

Screening of African Yam Bean Accessions for Imbibition and Seed Physiological Quality

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Abstract

African yam bean is a nutritionally-important but neglected food crop with several health benefits. But its large scale cultivation and consumption are still limited by lack of systematic genetic improvement and breeding programme for the crop. Preliminary studies have established that the inherent field establishment potential of African yam bean is low. Hence the need to screen available accessions to identify those with outstanding seed physiological qualities for selection as parental materials for further improvement. Thirty-four African yam bean accessions were collected from different farmers in five states of Southeastern Nigeria. Seed physiological quality (viability and vigour) was assessed using hundred seed weight, water imbibition, standard germination, accelerated ageing and conductivity tests. The mean squares due to varietal effect were significant ($p < 0.05$) for germination index and highly significant ($p < 0.01$) for all other traits. Accessions ENAGag, ENAGmg 1 and ENAGmg 2 had high standard ($> 80\%$) and accelerated ageing ($> 70\%$) germination percentages. Only 11 of the accessions had an accelerated ageing germination percentage of above 50%. All but one of the 34 accessions had conductivity values less than $5.00 \mu\text{Scm}^{-1} \text{g}^{-1}$. On the average, African yam bean seeds require up to 76.9% moisture of their initial weight over a period of approximately 53 hours prior for the commencement of germination process. Accessions ENAGag, ENAGmg 1, ENAGmg 2, ENNKob, ENNSog, IMISis, IMOKeo 1 and IMOKeo 3 were outstanding and are therefore potential candidates for genetic improvement of seed quality in African yam bean.

Keywords: accelerated aging, African yam bean, conductivity, germination, imbibition

1. Introduction

African yam bean [*Sphenostylis stenocarpa* (ex. A. Rich.) Harms] is an underutilized indigenous legume consumed for its nutritious grains and tubers (Potter & Doyle, 1992). It is cultivated throughout West Africa countries particularly, Cameroon, Cote d'Ivoire, Ghana, Nigeria and Togo (Potter, 1992). It is a perennial climbing species whose morphotypes may be prostrate or erect and about 1-3 m in height. Its leaves are trifoliate, 2.7 to 13 cm long and 0.2 to 5.5 cm broad (Nnamani et al., 2017). The edible seeds have high amino acid content (lysine and methionine) which has been reported to be higher than those of pigeon pea, cowpea, and Bambara groundnut (Uguru & Madukaife, 2001). It is commonly cultivated by traditional farmers along the South West and South East regions of Nigeria (Nnamani et al., 2017). The propagation of African yam bean (AYB) is predominantly through seeds and despite its great nutritional potentials, the consumption and cultivation of the legume is still limited by lack of systematic genetic improvement studies on the crop. While 55% of farmers cultivating AYB in South East Nigeria reported poor availability of seeds, 60% reported poor seed quality as constraints to the extensive cultivation of African yam bean (Nnamani et al., 2017).

Seed viability and vigour constitute the physiological component of seed quality. Seed viability is the ability of the seed to germinate under optimal conditions, while seed vigor denotes inherent ability of seeds to emerge uniformly even under adverse environmental conditions in the field (Kandasamy et al., 2020). Low-vigor seeds emerge less uniformly than high-vigor seeds (Egli & Rucker, 2012), and delay in emergence affects the

subsequent stages of growth such as the seedling's competitive ability for light, water, and nutrients. These irregularities in crop emergence and development within a population result in decreased yield (Finch-Savage, 1995). Higher plant biomass and yield have been attributed to seeds with high physiological potential (Höfs, Schoeman, & Vaissayrel, 2004; Egli & Rucker, 2012). The extent that reserved food in seeds supports seedling establishment is not fully understood, nor is the variation in different varieties and the sizes of their seeds within the same variety/hybrids, since the small and large seeds tend to have different amounts and compositions of nutritional reserves (Eggert & von Wirén, 2015). Venuto, Redfearn, Pitman, & Alison, (2002) showed that seed weight significantly influences germination, seedling vigor and seasonal yield performance of annual ryegrass cultivars.

