible exploitation of heterosis to further improve the accessions.

Key words: African yam bean; morpho-agronomic characters; Pearson's correlation; principal component analysis

IZVLEČEK

BIVARIATNA ANALIZA GENETSKE RAZNOLIKOSTI MED AKCESIJAMI AFRIŠKEGA GOMOLJASTEGA FIŽOLA (*Sphenostylis stenocarpa* (Hochst. ex A. Rich.) Harms)

Variabilnost je zelo pomemben dejavnik v žlahtnenjenju poljščin. Dvoletna raziskava je bila opravljena s ciljem ovrednotenja genetske variabilnosti in analize odnosov med komponentami pridelka semena ter tvorbe in značilnosti gomoljev med 12 akcesijami afriškega gomoljastega fižola. Zbrani podatki so bili obdelani z analizo variance (ANOVA), analizo glavnih komponent (PCA), hierarhično in klastersko analizo. Izsledki so pokazali, da so imele interakcije med genotipi in leti (G × Y) statistično značilen vpliv na nekatere analizirane spremenljivke kot so dnevi do prvega cvetenja, dnevi do 50 % cvetenja, število strokov na rastlino, dolžina stroka ter pridelek semen in gomoljev na rastlino. Prvih pet glavnih component (PC) z lastnimi vrednostmi več kot 1.0 je prispevalo 66.70 % celokupne variabilnosti, PC1 in PC 2 pa sta pridali še 39.48 % variabilnosti v povezavi s pridelkom semena in gomoljev. Med genotipi so se jasno oblikovale tri heterotične skupine in akcesija AY03 je bila prepoznana po velikem pridelku semen, AY10 pa po velikem pridelku gomoljev. Neznačilno povezavo med pridelkom semen in gomoljev pri teh akcesijah bi bilo priporočljivo dodatno testirati glede prilagodljivosti na različne agroekološke razmere, možnosti njihovega izboljšanja in potencialne uporabe heterotičnega učinka.

Ključne besede: afriški gomoljasti fižol; morfološko-agronomske lastnosti; Pearsonova korelacija; analiza glavnih komponent

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1 INTRODUCTION

Global food security is being threatened with increasing dependence on a few major staple crops and this has resulted in an alarming reduction in crop diversity and variability (Ikhajiagbe and Mensah, 2012). African yam bean (*Sphenostylis stenocarpa*) (AYB) is one of the under-utilized legumes grown in Nigeria, Central African Republic, Gabon, Zaire and Ethiopia. It is used as food or food components and provides two consumable products; the tuber which grows as the root sink and the actual yam beans which develop in pods above ground (Olasoji et al., 2011). AYB performs better when intercropped than when grown as sole crop (Adeniyan et al., 2007). Grain yield of about 248 - 4,130.46 kg/ha has been reported for this crop (Adewale, 2011). Like other grain legumes, AYB is an excellent food, low in fats and rich in protein, carbohydrate, fibre, minerals and vitamins (Akande et al., 2012).

Information on the genetic variability among genotypes and its potential use is vital in the crop genetic improvement. This will enhance the identification of useful genes and their behaviour in breeding programmes (Ogunniyan and Olakojo, 2014). However, numerous techniques have been proposed to estimate genetic divergence in crop accessions. Among such techniques are principal component analysis (PCA) proposed by Gower, 1966) and numerical taxonomic (Sneath, and Sokal, 1973). PCA is useful for reducing and interpreting large multivariate data sets with underlying linear structures and for discovering previously unsuspected relationships among crop characters (Ogunniyan and Olakojo, 2014).

Research has been carried out on AYB concerning morphological characteristics of the crop (Akande, 2009; Popoola et al., 2011); genetic variability in its seed quality (Olasoji et al., 2011); nutritive and anti-nutritive factors in the beans (Ajibade et al., 2005). However, there is little baseline information on the relationships between seed yield, tuber production and their components coupled with its improvement. Also, presently, there is no known released variety of the crop in Nigeria, it is only found in the hands of old farmers (Saka et al.,2004; Adewale et al., 2012; Ojuederie et al., 2014), thus make it vulnerable to extinction. Therefore, in order to accelerate the general acceptance of AYB as one of the means to proffer solution to the problem of malnutrition among children and nursing mothers in Sub-Saharan Africa, there is need to genetically improve AYB. The objectives of this research are therefore to assess genetic variability among twelve accessions of AYB from the forest agro-ecology of Nigeria using Principal Component Analysis (PCA) and also, determine the relationship among seed yield, its components and tuber production characters of the AYB accessions.

2 MATERIALS AND METHODS

Twelve accessions of African yam bean (AYB) coded as AY01, AY02, AY03, AY04, AY05, AY06, AY07, AY08, AY09, AY10, AY11 and AY12 that were previously collected from six states of Nigeria (Figure 1) were obtained from the germplasm collection of the Institute of Agricultural Research and Training (IAR&T), Moor Plantation, Ibadan, Nigeria. The six states of collection fall within the forest agro-ecology of Nigeria. The experiment was carried out at the screen house of IAR & T, Ibadan in 2015 and 2016. Plastic pots were filled with 10 kg of sieved top soil. Two seeds were sown per pot which were later thinned to one plant per pot. The experiment was laid out in a completely randomised design with four replicates. Hand weeding was carried out once a month until the crops reaches physiological maturity. The plants were supported with long dry sticks. Insect pests were controlled with the application of Cypermethrin (200 g/l pyrethroid) E.C (NPIC, 1988) at 1.5 ml/litre with one spoon of fungicide powder (Benlate with active ingredient: (50 % methyl 1-(butylcarbamoyl-2-benzimidazolecarbamate) manufactured by DuPont company, Wilmington, Delaware, U.S.A using knapsack sprayer at vegetative and flowering stages.

