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Full Length Research Paper

Seed metrics for genetic and shape determinations in African yam bean [Fabaceae] (*Sphenostylis stenocarpa* Hochst. Ex. A. Rich) harms

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The metric measures on seeds, their correlation and relationship are important for systematic breeding for seed yield and shape determination. Variations among eighty genotypes of African yam bean (AYB) for six metric seed characters (seed length, width and thickness and their ratios) were evaluated in this study. Paired comparison among the six characters revealed very high significance ($P < 0.001$), approving the six traits as unique parameters for evaluating AYB. They equally exhibited high and substantial genetic variance: the genotypic proportion of the total variation ranged between 90 and 97%, broad sense heritability (81 - 94%) and genetic advances (14 - 31%). Seed length and width had the highest joint inheritance of 99.04%, the least, 4.32% was between width and WT as depicted by co-heritability. Positive and significant ($P < 0.05$) phenotypic and/or genotypic correlation existed between seed width and thickness, the three ratios and seed length with the ratios except WT. Non-significant negative correlation existed between seed thickness with LT and WT. There were very reliable and highly significant linear relationships between the seed traits except for length and width whose relationship was non-linear. Breeding concentration on any of these traits may simultaneously influence the others. The seed shape indices were the metric ratios and the flatness index; they described the common shapes of AYB seeds as: round/spherical, oval/ellipsoidal, oblong and rhomboid.

Key words: Seed metrics, seed shape, co-heritability, flatness index, heritability.

INTRODUCTION

African yam bean (*Sphenostylis stenocarpa* Hochst. Ex. A. Rich) Harms) like other tuberous legumes (e.g. *Pachyrhizus* sp. belongs to the Fabaceae family. It is the most important cultivated specie in the genus *Sphenostylis* (Potter and Doyle, 1992) and it is indigenous to tropical Africa. By the name, it is a crop of dual food products: pulse and tuber. The use of the exceptionally nutritious pulse (Rachie, 1973) is popular in West Africa. The use of the tuber is very common in the meal of some tribes in Central Africa (Potter, 1992) . The protein content is up to 19 and 29% in tuber and in seed grains respectively (National Research Council, 1979; Uguru and Madukaife, 2001).

African yam bean (AYB) is an underutilized specie with great genetic and economic potentials. No literature had reported the mating system of AYB; we speculate cleistogamy with high selfing rate because the floral

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structure resembles that of other legumes. However, the seeds harbor vast genetic diversities for: nutritive and anti-nutritive factors (Ajibade et al., 2005; Betsche et al., 2005), protein content (Uguru and Madukaife, 2001), colour and colour pattern (Oshodi et al., 1995), shapes (Dalziel, 1948; Kay, 1987) and lecitin content (Okeola and Machuka, 2001) etc. Marked genetic variations may exist among the metric measurements (length, width, thickness and their ratios) on the seeds; to understanding this is one of the essences of this study.

The various metric measurements on seeds are very important quantitative variables for determining size and shape of seeds (Wyllie-echeverria et al., 2003). Seed size and shape are important determinants of seed dispersal and probable loss (Cerda and Garcia-Fayos, 2002), moisture imbibitions and germination of seeds (Balkaya and Odabas, 2002) and grain grading quality. In soybean, seed size and shape has been reported to be highly correlated and important grading parameters of seed grains (Shahin et al., 2006). Moreover, demand for seed grains for human consumption is linked to size and shape (Shahin et al., 2006). The mass, oil and protein content of seeds are well associated with seed metrics (Omokhafe and Alika, 2004; Kaushik et al., 2007).

Therefore breeding for seed grain yield, size, shape, mass, oil and protein content demands a fundamental assessment of the seed metrics, their individual genotypic and inter-genotypic response(s) . Published information on the seed metrics of African yam bean, their genotypic variation and inter-character relationship is not available. Genotypic variability and heritability of traits are important factors determining the worthwhile-ness of embarking on crop genetic improvement. In addition, the genetic interrelationship among traits is efficient for systematic selection procedure of co-inherited traits (Belay et al., 1993).