Vigour tests are efficient in identifying less advanced stages of seed deterioration and they facilitate decision making in seed production enterprises, especially in establishing storage, commercialization, and quality control policies (Medeiros, Silva, Capobianco, Fialho, & Dias, 2019). The main objective of vigor tests is to identify possible differences in the physiological potential of seed lots which have similar germination percentages (Marcos-Filho, 2015). The use of tests based on different principles could be combined to present more reliable response with respect to the physiological potentials of the seed lots. Among vigor tests, accelerated ageing and electrical conductivity tests are considered the most sensitive tests for categorizing seed lots (Medeiros et al., 2019). The accelerated ageing test provides valuable information regarding storage and field emergence potentials of seedlings (Marcos-Filho, 2015), while the electrical conductivity test is useful for speedy assessment of the integrity of cellular membranes in seeds (Silva, Lopes, Marcos-Filho, & Vieira, 2012). It is known that degeneration of cell membranes is the first event in the seed deterioration process. The greater the conductivity value, the lower the seed germination and vigor, due to loss of cell membrane integrity (Medeiros et al., 2019). Therefore, the tests results reflect the physiological potential of seeds, and inferences can be made regarding the storage potential of diverse seed lots (Binotti et al., 2008).

The vigour of AYB seeds is known to be inherently low (Olisa, Ajayi, & Akande, 2010a). But this inference was based on a limited number of accessions. Hence this study with the aim to screen 34 available accessions of African yam bean for viability cum vigour characteristics with the view of identifying accessions with outstanding seed physiological qualities for selection in breeding as well as conservation programmes.

2. Materials and Methods

2.1 Seed Collection

Thirty four African yam bean accessions were collected from different AYB stakeholders (farmers' gene bank and vendors) in five states of Southeastern Nigeria (Table 1). The study area was Southeastern Nigeria, comprising of Abia, Anambra, Ebonyi, Enugu and Imo States (Figure 1).

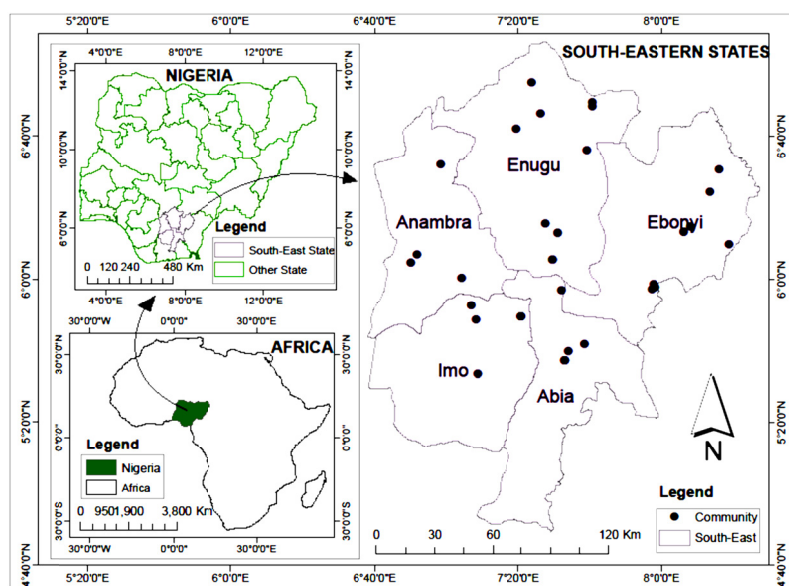


Figure 1. Southeastern states of Nigeria where samples of African yam bean (*Sphenostylis stenocarpa*) accessions were collected. Source (Nnamani et al., 2017)

Table 1. Details of the Africa yam bean accessions collected within the Southeastern part of Nigeria