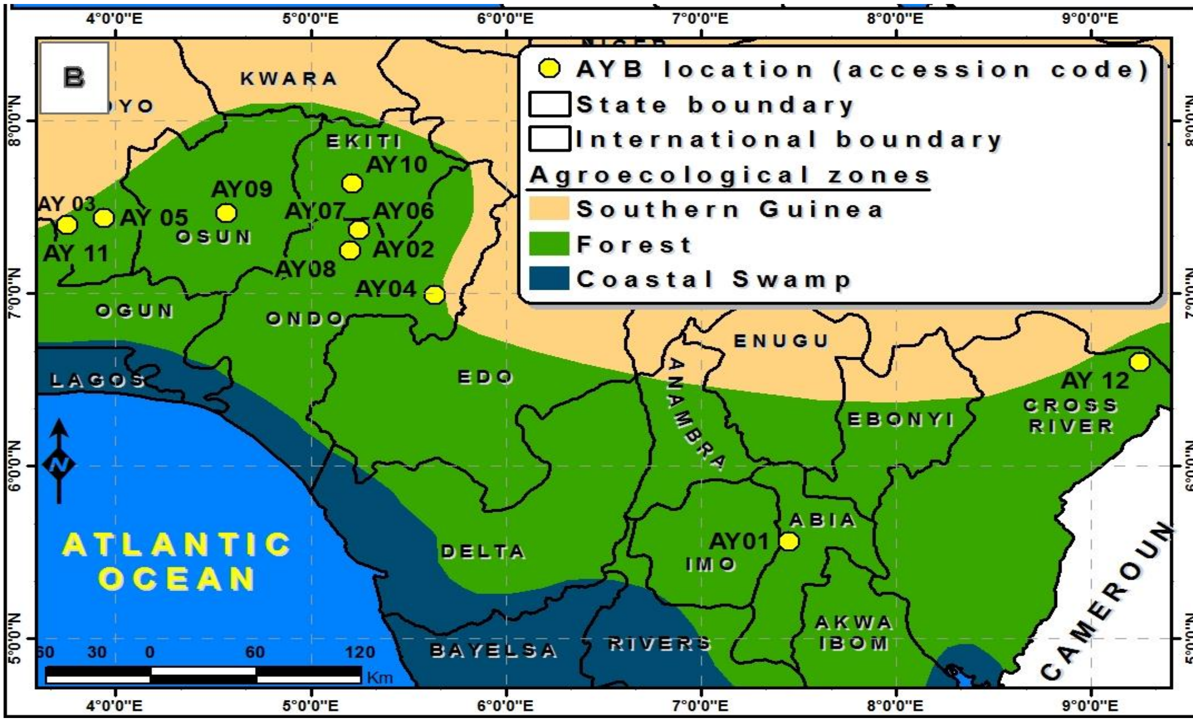

Figure 1: Locations and distribution of AYB accessions across collection sites

Twenty (20) morphological characters namely; days to first flowering, days to 50 % flowering, terminal leaf length (cm), terminal leaf width (cm), petiole length (cm), number of seeds per pod, number of pod per peduncle, number of pod per plant, pod mass per plant (g), pod length (cm), seed yield per plant (g), 100 seed yield per plant (g), days to physiological maturity, seed length (cm), seed width (cm), seed thickness (cm), tuber yield per plant (g), tuber smallest mass (g), tuber biggest mass (g), and number of tubers per plant were collected based on AYB descriptors (Adewale and Dumet, 2010).

Data obtained were subjected to combined analyses of variance (ANOVA). Difference between the treatments were separated using Duncan Multiple Range Test (DMRT) at 5 % or 1 % levels of significance. Principal component analysis was carried out and components with Eigen values > 1.0 were considered. Contributing characters with values > 0.6 were considered relevant for principal components (Matus et al., 1999). Accessions were clustered into groups based on hierarchical clustering using squared Euclidean distance and k-means clustering analysis was used to evaluate character contribution to clustering groups. Pearson's moment correlations between morpho-agronomic characters and tuber yield characters were determined using IBM SPSS (Version 23.0, 2015).

3 RESULTS

3.1 Analysis of variance (ANOVA) for morpho-agronomic variables of AYB accessions

Combined analysis of variance (ANOVA) for morpho-agronomic variables of the 12 AYB accessions evaluated in 2015 and 2016 are presented in Table 1. The results of the combined analysis revealed that genotype exhibited significant differences in all of the variables except terminal leaflet length, petiole length and number of seeds per pod. There were significant differences in some of the variables based on years of evaluation while results of variables such as terminal leaf length, terminal leaf width, petiole length, number of seeds per pod, number of pod per peduncle, 100 seed mass, seed length and seed width were not significantly different from each other in both years (across the years). Also, genotype by year (G ×Y) interaction had significant effects on some of the variables (days to first flowering, days to 50 % flowering, number of pod per plant, pod length, seed yield per plant and tuber yield per plant) in this study.