Initial reports by Dalziel (1948) and Baudoin and Mergeai (2001) merely speculated the seed shapes of AYB to include: ellipsoidal/rhomboid, rounded/ovoid or truncated/cylindrical. The justification for such classifications was not based on the metric measures on the seed; whereas shapes are most determined by the metric measures on figures (Loncaric, 1998). There are no consistent evaluation criteria for shape description although there are many methods for evaluating shapes (Loncaric, 1998). The choice of methods depends on the properties of the shape to be described. In this study, shape descriptor vectors were generated from some metric measures on the seeds and the shapes were matched to the evolved metric models for the descriptions of the shapes of AYB seeds.

Since no research had earlier reported the variability and genetics of the seed metrics of AYB and neither had the quantitative approach to classifying AYB seeds into shapes been employed; the present study was therefore proposed with the following objectives:(1) to understand the variability among the eighty genotypes of AYB for six seed characters, (2) to test the suitability of the six characters as quantitative parameters for discriminating and evaluating AYB, (3) to understand their inter-character association as genetic indices of seed yield and (4) to classify AYB seeds into shapes based on shape indices generated from the ratios of the seed metrics.

MATERIALS AND METHODS

A population of ten plants per genotype, one plant/stand at 1 x 1 m spacing was maintained for the characterization of eighty genotypes of AYB at the International Institute of Tropical Agriculture (IITA), Ibadan in 2006. A list of the eighty AYB genotypes with colour code description by Kornerup and Wanscher (1978) is in Table 1. The pods were fumigated for 48 h after harvest before threshing. The seeds were cleaned and dried at 5°C. The seeds were withdrawn from the drying room for permanent storage when the moisture content had stabilized at 12%.

Ten seeds in three replicates were randomly selected from each seed lot of the 80 genotypes; the experimental layout was a completely randomized design. The seed length (distance between the two ends of the seed, parallel to the hilum), seed width (distance on the seed measured from hilum to the keel) and seed thickness (distance measured perpendicular to the seed length) were measured in millimeters using the vernier caliper according to Kaushik et al. (2007). The ratios between the seed length, width and thickness were estimated from the individual values of the length, width and thickness of the seeds following Omokhafe and Alika (2004).

The means from the ten individual samples per replicate for each genotype were generated for the six characters. These were subjected to descriptive and comparative (paired t-test) statistics/analysis and then analysis of variance according to Gomez and Gomez (1984). The fifteen possible paired combinations of the six characters were subjected to covariance analysis following Singh and Chaudhary (1985).

The phenotypic and genotypic coefficient of variation (PCV and GCV), broad sense heritability (H^2), genetic advance (GA as % of mean), co-heritability, phenotypic and genotypic correlation coefficients (PCC and GCC) and regression were estimated according to Singh and Chaudhary (1985) from the components of variance and covariance are as follows:

$\mathrm{PCV} = 100 \quad {}^{2}p/x,$

$\mathrm{GCV} = 100 \quad {}^{2}g/x,$

$H^2 = \; {}^{2}g/ \; {}^{2}{}_{p},$

$\mathrm{GA\ (as\ \%\ of\ mean)} = (i.\ {}^{2}{}_{g}/\ {}^{2}{}_{p})100/x,$

$\text{Co-heritability} = {}^{2}g_{1,\ 2}/\ {}^{2}p_{1,\ 2},$

$\mathrm{PCC} = \; {}^{2}p(1,\ 2)/\ {}^{2}p(1) \quad {}^{2}{}_{p(2)},$

$\mathrm{GCC} = \; {}^{2}g(1,\ 2)/\ {}^{2}g(1) \quad {}^{2}{}_{g(2)},$

Where, x is the mean, ${}^{2}{}_{g}$ is genetic variance (genotypic mean square - error mean square)/number or replications, ${}^{2}{}_{p}$ is phenotypic variance (genotype mean square/number of replications).