S/N	Sample Code	State	LGA	Community	Longitude	Latitude	Source
1	ABBEuz	ABIA	Bende	Ngwu Uzoakoli	7°55.07'E	5°62.02'N	Farmer
2	ABBEuz 1	ABIA	Bende	Ngwu Uzoakoli	7°55.23'E	5°62.22'N	Farmer
3	ABUNum 2	ABIA	Umuahia North	Ubani Makt	7°56.78'E	5°66.23'N	Vendor
4	ABBEuz	ABIA	Bende	Ngwu	7°55.08'E	5°62.02'N	Farmer
5	ABBEuz 1	ABIA	Bende	Court	7°64.26'E	5°69.57'N	Farmer
6	ANAGan	ANAMBRA	Aghamelum	Anaku	-	-	Vendor
7	ANAGug	ANAMBRA	Aguata	Uga	-	-	Farmer
8	ANINum	ANAMBRA	Idemili North	Umuoji	-	-	Farmer
9	ANISnn	ANAMBRA	Idemili South	Nnobi	-	-	Market
10	EBANam	EBONYI	Afipko North	Amata	7°97.1'E	5°96.57'N	Farmer
11	EBANao 1	EBONYI	Afipko North	Apku Oha	7°96.34'E	5°97.97'N	Farmer
12	EBANau	EBONYI	Afipko North	Apku Ugo	7°95.47'E	5°95.47'N	Farmer
13	EBIKea	EBONYI	Ikwo	Eleke Achara	8°13.56'E	6°24.33'N	Farmer
14	EBIKok	EBONYI	Ikwo	Okputomo	8°10.43'E	6°22.13'N	Farmer
15	EBISlo	EBONYI	Ishielu	Labassa Okpoto	7°51.82'E	6°21.69'N	Farmer
16	EBIZib	EBONYI	Izzi	Iboko	8°22.59'E	6°40.68'N	Farmer
17	EBIZig	EBONYI	Izzi	Igboagu	-	-	Farmer
18	EBIZwa	EBONYI	Izzi	Waka	8°31.5'E	6°16.44'N	Farmer
19	ENAGag	ENUGU	Agwu	Agbaogugu	7°46.07'E	6°25.72'N	Farmer
20	ENAGmg 1	ENUGU	Agwu	Mgbowo	7°49.57'E	6°09.46'N	Farmer
21	ENAGmg 2	ENUGU	Agwu	Mgbowo	7°49.57'E	6°09.46'N	Farmer
22	ENANam 2	ENUGU	Aninri	Amoro	7°53.7'E	5°95.1'N	Farmer
23	ENISib	ENUGU	Igboeze South	Ibagwa	7°39.84'E	6°91.63'N	Farmer
24	ENIWea	ENUGU	Igbetiti West	Eke Aku	7°32.68'E	6°70.29'N	Farmer
25	ENNEub	ENUGU	Nkanu East	Ubahu	7°67.93'E	6°80.52'N	Vendor
26	ENNKob	ENUGU	Nkanu East	Obe	7°67.94'E	6°82.56'N	Farmer
27	ENNSeh	ENUGU	Nsukka	Ehandagu	7°65.24'E	6°59.90'N	Farmer
28	ENNSog	ENUGU	Nsukka	Ogbaozara	7°43.96'E	6°77.26'N	Farmer
29	IMIKum	IMO	Ikeduru	Umudi	-	-	Vendor
30	IMINak	IMO	Ideato North	Akuokwa	-	-	Farmer
31	IMISis	IMO	Ideato South	Isiekenesi	-	-	Vendor
32	IMOKeo 1	IMO	Okigwe	Eke Okigwe	7°34.95'E	5°82.56'N	Farmer
33	IMOKeo 2	IMO	Okigwe	Eke Okigwe	7°34.96'E	5°82.57'N	Farmer
34	IMOKeo 3	IMO	Okigwe	Eke Okigwe	7°34.96'E	5°82.57'N	Farmer

Source: Field survey, 2016.

2.2 Hundred Seed Weight

One hundred seeds in three (3) replicates of each accession were counted and weighed using a sensitive measuring scale.

2.3 Standard Germination Test

This test was conducted following International Seed Testing Association (ISTA) 2018 rules (ISTA, 2018). Fifty seeds in four replicates were planted on moistened sterilized riverbed sand for 10 days in plastic bowls and covered with transparent polythene sheets to maintain humidity. Counts were taken daily from the 3rd to the 10th day after planting (DAP) (Olisa et al., 2010a). Germination was assessed as a percentage of seeds producing normal seedlings as defined by ISTA (International Seed Testing Association) rules:

$$\text{Germination percentage (GPCT)} = \frac{100 \times \text{Number of seedlings emerged 10DAP}}{\text{Total number of seeds planted}} \quad (1)$$

Germination index (GI): This was calculated as proposed by Fakorede and Agbana (1983) as,

$$\text{Germination Index} = \frac{\sum [(\text{number of plants emerged in a day}) (\text{DAP})]}{\text{Total Number of plants emerged by the 10}^{\text{th}} \text{ day}} \quad (2)$$