Table 1: Combined analysis of variance (ANOVA) of AYB accessions based on morpho-agronomic characters evaluated in 2015 and 2016

	Mean squares			
Variables	Genotype(G)	Year(Y)	G x Y	Error
Days to first flowering	304.21**	2552.34**	265.96**	50.41
Days to 50% flowering	426.97**	2223.38**	401.08**	38.21
Terminal leaf length (cm)	2.33	10.29	1.67	1.41
Terminal leaf width (cm)	0.71**	0.57	0.31	0.23
Petiole length (cm)	0.61	7.34	1.01	0.66
Number of seeds per pod	29.22	28.83	35.6	32.7
Number of pod per peduncle	1.11**	0.17	0.33	0.36
Number of pod per plant	190.85**	1340.04**	145.46**	56.79
Pod weight per plant (g)	2533.40**	7208.24**	1333.82	783.02
Pod length (cm)	44.26**	1727.21**	48.55**	5.34
Seed yield per plant (g)	1094.70**	3654.98**	745.21*	337.87
100 seed yield per plant (g)	53.33**	16.02	9.72	10.23
Days to physiological maturity	145.81**	1268.76**	53.58	29.96
Seed length (cm)	0.80*	0.08	0.17	0.33
Seed width (cm)	0.65**	0.71	0.22	0.21
Seed thickness (cm)	1.00**	1.18*	0.59	0.28
Tuber yield per plant (g)	22642.57**	76155.91**	10530.08**	3964.4
Tuber smallest mass (g)	169.31**	6.63*	38.77	27.22
Tuber biggest mass (g)	3848.19**	885.8*	994.41	684.13
Number of tubers per plant	44.32**	83.44**	13.41	7.64

*, ** Significant at ($p < 0.05$) and ($p < 0.01$) respectively

3.2 Effect of years of evaluation on the performance of AYB accessions

AYB accessions flowered earlier in 2016 (134 days after planting) than in 2015 (144 DAP) and attained 50 % flowering with mean values of 142 and 152 DAP in 2016 and 2015 respectively (Table 2a). Higher seed yield per plant and pod mass were recorded in 2016 (34.10 g and 50.29 g) than in 2015 (21.76 g and 32.96 g) respectively while 2015 significantly favoured tubers production with tuber yield per plant mean value of 102.36 g than in 2016 (46.03 g) (Table 2b; 2c; 2d). Significant genotypic differences were observed among the genotypes evaluated in 2015 and 2016; accessions AY03 and AY01 had the highest seed yield per plant with values of 54.76 g and 76.05 g in 2015 and 2016 respectively while the lowest seed yield per plant was obtained in AY08 (8.26 g) and AY12 (14.65 g) in 2015 and 2016 respectively (Table 2b; 2c). On the other hand, AY02 gave the highest tuber yield per plant (265.58 g) in 2015 and AY10 gave the highest tuber yield per plant (150.28 g) in 2016 while AY11 and AY12 did not produce tubers in both years (Table 2d).

3.3 Mean performance of AYB accessions based on morpho-agronomic variables across the year of evaluation

Significant genotypic differences were observed among the genotypes evaluated across the years; days to first flowering varied from 131 to 149 days in accessions (AY07, AY08) and AY12 respectively with mean of 139 days after planting. Accessions AY08 and AY12 attained 50 % flowering between 134 to 157 days respectively with mean of 147 days (Table 2a). AY01 and AY03 had higher seed yield per plant with values of 46.32 g and 47.50 g respectively compared to the other accessions. Number of pod per plant ranged from 4 to 21 with mean of 12. Pod mass among these accessions with mean of 41.63 g ranged from 18.86 g (AY12) to 69.26 g (AY03). AY05 had the longest pods (20.36 cm) while the shortest pod (12.98 cm) was obtained in AY08 with long and recorded mean value of 16.23 cm (Table 2b). Also, AY03 and AY12 attained physiological maturity between 197 to 210 days with mean value of 203 days (Table 2c). All of the AYB accessions produced tubers at maturity except AY11 and AY12

(Table 2d, Figure 2). Accessions AY10 and AY02 produced the highest average tuber yield per plant (150.28 g and 149.47 g respectively) (Table 2d). A high level of variability existed in the tuber characters of the accessions evaluated as reflected by coefficient of variation (CV) with the highest variability found in the smallest tuber masses, followed by tuber yield per plant, the biggest tubers mass per plant, seed yield per plant and pod mass per plant while the least variability was found in days to physiological maturity.

Table 2a: Mean values of the AYB accessions for morpho-agronomic characters evaluated in 2015 and 2016

	Days to 1st flowering			Days to 50 % flowering			Terminal leaflet length (cm)			Terminal leaflet width (cm)			Petiole length (cm)		
ACC.	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
AY01	142.75ab	130.25ab	136.50cde	150.00abc	135.50e	142.75def	8.00a	8.33a	8.17a	3.12a	3.14a	3.13a	4.34a	6.02a	5.18a
AY02	143.50ab	142.50a	143.00abc	149.50abc	147.50bcd	148.50bcd	8.20a	7.09a	7.64a	2.97a	2.69a	2.83a	5.15a	4.79a	4.97a
AY03	136.00b	131.50ab	133.80de	141.50c	142.75de	142.13def	7.38a	7.70a	7.54a	2.92a	3.58a	3.25a	4.82a	5.36a	5.09a
AY04	149.25ab	135.00ab	142.10abc	160.00a	144.00cde	152.00abc	7.04a	7.78a	7.41a	2.63a	2.93a	2.78a	4.84a	5.29a	5.07a
AY05	143.25ab	135.00ab	139.10cde	150.50abc	145.00cd	147.75cde	8.87a	7.29a	8.08a	3.41a	3.06a	3.23a	4.47a	4.81a	4.64a
AY06	145.50ab	141.50ab	143.50abc	152.75abc	154.75ab	153.75abc	6.47a	6.59a	6.53c	2.46a	2.46a	2.46a	3.74a	4.59a	4.17a
AY07	139.25ab	123.00bc	131.10e	148.25abc	125.00f	136.63fg	7.50a	7.49a	7.50a	3.07a	3.20a	3.14a	4.04a	5.46a	4.75a
AY08	153.00a	109.75c	131.40e	158.00ab	110.75 g	134.38g	8.45a	7.58a	8.02a	3.33 a	2.94a	3.14a	4.52a	5.08a	4.80a
AY09	150.25ab	144.50a	147.40ab	157.50abc	153.00abc	155.25ab	7.26a	6.04a	6.65a	2.61a	2.24a	2.43a	4.96a	4.42a	4.69a
AY10	134.50b	131.25ab	132.90de	142.75bc	140.00de	141.38ef	8.97a	7.35a	8.16a	3.64a	2.84a	3.24a	4.27a	5.80a	5.04a
AY11	144.75ab	135.00ab	139.90bcd	151.50abc	148.25bcd	149.88bc	8.83a	6.81a	7.82a	3.44 a	2.93a	3.19a	4.85a	4.99a	4.92a
AY12	150.00ab	149.00a	149.50a	156.75abc	157a	156.88a	8.17a	7.22a	7.70a	3.26a	2.99a	3.13a	4.67a	4.72a	4.70a
Mean	144.33a	134.02b	139.2	151.58a	141.96b	146.77	7.93a	7.27a	7.6	3.07a	2.92a	2.99	4.56a	5.11a	4.83
CV	4.43	5.78	5.1	4.3	4.11	4.21	16.32	14.66	15.6	15.92	16.01	16	18.24	15.42	16.8