The standard selection differential (i) for 5% selection intensity was 2.06, ${}^{2}g\ ({}_{1,\ 2})$ is genetic covariance (genotype mean product of characters 1 and 2 - error mean product for same characters)/ number of replications, ${}^{2}{}_{p(1,\ 2)}$ is phenotypic covariance (genotype mean product plus error mean product for characters 1 and 2). The standard deviation (Sd) and standard error (SE) of the heritability value was calculated following Tenkouano et al. (2002) as:

Table 1. Morphological descriptions of the 80 African yam bean genotypes based on seed coat colours.

Genotypes	Seed coat colours	Colour codes in Methuen book of colour chart (Kornerup and Wanscher, 1978)
TSs1	Light brown	6D5-6
TSs2	Agate	7E7
TSs3	Rusty brown	6E8
TSs4	Leather brown	6E6
TSs6	Cocoa brown	6E6-7
TSs7	Camel brown	6D4
TSs8	Reddish golden(V)	6C3
TSs9	Camel brown	6D4
TSs10	Camel brown(V)	6D4
TSs11	White	-
TSs12	Brown	6E8
TSs13	Teak brown	6F5
TSs16	Greyish white	6B1
TSs18	Camel brown(V)	6D4
TSs22	Sun-burn brown	6D5
TSs23	Camel brown(V)	6D4
TSs24	Cognac brown(V)	6E7
TSs27	Light brown(V)	6D7
TSs30	Sahara brown	6C5
TSs31	Red-haired brown(V)	6C4
TSs32	Sun-burn brown(V)	6D5
TSs33	Sun-burn brown(V)	6D5
TSs36	Birch back	6B2
TSs38	Sun-burn brown(V)	6D5
TSs39	Greenish grey	6B1-2
TSs40	Reddish golden	6C3
TSs44	Camel brown	6D3-4
TSs46	Cocoa brown	6E5-6
TSs47	Brownish grey	6C2
TSs48	Sahara brown	6C5-6
TSs49	Sun-burn brown(V)	6D5
TSs50	Greyish white	6B1
TSs53	Brown	6E8
TSs55	Sun-burn brown	6D5
TSs56	Camel brown	6D4
TSs57	Reddish golden(V)	6C3
TSs58	Light brown(V)	6D8
TSs59	Camel brown	6D4
TSs60	Reddish golden	6C3
TSs61	Red-haired brown	6C4
TSs62	Cinnamon brown	6D6
TSs63	Red-haired brown	6C4
TSs65	Leather brown(V)	6E6
TSs67	Dark brown	7F8
TSs69	Deep purple	14F8
TSs76	Reddish grey	7B2
TSs77	Brown	7E5-6
TSs78	Brown	7E5-6
TSs79	Agate(V)	7E7

Table 1. Contd.

TSs81	White	-
TSs82	Sun-burn brown	6D5
TSs83	Cognac brown	6E7
TSs84	Sun-burn brown	6D5
TSs86	Camel brown	6D4
TSs87	Sun-burn brown	6D5
TSs89	Agate	7E7
TSs90	Brownish orange(V)	6C3
TSs91	Camel brown(V)	6D4
TSs92	Agate	7E7
TSs93	Agate	7E7
TSs94	Brown	7E5-6
TSs95	Light brown	7D5
TSs96	Light brown	7D5
TSs98	Sun-burn brown	6D5
TSs100	Sun-burn brown	6D5
TSs101	Dark brown(V)	7F8
TSs104A	Brownish orange(V)	6C3
TSs104B	Greyish white	6B1
TSs109	Tan brown	6E6
TSs111	Sun-burn brown	6D5
TSs112	Rusty brown	6E7-8
TSs116	Camel brown	6D4
TSs117	Agate	7E8
TSs118	Yellowish grey	4B2
TSs119	Brownish orange	6C3
TSs125	Cocoa brown	6E6
TSs126	Light blond	4C3
TSs127	Greyish white	1B2
TSs128	Brownish orange	5C3
TSs130	Tan brown (V)	6E6

NB: the prefix "(V)" was meant to denote variegation or speckling on seeds with respective testa basal colours; others without the prefix are monocoloured.