2.4 Accelerated Ageing Test

Fifty seeds in three replicates from each of the accessions were weighed and placed in wire mesh in accelerated ageing boxes containing 40 ml of distilled water. The seeds were aged by placing them in an accelerated ageing chamber at 43°C for 72 h at the end of which the seeds were re-weighed. The amount of water imbibed during the ageing (WIA) process was calculated as the difference between the final and initial weights (g) of the seeds and expressed as a percentage of initial weight. Standard germination test was then conducted with the aged seeds as described above to achieve the accelerated ageing germination percentage (AAT). Accelerated ageing germination index (AAI) was calculated by substituting the germination counts after accelerated ageing into the formula used earlier to obtain germination index.

2.5 Conductivity Test

Three replicates of 50 pre-weighed seeds from each accession were soaked for 24 h in 100 ml distilled water in 200 ml conical flasks covered with aluminium foils to prevent contamination. The conductivity of water was also measured using a flask with 100 ml distilled water without seeds. Conductivity was measured using Jenway 4510 (Bibby Scientific Ltd., Staffordshire, UK) conductivity meter. The results were expressed as $\mu\text{Scm}^{-1} \text{g}^{-1}$:

$$\text{Conductivity (COND)} = \frac{\text{Conductivity } (\mu\text{S}) \text{ for each flask} - \text{Conductivity of distilled water}}{\text{Initial weight (g) of seed sample}} \quad (3)$$

2.6 Vigour Index

Vigour index was calculated as an average of the percentage difference across the treatments in each of the tests (Awosanmi, 2010). The higher the VI, the more stable the genotype.

$$\text{VI} = [(\text{GPCT} + \text{AAT} + \text{COND}\%)/3] \quad (4)$$

Where, GPCT = Germination percentage, AAT = Accelerated ageing germination percentage, COND = conductivity.

Conductivity values were converted to % as follows:

$$\text{COND}\% = [100 \times (30 - \text{COND})/30] \quad (5)$$

Given that lower conductivity values indicate higher quality, the factor 30 was used based on interpretation of conductivity values in relation to field emergence as suggested by Hampton and TeKrony (1995). Therefore, seed lots with conductivity values greater than $30 \mu\text{Scm}^{-1} \text{g}^{-1}$ were regarded as not suitable for sowing especially under adverse weather conditions (Awosanmi, 2010).

2.7 Water Imbibition Test

This was carried out by planting 10 pre-weighed individual seeds from each accession in pre-numbered positions on a paper towel in a covered transparent plastic box. This was replicated 3 times. The seeds were removed at intervals of 6 h, weighed and returned to continue imbibition until sprouting or the emergence of the radicle. The duration of imbibition (DIM) was the period in hours from the planting to the time 50% of the seeds per replicate emerged radicle. The amount of water imbibed was then calculated and expressed in percentage (WIP) as the difference between the initial and final weights according to Olisa, Ajayi, and Akande (2010b).

2.7 Statistical Analyses

Analysis of variance was carried out using statistical analysis system (SAS) and the means were separated using least significant difference (LSD) at 1 and 5% levels of probability. Correlation analysis was also carried out to evaluate the relationship among the tests.

3. Results

There were significant accession effects for all the traits: hundred seed weight, germination percentage, germination index, water imbibed during ageing, accelerated ageing germination percentage, accelerated ageing germination index, conductivity, vigour index, water imbibition percentage and duration of imbibition (Table 2). The coefficient of variation was less than 20 for 7 out of the 10 traits assessed, the exceptions being germination percentage, accelerated ageing water imbibed and accelerated ageing test. Also, the coefficients of determination (R^2) values were high (> 70%) for hundred seed weight, germination percentage, accelerated ageing germination percentage, conductivity, vigour index, water imbibition percentage and duration of imbibition, and moderate (50-69%) for germination index, water imbibed during ageing and accelerated ageing germination index (Table 2).

Table 2. Mean square values from the Analysis of variance of the 34 African yam bean accessions subjected to seed physiological tests.