Means with the same letter(s) in the same column or row are not significantly different from each other at p = 0.05; ACC: Accessions; CV: coefficient of variation

Table 2b: Mean values of the AYB accessions for morpho-agronomic characters evaluated in 2015 and 2016

	Number of seed per pod			Number of pods per peduncle			Number of pods per plant			Pod mass per plant (g)			Pod length (cm)		
ACC.	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
AY01	14.00a	17.22a	15.61a	1.50a	2.00a	1.75a	7.00a	34.92a	20.96a	25.59bc	93.27a	59.43ab	24.41a	11.27bcd	17.84bc
AY02	12.25a	10.75a	11.50a	2.25a	2.00a	2.13a	12.25a	13.25ab	12.75abcd	51.34abc	31.25bc	41.29abcd	17.74d	16.25ab	17.00bc
AY03	14.50a	13.00a	13.75a	1.75a	2.50a	2.13a	14.75a	19.38ab	17.06	68.04a	70.47abc	69.26a	20.19cd	8.90d	14.54cd
AY04	14.00a	13.83a	13.92a	2.75a	2.75a	2.75a	10.50a	18.88ab	14.69abcd	41.51abc	66.63abc	54.07abc	20.95abcd	8.18d	14.56cd
AY05	14.75a	15.55a	15.15a	2.50a	2.50a	2.50a	10.50a	19.50ab	15.00abc	57.75ab	75.36ab	66.55a	22.60abc	18.12ab	20.36a
AY06	14.50a	14.25a	14.38a	2.25a	2.00a	2.13a	4.00a	4.25b	4.13e	16.31c	22.10c	19.20d	20.11cd	9.01cd	14.56cd
AY07	14.00a	11.92a	12.96a	1.75a	1.75a	1.75a	5.25a	14.62ab	9.94bcde	18.91c	40.71bc	29.81bcd	19.87cd	7.87d	13.87d
AY08	10.50a	11.57a	11.04a	1.25a	1.75a	1.50a	2.75a	22.62ab	12.69abcd	12.49c	74.95ab	43.72abcd	18.01d	7.95d	12.98d
AY09	13.25a	13.00a	13.13a	1.50a	1.75a	1.63a	8.25a	9.50b	8.88bcde	29.93abc	31.00bc	30.47bcd	18.80cd	18.75a	18.78ab
AY10	11.50a	25.25a	18.38a	2.25a	1.50a	1.88a	13.25a	18.25ab	15.75abc	31.70abc	55.29abc	43.50abcd	18.13d	16.05abc	17.09bc
AY11	14.00a	14.16a	14.08a	2.00a	2.00a	2.00a	8.00a	8.25b	8.13cde	25.50bc	21.22c	23.36cd	20.48bcd	8.52d	14.50cd
AY12	14.25a	14.14a	14.20a	1.50a	1.75a	1.63a	4.75a	7.5b	6.13de	16.48c	21.25c	18.86d	24.34a	12.97bcd	18.65ab
Mean	13.46a	14.55a	14.01	1.94a	2.02a	1.98	8.44b	15.91a	12.17	32.96b	50.29a	41.63	20.47a	11.99b	16.23
CV	16	53.56	40.83	35.73	24.4	30.36	67.31	56.68	61.9	71.84	63.05	67.22	7.73	23.87	14.24

Means with the same letter(s) in the same column or row are not significantly different from each other at p = 0.05; ACC: Accessions; CV: coefficient of variation

Table 2c: Mean values of the AYB accessions for morpho-agronomic characters evaluated in 2015 and 2016