$Sd(H^2) = (2/n_1+2 + 2/n_2+2)(1- H^2)$ and $SE = 100Sd/ n$

Where n_1 and n_2 are the degrees of freedom of the genotypes and the error source of variation respectively and n is the sample size.

The means of traits were compared using critical difference (CD), following the formula of Singh and Chaudhary (1985):

$CD = (2 MS_e/r)^{1/2} \times t$

Where; Mse is the error mean square, r is the number of replicates and t is the tabulated value at 5 or 1% level of significance for the degree of freedom of error mean square.

The regression coefficient was tested by a t-test statistics of: $t = b/SE$, following Singh and Chaudhary (1985), where b is the regression coefficient and SE is the standard error.

The generation of the shape descriptor vectors (length, width thickness etc.) is fundamental to shape description (Loncaric, 1998). The description and the classification of AYB seeds into various group of shapes was determined by the following seed shape indices: the Eccentricity Index (EI) - ratio of the seed length to the width according to Balkaya and Odabas (2002), the Flatness Index (FI) of Cerda and Garcia-Fayos (2002), which is estimated as: $(L + W)/ 2T$, where: L, W and T are respective metric measurements for length, width and thickness on the seeds and the ratios of the seed length to thickness and width to thickness. Pearson correlation was used to investigate the relatedness among these indices. The intervals (minimum to maximum) of the values generated for each index among the genotypes were grouped into four quartiles ranges. Means and standard errors were estimated for the population of genotypes within each group, the shapes were then matched to the indices.

RESULTS AND DISCUSSION

Descriptive statistics and variability among six metric measurements on AYB seeds

The mean, minimum and maximum values with the critical differences (P = 0.01 and 0.001) of the six variables are shown in Table 2. TSs82 was the genotype

Table 2. Descriptive statistics of six seed traits of African yam bean.

Traits	Mean ± SE	Min. (mm)	Max.(mm)	$CD_{0.01}$	$CD_{0.001}$
Seed length	8.91 ± 0.069	7.18 (TSs39)	10.45 (TSs82)	0.346	0.451
Seed width	6.96 ± 0.035	6.14 (TSs39)	7.59 (TSs87)	0.270	0.351
Seed thickness	6.77 ± 0.044	5.82 (TSs89)	7.79 (TSs44)	0.298	0.387
LW	1.29 ± 0.009	1.12 (TSs79)	1.48 (TSs125)	0.071	0.092
LT	1.33 ± 0.013	1.07 (TSs44)	1.70 (TSs89)	0.076	0.099
WT	1.03 ± 0.005	0.94 (TSs44)	1.22 (TSs89)	0.049	0.063

Note: LW = Seed length/Seed width, LT = Seed length/Seed thickness and WT = Seed width/Seed thickness.CD - Critical difference; resultant mean difference between two traits compared that exceeds the critical difference value e.g. CD (1%), is significant at P = 0.01.

with the longest seed (10.45 mm); TSs87 the widest (7.59 mm) and TSs44 the thickest (7.79 mm). The genotype with the least seed length and width was TSs39. TSs89 had the least thickness of 5.82 mm; it is the slimmest genotype, because it has the highest and significant width/thickness and length/thickness of 1.22 and 1.70 respectively. For all the genotypes tested, the seed length was longer than the width and thickness but the difference between seed width and thickness was not consistent. The seed width of forty- eight genotypes was significantly (P = 0.01) higher than the seed thickness, seeds of twenty-one genotypes had longer thickness than width but the differences between the width and thick ness of eleven genotypes was statistically non significant. The least ratio of width and thickness (0.94) was in TSs44 (Table 2).

