Ethiopian Journal of Environmental Studies & Management 12(4): 441 – 451, 2019.
ISSN:1998-0507 doi: https://ejesm.org/doi/v12i4.9
Submitted: July 10, 2019 Accepted: September 04, 2019

VARIATION IN MORPHOMETRIC CHARACTERS OF *Vitellaria paradoxa* (C.F Gaertn) SEEDS IN RELATION TO GERMINATION AND SEEDLINGS BIOMASS

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Abstract

Seed morphological characteristics were examined on germination and early growth of Vitellaria paradoxa. Seeds were sourced from Eruwa, Saki and New-Bussa in the Derived, Southern Guinea and Northern Guinea Savanna ecological zones of Nigeria respectively and classified into three sizes: large (length ≥45.00 mm); medium (length 40.00 - 45.00 mm) and small (length ≤40.0 mm). The seeds were sown, germination was monitored and recorded. Twelve weeks old seedlings were pricked into polythene pots filled with top soil arranged in 3x3 factorial experiment fitted in Completely Randomised Design (CRD) with three replicates. The seedlings were assessed for plant height (cm), stem diameter (mm), leaf production, and leaf area (cm^2) on monthly basis for six consecutive months. The data collected were subjected to Analysis of Variance and the means were separated with Least Significant Difference (LSD) at 5% level of significance. Results indicated that both seed sizes and sources affected germination performance. Highest mean seed germination (84.4%) was observed from large-sized seed from Saki while medium and small seed sizes from New-Bussa had 80.4% and 84.1% mean seed germination respectively. Seed source and size had significant influence ($p \leq 0.05$) on early seedling growth of V. paradoxa. However, small-sized seeds gave optimum performance for mean stem diameter, leaf production and leaf area with 4.69 mm; 3.85 and 48.7 cm^2, respectively while large seed size had the highest mean height (6.72 cm). Seedlings growth is highly linked to seeds sizes; larger seeds had higher germinability and growth rate than the smaller seeds.

Key words: *Vitellaria paradoxa*, *Morphology, Seed source, Seed size*

Introduction

Morphological variations in fruits and seeds affect the performance and adaptation of plants. All plant species face a fundamental reproductive trade off and they can produce either many small seeds or a few large seeds. Consideration for superior seed morphological traits is of paramount importance in domestication programme. *Vitellaria paradoxa* (C.F Gaertn), one of the priority indigenous trees for rural communities in Nigeria savanna, a dicotyledonous plant in the family Sapotaceae and commonly known as butter tree, shea tree, shea butter tree or shea nut tree. The local names include: “Lulu” (Arabic); “Karité” (French); “Kadanya” (Hausa); “Kayere” (Fulani); “Okwuma” (Igbo), “Chammal” (Tiv) and “emi/emi-gidi” (Yoruba). It is a small to medium-sized deciduous tree in the savanna areas and cultivated fields (Hall *et al.,* 1996). The fruit which is a berry is oblong, ovoid, glabrous, subglobose or ellipsoid in shape (Pennington, 1991) borne on 1.5-3.0 cm long pedicel, containing seed (commonly referred to as the nut and consists of a testa enclosing an embryo (Kershaw and Hardwick, 1986; Hall *et al*., 1996). The fruit length is most commonly between 4-5 cm (occasionally up to 8 cm) and the diameter is between 2.5- 5.0 cm. The diameter is never less than 50% of the length (Vivien, 1990). Fruit size and shape is greatly influenced by the number of seeds it contains, usually one, often two and rarely three seeds.

Variation in morphological traits emphasizes the importance of selecting suitable seed source before commencing conservation programme. Studies show existence of variations in tropical fruits and seeds which could be useful for breeding, improvement, conservation and utilization. Leishman *et al*. (2000) asserted that small-sized seeds favour the germination of numerous seedlings while large seeds favour the survival of seedlings in the face of common stresses such as herbivory, drought or shade. Hence, the advantage of large-seeded species is expected to be greatest during early seedling development and to diminish until seed reserves have been fully exhausted. Variations in tropical fruit and seed characters are very crucial for breeding, improvement, conservation and utilization of the species.

There is sparse information on the effect of morphological characteristics seed sources of *V. paradoxa* on its germination, growth and biomass estimation. Thus, the objective of this study was to assess the effect of morphological characteristics seeds of *V. paradoxa* and seed sources on seedlings performance.

Materials and Methods

Fallen fruits were collected from ten (10) mother trees each, from the selected sources (Eruwa, Saki and New-Bussa); seeds extracted and each seed lot thoroughly mixed before selection. **Eruwa** (latitude 7°47′ N and longitude 3°51′ E) in moist woodland or Derived Savanna, **Saki (**latitude 8° 40′ N and longitude 3° 19′ E) in the dry woodland or Southern Guinea Savanna and **New-Bussa** (latitude 9°35′ N and longitude 3°33′ E) in the drier woodland or Northern Guinea Savanna ecological zone of Nigeria (Ojanuga, 2006).

Fifty (50) seeds were randomly selected from seed lot from each source and morphological characteristics (weight (g), length (cm), diameter (cm), and volume (cm^3)) were examined at the Pathology Laboratory of the International Institute of Tropical Agriculture (IITA). The seed weight was measured using "AND HF-2000G Top loading balance with d = 0.01 g and max. 2100 g" while the length and diameter of the seeds were measured with a digital Vernier caliper. Seed volume was measured using displacement method. Completely Randomized Design (CRD) was used on four seed morphological characteristics with four replicates. The data collected were subjected to one-way Analysis of Variance and the means were separated using Least Significant Difference (LSD) at 5% level of probability.