	Seed yield per plant (g)			100 seed yield per plant (g)			Days to physiological maturity			Seed length (cm)			Seed width (cm)		
ACC.	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
AY01	16.60b	76.05a	46.32a	21.32a	21.33a	21.33a	210.25a	198.00abcd	204.13abc	8.12a	8.20a	8.16a	6.01a	5.84a	5.93a
AY02	30.70ab	30.25ab	30.47abc	20.88a	20.88a	20.88a	197.75a	197.75abcd	197.75de	7.58a	7.50a	7.54a	6.30a	5.75a	6.03a
AY03	54.76a	40.24ab	47.50a	23.30a	21.89a	22.59a	197.75a	195.75bcd	196.75e	7.51a	7.74a	7.63a	6.18a	6.22a	6.20a
AY04	15.37b	34.48ab	24.93bc	20.40a	17.13a	18.77a	207.00a	193.50cd	200.25bcde	7.75a	7.90a	7.83a	5.76a	6.25a	6.00a
AY05	40.60ab	38.78ab	39.69ab	26.27a	28.27a	27.27a	206.25a	200.25abcd	203.25abcd	8.11a	7.61a	7.86a	6.29a	5.84a	6.07a
AY06	11.16b	15.84b	13.50c	22.55a	22.75a	22.65a	206.75a	193.75cd	200.25bcde	7.95a	7.50a	7.72a	6.40a	6.01a	6.21a
AY07	13.06b	26.12ab	19.59bc	20.48a	23.59a	22.03a	206.00a	192.00d	199.00cde	7.57a	7.46a	7.51a	5.98a	6.15a	6.07a
AY08	8.26b	41.36ab	24.81bc	26.12a	26.55a	26.34a	207.75a	203.50abc	205.63ab	8.41a	8.39a	8.40a	6.88a	6.50a	6.69a
AY09	20.85ab	23.00b	21.93bc	18.55a	18.55a	18.55a	209.25a	207.50a	208.38a	7.48a	7.00a	7.24a	5.88a	5.25a	5.56a
AY10	22.45ab	43.21ab	32.83abc	22.27a	23.36a	22.82a	208.00a	204.75ab	206.38ab	7.79a	7.66a	7.73a	6.50a	6.30a	6.40a
AY11	16.61b	25.19ab	20.90bc	18.35a	23.66a	21.00a	211.75a	200.75abcd	206.25ab	7.60a	7.93a	7.77a	6.00a	5.89a	5.95a
AY12	10.66b	14.65b	12.66c	21.88a	24.24a	23.06a	212.75a	206.50abc	209.63	7.98a	8.27a	8.13a	6.32a	6.45a	6.38a
Mean	21.76b	34.10a	27.93	21.86a	22.68a	22.27	206.77a	199.5b	203.14	7.82a	7.76a	7.79	6.21a	6.04a	6.12
CV	67.54	62.89	65.82	14.39	14.33	14.36	3.11	2.16	2.69	6.57	8.04	7.33	7.31	7.68	7.49

Means with the same letter(s) in the same column or row are not significantly different from each other at p = 0.05; ACC: Accessions; CV: coefficient of variation

Table 2d: Mean values of the AYB accessions for morpho-agronomic characters evaluated in 2015 and 2016

	Seed thickness (cm)			Tuber yield per plant (g)			Tuber smallest mass (g)			Tuber biggest mass (g)			Number of tubers per plant		
ACC.	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
AY01	6.09ab	6.00abc	6.05bcd	76.36b	70.81abc	73.58bcd	3.60ab	3.13b	3.37cd	53.73a	46.81ab	50.28ab	4.00ab	4.50ab	4.25abc
AY02	6.41ab	5.00c	5.70cd	265.58a	33.36bc	149.47a	10.79ab	19.15a	14.97a	56.69a	50.53ab	53.61ab	9.75a	1.50bc	5.63ab
AY03	6.25ab	6.23ab	6.24abc	41.78b	10.14c	25.97de	2.37ab	1.18b	1.77cd	35.50ab	23.92ab	29.71bc	4.00ab	2.25abc	3.13bc
AY04	5.66ab	6.03abc	5.85bcd	83.61ab	49.89abc	66.75cde	7.26ab	6.60ab	6.93bc	36.88ab	47.58ab	42.23bc	5.50ab	6.00a	5.75ab
AY05	6.31ab	5.51abc	5.91bcd	72.92b	12.05c	42.49cde	12.07a	1.08b	6.57bc	37.91ab	18.62b	28.27bcd	2.75ab	1.75bc	2.25cd
AY06	6.57ab	6.29ab	6.43ab	141.69ab	55.22abc	98.45abc	2.22ab	1.04b	1.63cd	55.76a	27.38ab	41.57bc	6.50ab	6.00a	6.25ab
AY07	6.20ab	6.24ab	6.22abc	170.97ab	10.84c	90.91abcd	2.57ab	1.02b	1.79cd	62.80a	10.54b	36.67bc	6.25ab	4.00ab	5.13abc
AY08	6.88a	6.58a	6.73a	143.23ab	132.19ab	137.71ab	3.40ab	7.16ab	5.28cd	56.30a	97.16a	76.73a	8.50ab	3.38abc	5.94ab
AY09	5.93ab	5.25bc	5.59d	81.91ab	27.58bc	54.75cde	3.44ab	1.02b	2.23cd	16.82ab	16.94b	16.88cd	8.25ab	5.25ab	6.75a
AY10	6.16ab	6.02abc	6.09bcd	150.28ab	150.28a	150.28a	11.04ab	11.04ab	11.04ab	39.70ab	39.70ab	39.70bc	6.25ab	4.75ab	5.50ab
AY11	5.18b	5.81abc	5.50d	0.00c	0.00c	0.00e	0.00b	0.00b	0.00d	0.00b	0.00c	0.00e	0.00b	0.00c	0.00d
AY12	5.97ab	5.97abc	5.97bcd	0.00c	0.00c	0.00e	0.00b	0.00b	0.00d	0.00b	0.00c	0.00e	0.00b	0.00c	0.00d
Mean	6.13a	5.91b	6.02	102.36a	46.03b	89.04	4.89a	4.37b	4.63	37.67a	31.60b	34.64	5.15a	3.28b	4.21
CV	9.26	8.26	8.8	74.29	100.64	77.47	98.36	127.93	102.82	56.38	95.84	68.94	69.52	47.97	59.88