It is necessary to ascertain that the metric measurements (length (SL), width (SW), thickness (ST), length/width (LW), length/thickness (LT) and width/thickness (WT)) on the seeds were not mere duplication of a single character. T-test statistics combined the six traits into 15 paired combinations (Table 3) . All the paired character comparison significantly ($P < 0.001$) negated the null hypothesis. Their means are significantly ($P < 0.001$) different from each other, hence, none of the characters could be a substitute for the other in any evaluation or classification studies on AYB. Therefore, the six characters are unique discriminatory traits for AYB. Wyllie-echeverria et al. (2003) did show that seed size and seed metrics were important discriminators of *Zostera marina*. The inclusion of these quantitative traits in the taxonomic descriptions of AYB can increase the confidence and the accuracy of morphological classification. In *Kohlrauscchia spp*, the testa characters are the most constant and reliable morphological descriptors for separating the taxon (Ball and Heywood, 1962).

Genetic variability

Table 4 presented the F-values, phenotypic and genotypic coefficients of variation, broad sense heritability and genetic advances. There were significant (P 0.05) differences among the eighty genotypes for all the six characters (Table 4). Generally the PCV and GCV were low for all the traits with very high genetic proportion (>90%). However, the heritability estimates for the six characters were very high, ranging from 86% (in WT) to 94% (in seed length). Such higher heritability for seed length compared with that of other dimensions on the seeds have been obtained in oat by Harper *et al.* (1970). This is similar to the finding reported by Kaushik et al. (2007). The high broad sense heritability estimate suggests that the traits have high genetic potentials, the effect of the environment in determining them is low and additive gene effect could be playing predominant role on their expression. Reliable selection of genetic materials can be made on the basis of high broad sense heritability estimates for cowpea (Kandasamy et al., 1989 and Thiyagarajan, 1990). Only four of the parameters (ST, LW, SL and LT) showed high to very high genetic advances in the proportions of 19.6, 20.6, 24.0 and 30.6 respectively; they equally had high broad sense heritability. Johnson *et al.* (1955) and Siddique and Gupta (1991) had obtained similar results. The combination of high heritability and genetic advances are important indicators of the predominant role of additive gene effect in traits (Manju and Sreelathakumary, 2002). Predictability of high performance and hence selection of materials based on the above criteria may lead to successful breeding programme in AYB.

Inter-character relationships

The correlation coefficients in Table 5 tested the relationships among traits more precisely with reference to genotypic and phenotypic relationships between traits combining. All the phenotypic correlation coefficients (PCC) in Table 5 were higher than their respective genotypic correlation coefficient (GCC). PCC and GCC between seed length and the other five traits were only positive and significant at $P< 0.05$ for LW and LT. The three ratios had positive and significant correlation between themselves. From this study the phenotypic and genotypic correlation between seed length and width did

Table 3. Paired comparison of the means of the six seed traits of African yam bean.

	SL (8.91)	SW (6.96)	ST (6.77)	LW (1.29)	LT (1.33)	WT (1.03)
SL (8.91)	-	32.23***	27.27***	122.12***	126.34***	117.04***
SW (6.96)		-	5.95***	151.11***	147.42***	170.68***
ST (6.77)			-	113.37***	102.41***	120.62***
LW (1.29)				-	6.05***	29.44***
LT (1.33)					-	29.57***
WT (1.03)						-

Note: SL = Seed length, SW = Seed width, ST = Seed thickness, LW = Seed length/width, LT = Seed length/thickness and WT = Seed width/thickness. The overall mean (in mm) of genotypes in parenthesis. *** - significance at $P < 0.001$.

Table 4. Measures and estimates of variances of six seed traits of African yam bean.

Traits	Genotypic F-value	GCV (%)	PCV (%)	Heritability ± SE	Genetic advance (%)
Seed length	15.05***	12.03	12.42	93.77 ± 0.005	23.99
Seed width	6.31**	7.77	8.36	86.32 ± 0.010	14.87
Seed thickness	8.27**	10.10	10.69	89.21 ± 0.008	19.64
LW	6.09**	10.87	11.73	85.90 ± 0.011	20.75
LT	11.41**	15.49	16.16	91.94 ± 0.006	30.60
WT	4.2*	7.69	8.56	80.77 ± 0.015	14.24

Note: *, **, *** - significance at $P < 0.05$, 0.01, 0.001.