SV	df	HSW	GPCT	GI	WIA	AAT	AAI	COND	VI	WIP	DIMB
Rep	2	0.36	538.16	0.58	50.44	265.53	0.18	0.13	169.17**	18.32	1.06
Acc	33	143.69**	2315.17**	0.81*	112.86**	1878.15**	0.71**	2.84**	813.95**	67.24**	158.56**
Error	66	2.54	173.23	0.41	27.38	106.50	0.24	0.13	28.66	10.62	0.70
Mean		33.29	64.31	5.07	22.80	34.82	4.93	3.18	62.85	76.90	52.76
CV		4.79	20.46	12.64	22.95	29.63	9.89	11.39	8.52	4.24	1.58
R ²		96.58**	87.14**	51.09*	67.91**	89.89**	60.73**	91.59**	93.50**	76.30**	99.13**

Note. SV: Sources of variation; df: degrees of freedom; Rep: Replication; Acc: Accession; HSW: Hundred Seed weight (g); GPCT: Germination percentage (%); GI: Germination index; WIA: Water imbibed during accelerated ageing (%); AAT: Accelerated ageing germination percentage (%); AAI: Accelerated ageing germination index; COND: Conductivity per gram of seed ($\mu\text{Scm}^{-1} \text{g}^{-1}$); VI: Vigour index; WIP: Percentage water imbibed (%); DIM: Duration of imbibition (hrs).

Significant differences existed in the seed physiological quality of the AYB seeds collected from the 5 states in Southeast, Nigeria. Seeds collected from Enugu State had outstanding seed physiological traits in terms of hundred seed weight, highest germination percentage, accelerated ageing germination percentage and highest vigour index. While seeds from Anambra State performed poorly among the other states (Table 3).

Table 3. Mean values of the performance of the 34 African yam bean accessions for seed physiological tests across the states of collection

States	HSW	GPCT	GI	WIA	AAT	AAI	COND	VI	WIP	DIM
Abia	35.62	68.53	5.42	19.68	31.20	5.36	2.65	63.63	74.48	60.80
Anambra	30.64	43.00	5.65	19.70	21.33	5.50	4.27	50.04	75.98	56.00
Ebonyi	29.79	57.85	4.91	24.85	20.96	4.75	3.36	55.88	79.47	47.33
Enugu	37.50	72.47	4.95	21.80	49.47	4.77	3.03	70.62	75.65	52.80
Imo	31.37	71.11	4.93	26.01	43.22	4.78	2.88	68.25	77.76	52.00
LSD _{0.05}	2.60	21.46	1.04	8.53	16.82	0.80	0.59	8.73	5.31	1.36

Note. HSW: Hundred Seed weight (g); GPCT: Germination percentage (%); GI: Germination index; WIA: Water imbibed during accelerated aging (%); AAT: Accelerated ageing germination percentage (%); AAI: Accelerated ageing germination index; COND: Conductivity per gram of seed ($\mu\text{Scm}^{-1} \text{g}^{-1}$); VI: Vigour index; WIP: Percentage water imbibed (%); DIM: Duration of imbibition (hrs).

The accessions differed widely in HSW, ranging from 22.70 to 52.83 g. Out of the 34 accessions evaluated, 11 had HSW < 30 g, 13 were 30-35 g, 7 were 36-40 g, and 3 had HSW > 40 g (Table 4). 33 of the 34 accessions had germination percentages ranging from 2.67 to 98%. Only 9 accessions had germination percentage that was less than 50% while for more than half of the accessions, germination percentage was above 70%. Unlike seed weight (HSW) and viability (GPCT), germination index, GI, was less variable, ranging from 3.98-6.61 days with a mean of 5.07 days. The range of the amount of water imbibed varied widely. While ENIWea absorbed 130% and EBIZig and EBIZib up to 100% of the initial weight, ENAGmg series absorbed less than 50% of their respective weights (Table 4). Accessions ENAGag, ENAGmg 1, ENAGmg 2 also had germination percentages greater than 80% combined with germination percentage after accelerated ageing test (AAT) of above 70%. Although ABBEuz, EBIKea, EBIZib, EBIZwa, ENNEub and IMOKeo 2 accessions had very high mean values for germination percentage (> 80%), the percentage of germination after being subjected to accelerated ageing test drastically reduced to beyond half of the initial germination percentage.