Means with the same letter(s) in the same column or row are not significantly different from each other at p = 0.05; ACC: Accessions; CV: coefficient of variation

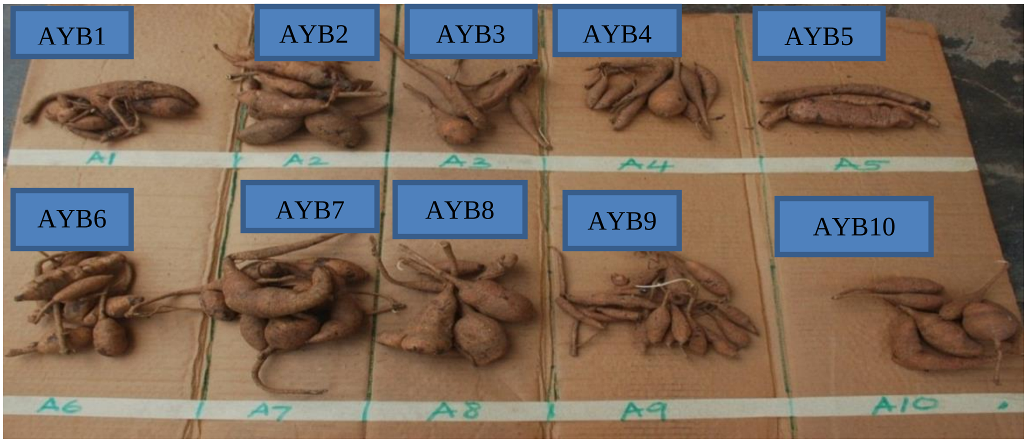

Figure 2: Tubers of ten accessions of the African yam bean (AYB) harvested in this study

3.4 Principal Component Analysis (PCA)

The results of PCA of morpho-agronomic variables of the accessions revealed that five component axes had Eigen values that are greater than 1.0 and accounted for 66.70 % of the total variation. Relative discriminating power of the PCA as revealed by Eigen value was 4.96, 2.94, 2.17, 1.88 and 1.40 for PC1, PC2, PC3, PC3 and PC5 respectively (Table 3). PC 1 accounted for 24.79 % of the variation and is associated with days to first flowering, days to50 % flowering, petiole length, number of pod per peduncle, number of pod per plant, pod mass per plant, and seed yield per plant while the second principal component (PC2) was responsible for 14.69 % of the variation and was mainly associated with tuber yield per plant, seed width, seed thickness, days to physiological maturity and terminal leaflet length. The third principal component (PC3) accounted for 10.85 % of the variation and was mainly associated with tuber variables (tuber yield per plant, tuber smallest and biggest mass, and number of tuber per plant). The fourth and fifth principal components explained 9.38 % and 6.99 % of the variation respectively (Table 3).

Table 3: Characters with respect to its principal component, Eigen values and variation

Variables	PC1	PC2	PC3	PC4	PC5
Days to first flowing	-0.65*	0.29	0.29	0.40	0.26
Days to 50 % flowering	-0.65*	0.26	0.27	0.41	0.28
Terminal leaf length (cm)	0.48	0.57*	0.27	0.41	0.28
Terminal leaf width (cm)	0.49	0.45	0.41	0.20	-0.37
Petiole length (cm)	0.64*	0.00	0.15	0.20	-0.24
Number of seeds/pod	0.24	-0.27	0.25	0.43	0.64*
Number of pods/peduncle	0.56*	0.32	0.09	0.53	-0.22
Number of pods/plant	0.83*	-0.33	0.08	0.27	0.16
Pod mass/plant (g)	0.82*	-0.22	0.09	0.28	0.23
Pod length (cm)	-0.48	0.44	0.00	0.40	0.19
Seed yield/plant (g)	0.78*	-0.27	0.08	0.25	0.28
100 seeds mass (g)	0.34	0.18	0.26	-0.36	0.27
Days to physiological maturity	-0.35	0.54*	0.24	0.08	0.07
Seed length (cm)	0.36	0.37	0.35	-0.28	0.24
Seed width (cm)	0.34	0.63*	0.24	-0.43	0.00
Seed thickness (cm)	0.35	0.56*	-0.01	-0.47	0.14
Tuber yield/plant (g)	0.30	0.60*	-0.62*	0.15	0.15
Tuber smallest mass (g)	0.11	0.12	-0.52*	0.18	-0.12
Tuber biggest mass (g)	0.42	0.31	-0.64*	0.00	0.06
Number of tuber/plant	0.13	0.35	-0.53*	0.19	0.34
Eigen values	4.96	2.94	2.17	1.88	1.40
Percentage variation	24.79	14.69.	10.85	9.38	6.99
Cumulative	24.79	39.48	50.33	59.71	66.70

*component contributors; 0.00: non-component contributors; PC: Principal component

3.5 Clustering of AYB accessions

Accessions were grouped into three clusters at the rescaled distance of 15 units (Fig 3); cluster 1 comprised of two accessions (AY11 and AY12). The members are late flowering, low seed and non-tuber producing genotypes. Cluster 2 contained seven accessions (AY03, AY05, AY01, AY04, AY06, AY07 and AY09); the members of this cluster are made up of high seed yield and medium tuber yield. Also, cluster 3 made up of three accessions (AY02, AY10 and AY08) that exhibited early to late flowering and with highest tuber yield (Fig. 3). Inter-cluster distance revealed that AYB clustered in groups 1 and 2 were closely related with the least inter-cluster distance of 65.97 units while groups 1 and 3 were distantly related with inter-cluster distance of 117.80 units (Table 4). Five AYB accessions initially sourced from Ondo state were found in groups 2 and 3 while the three AYB accessions initially sourced from Oyo state were found spread in groups 1and 2 while other accessions were one per state.