Table 5. Genotypic and phenotypic correlation coefficients and co-heritability estimates between the six traits

	SL	SW	ST	LW	LT	WT
SL	-	0.16^{ns} 0.16^{ns}	0.03^{ns} 0.03^{ns}	0.23^{*} 0.31^{**}	0.23^{*} 0.28^{*}	0.13^{ns} 0.15^{ns}
SW	0.99	-	0.21^{ns} 0.27^{*}	-0.02^{ns} -0.14^{ns}	-0.01^{ns} -0.05^{ns}	0.003^{ns} 0.09^{ns}
ST	0.76	0.79	-	-0.12^{ns} -0.15^{ns}	-0.18^{ns} -0.25^{*}	-0.18^{ns} -0.28^{*}
LW	0.76	0.16	0.79	-	0.27^{*} 0.35^{**}	0.14^{ns} 0.23^{*}
LT	0.83	0.27	0.70	0.78	-	0.23^{*} 0.30^{*}
WT	0.93	0.04	0.64	0.64	0.77	-

Note: Note: SL = Seed length, SW = Seed width, ST = Seed thickness, LW = Seed length: width, LT = Seed length: thickness and WT = Seed width: thickness. Upper diagonal bears the genotypic and phenotypic (in bold) correlation coefficients. Lower diagonal bears the co-heritability values. *, ** - significance at $P < 0.05$, 0.01, ns - non significance.

not agree with the finding of Omokhafe and Alika (2004) for rubber seeds, however, the correlation between seed width and thickness was similar to those obtained for Jatropha by Kaushik et al. (2007). However, in this population of AYB, the seed length and thickness had no significant correlation. The correlations of seed width and thickness with the three ratios were negative except between seed width and WT; significance ($P < 0.05$) was observed only between seed thickness with LT and WT. This denotes that improvement on the seed thickness will significantly lower the length to thickness and the width to thickness ratios of the seeds.

Co-heritability

The lower diagonal of Table 5 has the co-heritability values for pairs of characters. All the fifteen pairs exhibited positive co-heritability in the range of 0.043 (between seed width and WT) to 0.990 (between seed length and width). Although PCC and GCC disproved significant association between seed length and width, however, co-heritability estimate was highest between them. The disparity between PCC, GCC and co-heritability estimates, notwithstanding, selection of any of the seed metric traits have resulted in practical breeding

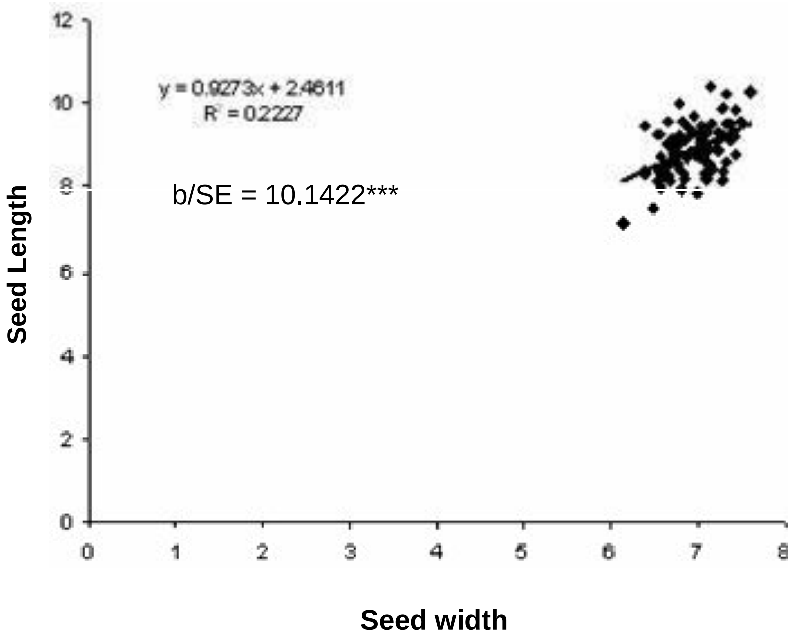

Figure 1a. Relationship between seed length and width of African yam bean.