Table 4. Mean values of the performance of the 34 African yam bean accessions when subjected to seed physiological tests

States	Accession	HSW	GPCT	GI	WIA	AAT	AAI	COND	VI	WIP	DIM
Abia	ABBE uz	34.97	85.33	5.60	21.02	25.33	5.01	3.22	66.64	76.77	66.00
Abia	ABBEug	38.89	76.67	5.12	20.23	56.67	5.49	2.45	75.05	73.53	58.00
Abia	ABBE nu 1	35.01	58.00	4.98	22.35	19.33	6.17	2.47	56.37	72.27	66.00
Abia	ABBE uz 1	36.76	64.67	5.32	19.30	36.00	5.63	1.87	64.81	73.02	60.00
Abia	ABUNum 2	32.47	58.00	6.08	15.50	18.67	4.50	3.24	55.29	76.83	54.00
Anambra	ANAGan	31.38	26.00	6.61	21.91	30.00	4.97	3.21	48.43	77.71	54.00
Anambra	ANAGug	33.68	84.00	5.02	19.90	22.00	5.43	3.20	65.11	75.70	50.00
Anambra	ANINum	27.56	62.00	5.30	22.46	33.33	6.09	3.26	61.49	77.82	54.00
Anambra	ANISnn	29.92	0.00	-	14.54	0.00	-	7.39	25.12	72.71	66.00
Ebonyi	EBANam	32.81	49.33	4.84	25.26	7.33	4.79	4.72	46.98	81.49	42.00
Ebonyi	EBANao 1	32.91	66.00	4.86	25.80	10.67	5.27	3.32	55.20	77.96	54.00
Ebonyi	EBANau	30.33	2.67	5.25	27.95	1.33	5.00	4.64	29.51	80.25	48.00
Ebonyi	EBIKea	25.20	90.67	4.81	35.75	35.33	4.92	2.65	72.39	88.98	48.00
Ebonyi	EBIKok	36.81	20.67	6.23	21.66	0.00	-	3.49	36.34	75.62	54.00
Ebonyi	EBISlo	29.85	34.00	3.98	21.73	29.33	4.70	2.47	51.71	78.27	42.00
Ebonyi	EBIZib	26.60	90.67	4.50	26.60	34.67	5.04	3.42	71.31	78.73	48.00
Ebonyi	EBIZig	24.47	80.00	5.04	24.60	51.33	4.45	2.55	74.27	73.98	42.00
Ebonyi	EBIZwa	29.13	86.67	4.74	14.33	18.67	3.88	2.93	65.19	79.97	48.00
Enugu	ENAGag	50.87	97.33	4.82	21.97	70.00	4.30	3.81	84.88	64.10	54.00
Enugu	ENAGmg 1	52.83	86.00	4.81	17.33	91.33	4.81	3.17	88.92	66.53	60.00
Enugu	ENAGmg 2	48.88	93.33	4.77	18.56	74.67	4.98	3.62	85.31	70.51	60.00
Enugu	ENANam 2	31.35	98.00	5.02	15.03	50.67	5.02	2.73	79.86	81.49	42.00
Enugu	ENISib	25.60	26.67	5.13	27.82	15.33	4.61	2.95	44.06	82.55	48.00
Enugu	ENIWea	29.33	56.00	5.10	37.92	29.33	4.22	2.91	58.55	74.95	54.00
Enugu	ENNEub	32.20	80.67	4.87	20.66	4.67	5.00	2.85	58.62	80.32	54.00
Enugu	ENNKob	36.60	89.33	5.36	20.25	72.00	5.12	2.17	84.70	74.21	66.00
Enugu	ENNSeh	32.86	33.33	4.79	20.01	21.33	4.90	3.54	47.63	79.62	42.00
Enugu	ENNSog	34.53	64.00	4.79	18.49	65.33	4.71	2.51	73.66	82.20	48.00
Imo	IMIKum	34.28	32.67	4.42	29.91	18.00	4.56	3.95	45.83	78.64	48.00
Imo	IMINak	36.55	60.67	4.47	18.75	11.33	4.39	2.74	54.29	79.91	48.00
Imo	IMISis	24.28	96.67	5.24	34.29	70.67	5.03	2.52	86.31	81.76	54.00
Imo	IMOKeo 1	22.70	73.33	4.88	35.37	68.00	4.62	3.06	77.05	74.54	48.00
Imo	IMOKeo 2	33.47	91.33	4.96	18.16	31.33	5.09	2.61	71.33	75.36	54.00
Imo	IMOKeo 3	36.91	72.00	5.59	19.89	60.00	4.97	2.38	74.69	76.38	60.00
LSD _{0.05}		2.60	21.46	1.04	8.53	16.82	0.80	0.59	8.73	5.31	1.36