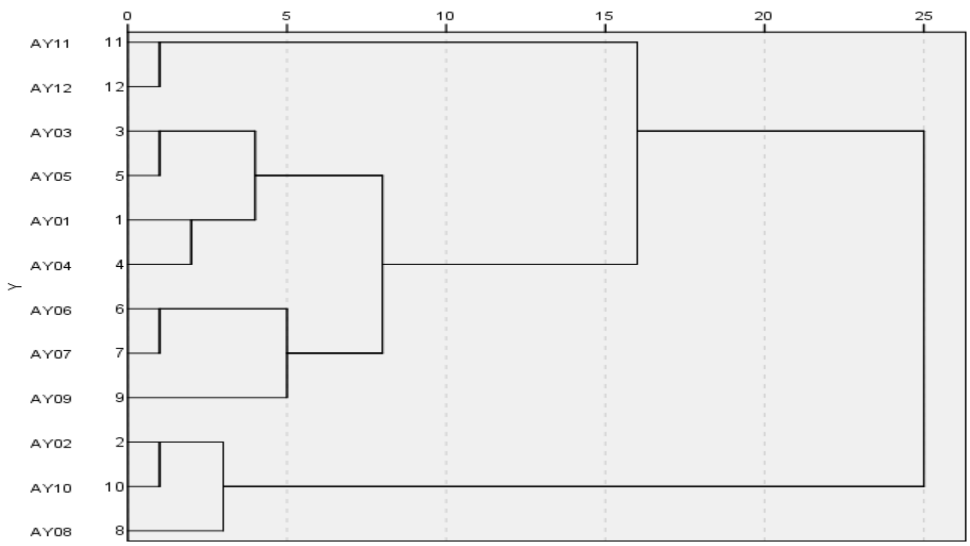

Figure 3: Dendrogram cluster of the 12 African yam bean accessions evaluated based on hierarchical clustering using squared Euclidean distance show the three clusters formed at the rescaled distance of 15 units

Table 4: Inter-cluster distance, according to K-mean clustering analysi

Cluster	1	2	3
1	-		
2	65.97	-	
3	117.80	80.54	-

3.6 Correlation between seed yield and tuber production variables

Correlation between pairs of seed yield variable and tuber production variables showed that some pairs of the variables evaluated were significant at 5 % probability level or highly significant at 1 % probability level (Table 5). Tuber yield per plant was positively and significantly correlated with seed width (0.26), seed thickness (0.38) and terminal leaflet length (0.32). Non-significant relationship with low magnitude of Pearson coefficient of correlation was obtained between tuber yield per plant and seed yield per plant (0.07). On the other hand, tuber yield per plant was inversely or negatively correlated with days to first flowering (-0.11), days to 50 % flowering (-0.09), number of seed per pod (-0.11), pod length (-0.15) (Table 5). Also, seed yield was positively and significantly correlated with number of pods per plant (0.84), pod mass per plant (0.84), number of seeds per pod (0.35) and pod length (0.27). Similarly, positive and significant association existed in tuber yield per plant with the biggest tuber mass (0.65), the smallest tuber mass (0.36) and number of tubers per plant (0.67) (Table 5).

Table 5: Pearson coefficient of correlation between pairs of morpho-agronomic characters

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	-	0.89**	-0.06	-0.11	-0.32**	-0.08	0.04	-0.44**	-0.38**	0.52**	-0.39**	-0.16	0.36**	-0.05	-0.08	-0.16	-0.11	-0.08	-0.38	0.06
B		-	-0.06	-0.15	-0.29**	-0.02	0.07	-0.46**	-0.38**	0.48**	-0.38**	-0.16	0.32**	-0.07	-0.11	-0.18	-0.09	-0.11	-0.33**	0.05
C			-	0.83**	0.46**	-0.06	0.26*	0.25*	0.28*	0.11	0.25*	0.09	0.19	0.34**	0.39**	0.23*	0.32**	0.07	0.20*	0.01
D				-	0.40**	-0.02	0.26*	0.28**	0.31**	-0.02	0.21*	0.20*	0.12	0.28**	0.39**	0.23*	0.15	-0.04	0.07	-0.06
E					-	0.08	0.20*	0.51**	0.44**	-0.32**	0.48**	0.06	-0.20	0.19	0.17	0.11	0.16	0.04	0.06	0.05
F						-	-0.10	0.37**	0.34**	-0.07	0.35**	0.11	-0.10	0.17	-0.04	-0.02	-0.11	-0.11	-0.08	-0.05
G							-	0.27**	0.33**	-0.05	0.20	0.03	-0.13	-0.08	0.00	-0.04	0.07	0.03	0.04	0.07
H								-	0.91**	-0.39**	0.84**	0.14	-0.33**	0.17	0.01	0.01	0.06	0.05	0.20*	0.03
I								*	-	-0.30**	0.84**	0.24*	-0.30**	0.18	0.09	0.10	0.11	0.02	0.25*	0.07
J										-	0.27**	0.40**	-0.10	0.55**	-0.12	-0.09	-0.15**	0.16	0.10	0.03
K											-	0.22*	-0.29**	0.19	-0.01	0.07	0.07	0.02	0.20*	0.07
L												-	-0.01	0.37**	0.34**	0.30**	0.04	-0.08	0.09	-0.63**
M													-	0.09	0.09	0.16	0.10	0.10	-0.11	0.12
N														-	0.49**	0.31**	0.05	0.01	-0.06	-0.08
O															-	0.68**	0.26*	-0.09	0.16	0.08
P																-	0.38**	-0.05	0.24*	0.23*
Q																	-	0.36**	0.65**	0.67**
R																		-	0.38**	0.05
S																			-	0.32**
T																				-