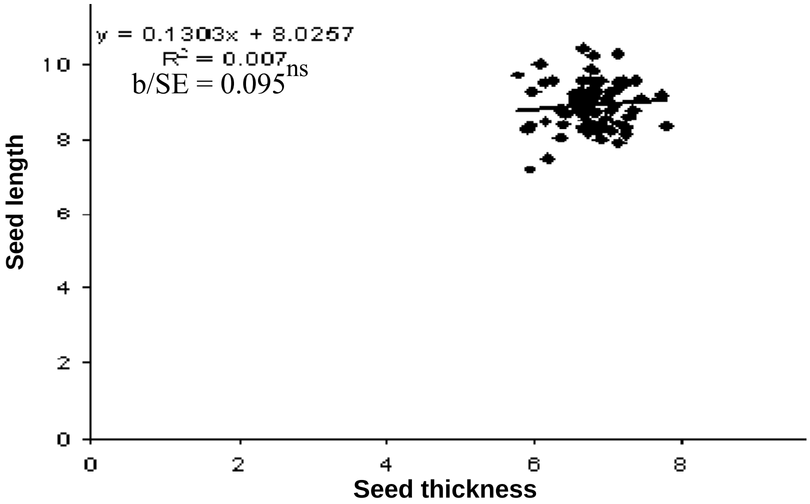

Figure 1b. Relationship between seed length and thickness of African yam bean.

progress of simultaneous traits (Omokhafe and Alika, 2004; Kaushik et al., 2007). Relatively high co-heritability (>0.64) was observed between seed length, width and thickness and between their ratios. This suggests that selection of either of the characters would simultaneously affect the others positively. Similar results have been obtained for some quantitative characters of mungbean (Singh and Malhotra, 1970), pea (Narsinghani et al., 1978) and safflower (Akbar and Kamran, 2006). Longer, broader and thicker seeds would have corresponding heavier weight, which is a determinant of 100 seed weight and hence seed yield. All the three ratios were highly (64 - 93%) co-heritable with seed length and thickness but their co- heritable status with seed width were less than 30%.

Relationships existing among the three seed metrics were presented graphically in Figures 1a, b and c. Good and predictable relationship (r = 0.47and 0.69) existed between the seed length and the seed width (Figure 1a) and between the seed width and the seed thickness (Figure 1c) respectively. The reliability of predictability through the resultant regression equation was tested and found to be highly significant (P < 0.001) between seed length and seed width and seed width and seed

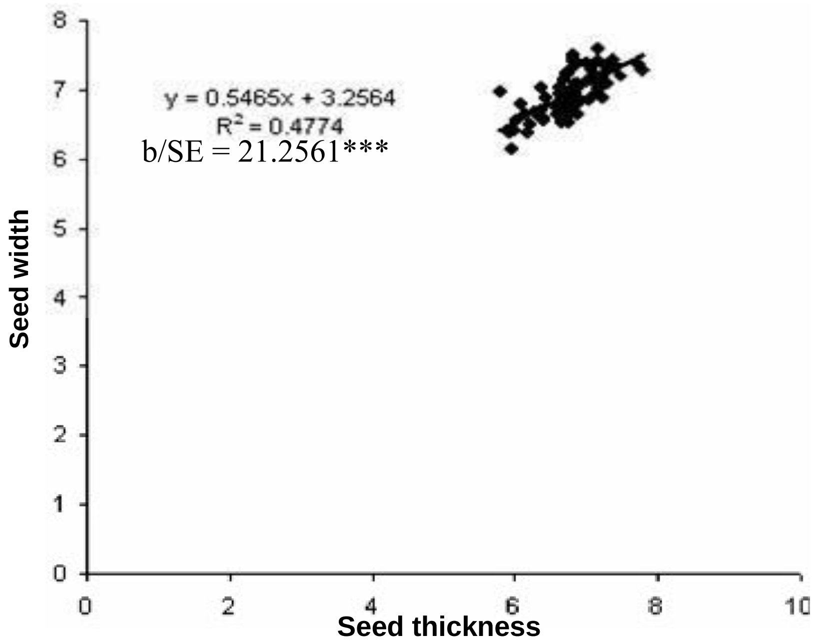

Figure 1c. Relationship between seed width and thickness of African yam bean.