Only 11 of the accessions had an accelerated ageing germination percentage of above 50%. The accelerated ageing germination values for the accessions varied from 0% to 91.33% (Table 4). Accessions ENAGmg 1 and ENNSog revealed a higher accelerated ageing germination percentage values than their standard germination percentage values, while other accessions had lesser values. Also, the accelerated ageing index values ranged from 3.88-6.17 days similar to the germination index values. All conductivity values for the 34 accessions were less than 5.00 $\mu\text{Scm}^{-1} \text{g}^{-1}$, except for ANISnn which had a value of 7.39 $\mu\text{Scm}^{-1} \text{g}^{-1}$. Conversely, accession ANISnn had the least vigour index value, while others had vigour index values ranging from 29.51 to 88.92. The water imbibed percentage varied from 64.10% (ENAGag) to 88.98% (EBIKea), while the duration in which the water was imbibed varied from 42 hrs to 66 hrs. Half of the accessions had VI above 65% (88.92-65.11) and the other half below, ranging from 25.12-64.81. The first 7 accessions with the highest VI were from Enugu and Imo States (Table 4).

From the correlation result (Table 5), a highly significant ($p < 0.01$) negative correlation existed between hundred seed weight and accelerated ageing water imbibed, hundred seed weight and percentage water imbibed, germination percentage and conductivity, conductivity and vigour index, and between percentage water imbibed and duration of imbibition. Whereas a highly significant ($p < 0.01$) positive correlation existed between germination percentage and accelerated ageing germination percentage, germination percentage and vigour

index, accelerated ageing germination percentage and vigour index. Also, a significant ($p < 0.05$) positive correlation existed between hundred seed weight and the duration of imbibition, germination index and duration of imbibition, accelerated ageing index and duration of imbibition. Furthermore, relationship between accelerated ageing germination percentage and conductivity, and between accelerated ageing germination percentage and percentage water imbibed were significant ($p < 0.05$) but negative.

Table 5. Correlation analysis of the seed physiological quality tests of the 34 African yam bean accessions ($n = 32$)

	HSW	GPCT	GI	WIA	AAT	AAI	COND	VI	WIP
GPCT	0.21								
GI	-0.02	-0.22							
WIA	-0.47**	-0.04	-0.12						
AAT	0.38*	0.63**	-0.09	0.03					
AAI	0.03	0.03	0.19	-0.10	-0.02				
COND	0.02	-0.54**	-0.01	-0.09	-0.41*	-0.19			
VI	0.31	0.91**	-0.18	-0.004	0.88**	0.01	-0.58**		
WIP	-0.69**	-0.14	-0.07	0.30	-0.40*	-0.08	-0.11	-0.28	
DIM	0.42*	0.10	0.40*	-0.23	0.17	0.44*	0.06	0.14	-0.53**

Note. HSW: Hundred Seed weight (g); GPCT: Germination percentage (%); GI: Germination index; WIA: Water imbibed during accelerated aging (%); AAT: Accelerated ageing germination percentage (%); AAI: Accelerated ageing germination index; COND: Conductivity per gram of seed ($\mu\text{Scm}^{-1} \text{g}^{-1}$); VI: Vigour index; WIP: Percentage water imbibed (%); DIM: Duration of imbibition (hrs).

3. Discussion

The accessions exhibited a widely divergent variability for both physical and physiological traits. The wide variability in the performance of the African yam bean accessions across the seed physical and physiological quality tests corroborates the report of Adewale and Odoh (2013) that Nigeria is among the centers of diversity of African yam bean. Olosoji, Akande, and Owolade, (2011) also reported genetic variability for seed quality among 10 accessions of AYB studied. The variation was observed in their seed sizes, amount and rate of water imbibed in the process of germination, viability status and speed of germination, ability to withstand stress or adverse conditions and the integrity of their seed coats. Accessions ENAGag, ENAGmg 1 and ENAGmg 2 had comparative larger seeds than other accessions and showed similarities in their performances across the tests indicating that they were of a similar genetic background. Seed size is an important physical indicator of seed quality that affects seed germination, emergence, seedling survival, plant growth and performance of the crop in the field (Adebisi et al., 2013; Makinde, Oyekale, & Daramola, 2020). The outstanding performances of large-seeded accessions can be attributed to their higher reserve content. Shahi, Bargahi, and Bargali, (2015) reported that distinct seed sizes have different levels of starch and other energy reserves which may be an important factor to improve the expression of germination and initial growth of seedlings. The seed size of the accessions also varied across their location of collection. Although, it is believed that seed sizes may vary widely between the crop species and the germination and growth environment, generally, large seeds have a higher seedling survival rate, larger biomass and adaptability than small seeds, under adverse conditions (Ambika, Manonmani, & Somasundaram, 2014).