*Means found significant at 5 %, ** significant at 1 % significant level

A: first flowing; B: days to 50 % flowering; C: terminal leaf length (cm); D: terminal leaf width (cm); E: petiole length (cm); F: number of seeds per pod; G: number of pod per peduncle; H: number of pod per plant; I: pod mass per plant (g); J: pod length (cm); K: seed yield per plant (g); L: 100 seed yield per plant (g); M: days to physiological maturity; N: seed length (cm); O: seed width (cm); P: seed thickness (cm); Q: tuber yield per plant (g); R: the smallest tuber mass (g); S: the biggest tuber mass (g); T: number of tubers per plant

4 DISCUSSION

Genetic variation is a prerequisite for successful crop improvement programme. Knowledge of genetic variation and relationships between accessions or genotypes is important to understand the available variability and its potential use in breeding programs (Yoseph et al., 2005). If the genetic variability of any crop specie is carefully exploited, same is capable of providing critical bases for improving the grain yield as well as other economic and important traits (Mahmood et al., 2003; Inamullah et al., 2006).

Africa yam bean has dual crop advantage because it produces both seeds and tubers; however, tuber formation seems to be dependent on the genetic make-up of the accessions. In this study, ten accessions produced tubers while two did not produce tubers. Significant difference among the accessions is an indication of the existence of genetic variations. Also, significant difference in the results of each year as well as their interaction in some of the traits, implies that the performances of the AYB accessions might be influenced by environmental factors and this would enable selection for the traits of interest in different agro-ecologies. Nwofia et al. (2014) had reported that genotype and year of evaluation had significant effects on some of the agronomic traits of African yam bean.

Hierarchical clustering based on twenty morpho-agronomic variables evaluated in this study, clustered the AYB accessions into three groups, where genotypes within the same cluster exhibit high homogeneity and high heterogeneity between the clusters. Also, the result obtained from the PCA showed that PC1 and PC2 accounted for 39.48 % of the variation, which was associated with seed and tuber yield variables. This indicates that days to first flowering, days to 50 % flowering, petiole length, number of pods per plant, pod mass per plant, seed yield per plant, seed width and tuber yield per plant were considered as major contributors to the total variation having PC values > 0.6 (Matus et al.,1999) in this study. These identified variables could facilitate effective selection in AYB improvement programmes.

Although, significant differences were obtained among the AYB accessions for some of the traits, 74.99 % of the accessions were grouped in two clusters of the three clusters formed by K-means analysis. These two clusters were the most closely related with the least inter-cluster distance of 65.97 units. These results justify the low genetic diversity observed among the African yam bean accessions in forest agro-ecology of Nigeria which needs to be improved. Akande (2007) had anticipated that through mutation breeding, introduction, recombination and selection, improved varieties which are more productive than those currently grown by farmers can be developed.

Non-significant relationship obtained between tuber yield per plant and seed yield per plant; could be a function of genetic make-up of the AYB accession. Several researchers (Marcelis, 1996; Farrar, 1996; Geigner et al.,1996) had reported that such occurrence could be competitiveness between the storage sinks (seeds and tubers) to import photo-assimilates, which is a function of environmental factors such as water, temperature and strength of the competing sinks. Identifying the molecular determinant of sinks strength would further increase yield. In addition, it could be observed from the Pearson coefficients of correlation, that number of seeds per pod, number of pods per plant, pods mass per plant, pod length and 100-seed mass greatly influenced seed yield. Also, the smallest tuber mass and the biggest tuber mass contributed to tuber yield in this study; this could be attributed to the positive and significant relationship obtained among these traits with seed yield and tuber yield. Ikhajiagbe et al. (2007) earlier reported that yield characters such as number of pods per plant, number of seeds per pod, 100-seed mass variables strongly influence grain yield of AYB. Hence, these variables could be used for indirect selection for seed yield and tuber yield. Significant positive correlations between yield and other agronomic characters that can improve yield are quite desirable in plant breeding, because it facilitates selection process and gains from selection (Bello and Olawuyi, 2015). Therefore, efforts should be geared towards improving them for better yield.

5 CONCLUSION

This study revealed that some of the traits of African yam bean genotypes like seed yield and tuber yield were significantly influenced by prevailing environmental factors across the years of evaluation. For instance, environmental factors favoured high seed yield in 2016 and high tuber yield in 2015. Also, significant genotypic differences were obtained among the genotypes evaluated across the years; AY03 and AY01 had the highest seed yield while AY10 and AY02 gave the highest tuber yield. On the other hand, AY01 and AY03 gave the highest seed yield in 2016 and 2015 respectively while highest tuber yield was obtained in AY02 and AY10 in 2015 and 2016 respectively. Three heterotic groups were clearly delineated among the genotypes with accessions AY03 and AY10 identified for high seed yield and tuber yield respectively.

However, non-significant relationship between tuber yield and seed yield per plant of these accessions, which could be attributed to their genetic make-up can be further tested in various agro-ecologies for their suitability, adaptability and possible exploitation of heterosis to further improve the accessions.

6 ACKNOWLEDGMENT

The effort and contributions of Late Prof. (Mrs) S.R. Akande to this research will forever be remembered. She collected and provided most of the African Yam Bean accessions used for this research work. May her gentle soul rest in peace.

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