Table 6. Pearson correlation coefficients of seed shape indices of African yam bean.

	LW (EI)	LT	WT	FI
LW(EI)	-	0.88^{***}	0.36^{**}	0.78^{***}
LT		-	0.76^{***}	0.98^{***}
WT			-	0.87^{***}
FI				-

Note: LW = Seed length: width (i.e. Eccentricity Index (EI)), LT = Seed length: thickness and WT = Seed width: thickness and FI = Flatness Index.
*, **, *** - significance at $P < 0.05, 0.01, 0.001$

thickness. It is noteworthy that quantitative raw measurements of seed metrics on genotypes within this population can be predicted with utmost accuracy ($p < 0.001$) from some equations: $Y = 0.9273X + 2.4611$ (seed length from known seed width) and $Y = 0.5465X + 3.2564$ (seed width from known seed thickness). No reliable ($r = 0.084$) regression equation was obtained between seed length and seed thickness (Figure 1b) in this study.

Seed shape of AYB

The shape of an object is a binary image representing the extent of the object (Loncaric, 1998), but a common problem in shape description research is how to judge the quality of a shape description method. Nevertheless, the goal of seed shape description is to uniquely characterize the shapes using its shape descriptor vectors. From Table 6, very high and significant correlations (r 0.76) exist among the seed shape indices except for between LW and WT ($r = 0.364$). The most used seed shape indices in literatures were: EI (LW) of Balkaya and Odabas (2002) and FI of Cerda and Garcia-Fayos (2002). The very high and significant correlation ($r = 0.867, 0.880$ and 0.982) of WT and LT with EI and FI (Table 6) indicates that WT and LT are equally potent indices for the description of the seed shapes of AYB. Every point on the surface of a round shaped seed is at an equal or almost equal distance from the centre, oval shapes are slight from round, oblong deviates from a square or circle due to elongation in length and long oblong have longer length that make its look rhomboidal. The mean and standard error for each of the shape indices are shown in Table 7 and the seeds of the following genotypes (among others) can be grouped thus: TSs2, TSs13, TSs44, TSs50, TSs53, TSs65, TSs79, TSs90, TSs111 and TSs130 are round; TSs1, TSs8, TSs9, TSs10, TSs18, TSs36, TSs38, TSs62, TSs63, TSs81, TSs93, TSs104A, TSs16, TSs17, TSs18 and TSs27 are oval; TSs12, TSs40 and TSs49

Table 7. The shape indices with the corresponding shapes of African yam bean seeds.

Seed shape indices models								Corresponding seed shapes
LW (EI)	**n**	**LT**	**n**	**WT**	**n**	**FI**	**n**	
1.170 ± 0.010	16	1.186 ± 0.010	24	0.989 ± 0.003	29	1.084 ± 0.006	19	Round
1.257 ± 0.006	35	1.332 ± 0.007	38	1.044 ± 0.003	40	1.180 ± 0.005	49	Oval
1.345 ± 0.006	22	1.455 ± 0.015	15	1.099 ± 0.004	10	1.284 ± 0.009	9	Oblong
1.440 ± 0.012	7	1.617 ± 0.037	3	-	1	1.358 ± 0.055	3	Rhomboid

Note: LW = Seed length: width (that is Eccentricity Index (EI)), LT = Seed length: thickness and WT = Seed width: thickness and FI = Flatness Index n = sample size.

are oblong and TSs82, TSs89 and TSs91 are rhomboid in shape. Among the eighty genotypes tested, the most prominent shape in AYB was the oval, followed by round then the oblong and rhomboid (Table 7). The obtained result here re-endorsed the affirmation of Harper et al. (1970) that seed shapes exhibits intra-specific variability. We recommend the six seed traits as unique parameters of AYB based on the wide variability between them and the use of the four seed shape indices as complements for the descriptions of AYB seed shapes.

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