The failure of accession ANISnn to germinate under stress and ideal conditions suggests that the embryo must have been dead despite that other features of the seed remain intact and dormancy is not associated with African yam bean (Olisa et al., 2010a). This loss of physiological quality could have been as a result of the inherent low vigour of African yam bean seeds upon which is superimposed a poor storage environment. Accessions EBANau and EBIKok were also losing their germination potential, revealing a gradual decline in viability and vigour owing to physiological deterioration. Physiological seed deterioration is a phenomenon which is not visually apparent. The inability of seeds to maintain vigour for a long period poses storage problems and can cause the specie/crop to go into extinction (Finch-Savage & Bassel, 2016).

Most of the accessions had very low vigour as revealed by their low germination after being subjected to accelerated ageing. This corroborates the fact that African yam bean seeds are inherently low in seed vigour (Olisa et al., 2010a). The significant positive relationship between standard germination percentage and

accelerated ageing germination percentage suggests that, accessions with higher germination under stress conditions will also exhibit higher germination under normal conditions, while poor germination under normal conditions will lead to poor performance under stress conditions. However, that some accessions like ENAGag, ENAGmg 1, ENAGmg 2, ENNKob, ENNSog, IMISis, IMOKeo 1 and IMOKeo 3 had higher and comparable standard germination and accelerated ageing germination percentages suggests that there exist a pool of high seed vigour potential among the African yam bean accessions that can be improved upon. High seed vigor enhances the ability to obtain optimal plant densities and high crop yields (Milosevic, Vujakovic, & Karagic, 2010). The germination index and accelerated ageing index values indicated that African yam bean seed germination occurs between averages of 4-7 days, whether under ideal or stressed conditions. These two test procedures (standard germination and accelerated ageing tests) alongside conductivity test were the key determinants of the vigour index of the accessions. The consistently low conductivity values for all the accessions could be as a result of their hard seed coat which could in turn reduce seed exudates. Tungate, Susko, and Rufty (2002) attributed low germination rate to the prevention of water and respiratory gases from penetrating into the seed by hard seed coats during imbibition. However, the considerably low conductivity values also indicated that the seeds were suitable for sowing. According to Hampton and TeKrony (1995) conductivity values less than $30 \mu\text{Scm}^{-1} \text{g}^{-1}$ indicate that the seeds are suitable for sowing, even under adverse conditions.

Even though the amount and duration of water imbibed did not follow any definite pattern nor correlate with the number of seeds that germinated, their persistent correlation with hundred seed weight under ideal conditions (WIP) and under stress (WIA) revealed that imbibition is strongly influenced by or dependent on the size or weight of the seed. Olisa et al. (2010b) stated that the duration of each phase of imbibition in African yam bean depended on seed properties such as size, content of hydratable substances, seed coat permeability and oxygen uptake. However, the speed of germination under both ideal and stress conditions in this study were influenced by the duration of water imbibed. That is, a delay in the number of days of the seed to germinate extended also the period during which water is imbibed prior to germination, without necessarily increasing the overall amount of water imbibed. On the average, African yam bean seeds require moisture of up to 76.9% of their initial weight over a period of approximately 53 hours prior for the commencement of germination.

4. Conclusion

Seed size is an important trait in African yam bean that could be improved upon for the selection of landraces of high seed physiological potentials. Conductivity test was not very effective in determining the variability in seed vigour. Seed germination in AYB can be easily assessed 7 days after planting. Accessions ENAGag, ENAGmg 1, ENAGmg 2, ENNKob, ENNSog, IMISis, IMOKeo 1 and IMOKeo 3 were outstanding and are therefore recommended for genetic improvement of seed quality in African yam bean.

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