The seeds were then classified into three (3) sizes: [large (length >45.00 mm), medium (length 40.00 – 45.00 mm) and small (length <40.0 mm)]. Seventy-five (75) seeds were selected from each of the three seed size classes and sown in germination trays (32 x 24 x 12) cm^3 inside a non-mist propagator at West African Hardwood Improvement Project (WAHIP) nursery, Forestry Research Institute of Nigeria (FRIN), Ibadan.

At the two-leaf stage (12 weeks after sowing), uniformly growing seedlings were transplanted into medium-sized black polythene pots (16 x 14 x 12) cm^3 containing topsoil. The 3x3 factorial experiment (3 seed sources and 3 size classes) was arranged in Completely Randomised Design (CRD) and replicated three times. The seedlings were allowed to stabilize for two weeks before the commencement of growth assessment. Growth evaluation was carried out once in a month on total height (cm), stem diameter at the collar (mm), leaf production, and leaf area (cm^2) for a period of six (6) months. Seedling height was measured from the soil level to the tip of the apical bud using meter rule. A digital Vernier caliper was used to measure stem diameter at the collar; number of leaves on each seedling were counted and recorded while leaf area meter was used to estimate the leaf area. At two months interval, harvests of the experimental materials were made and then separated into root and shoot for biomass assessment. Fresh weights of the various components (root and shoot) were determined using metler weighing balance before the samples were oven-dried at 80^{o}C until constant weights were achieved. Relative growth rate (RGR), net assimilation rate (NAR) and shoot/root ratios were derived from the dry weights and the transformed leaf area data obtained (Kivet *et al*., 1971; Ojo, 2008) as follows:

$$RGR\ (gg^{-1}month^{-1}) = \frac{\ln w_2 - lnw_1}{t_2 - t_1}$$

Where,
W_1 and W_2 = biomass at times t_1 and t_2
A_1 and A_2 = leaf area at times t_1 and t_2
lnA_1 and lnA_2 = natural logarithm of leaf area at times t_1 and t_2
lnw_2 - lnw_1 = natural logarithm of biomass at times t_1 and t_2.

Results

Seed Weight (g)

The highest mean seed weight of 12.40 g was obtained from Saki followed by Eruwa with 12.31 g while the lowest mean value (9.36 g) was obtained from New-Bussa. Seed weight had significant effect ($p \leq 0.05$) on the morphology of the seeds. Although, there was no significant difference ($p \leq 0.05$) in the weight of seeds from Saki and Eruwa; but were significantly ($p \leq 0.05$) higher than those from New-Bussa (Table 1). There was positive correlation (0.60) between seed weight and seed diameter. Also, positive correlation (0.56) existed between seed weight and seed length (Table 2).

Seed Length (cm)

Seeds length varied among the three sources ranging between 4.15 - 4.72 cm. Seeds from Saki had the highest mean value (4.72 cm). This was closely followed by those from Eruwa (4.55 cm) while New-Bussa had the least mean value of 4.15 cm. Sources had significant influence ($p \leq 0.05$) on the morphological characters of the seeds. However, the seeds lengths from the three sources were not significantly different from one another (Table 1). There was positive correlation (0.74) between seed weight and seed length while seed diameter was positively correlated with seed length (0.56) indicating that as the seed length increased, there were a correspondent increase in weight and diameter (Table 2).

Seed Diameter (cm)

Variation occurred in the seed diameter of *V. paradoxa* from between 3.53 cm and 3.61 cm. The highest mean value of 3.61 cm was obtained in seeds from Saki; followed by Eruwa (3.60cm) while New-Bussa had the least diameter (3.53 cm) (Table 1). Seeds diameter did not have any significant effect ($p \leq 0.05$) on the morphology of the seeds from the three sources ($p \leq 0.05$). However, positive correlation (0.60) existed between seed diameter and seed weight, therefore increase in seed weight led to increase in seed diameter. Also, seed diameter was highly correlated with seed length (0.56) (Table 2).

Seed Volume (cm³)

Volume of seeds of *V. paradoxa* varied among the three sources. This ranged between 9.08 cm^3 and 10.30 cm^3. The highest mean volume, 10.30 cm^3 was observed in seeds from Eruwa, closely followed by 10.20 cm^3 from Saki and the least from New-Bussa with 9.08 cm^3. Volume of seeds significantly affected the morphological characters of the seeds from the three sources ($p \leq 0.05$). However, seeds from Eruwa and Saki were significantly different ($p \leq 0.05$) from New-Bussa while Eruwa and Saki had higher volume than those from New-Bussa (Table 1).

The observed variation in seed characteristics is a natural phenomenon resulting from changes in environmental and genetic factors of species. It is a way of adapting individuals to changing habitat conditions. Ngulube *et al*. (1997) attributed variation in seed size in *Uapaka kiskiana* to genetic and environmental effects. The fact that many of the morphological characteristics of the seeds from Saki were higher than the two other sources could be attributed to the fact that the species might be growing in a more favourable environmental condition than the other two localities. This agrees with Susko and Louvett (2000) that seeds characteristics vary considerably among the extremes of a species' natural range.

Table 1: Morphological variables of *V. paradoxa* seeds from Eruwa, New-Bussa and Saki

	Seed Morphological Variables			
Seed sources	Weight (g)	Length (cm)	Diameter (cm)	Volume (cm^3)
Eruwa	12.31	4.55	3.60	10.30
New-Bussa	9.36	4.15	3.53	9.08
Saki	12.40	4.72	3.61	10.20
LSD	0.83	ns	Ns	0.91

Table 2: Pearson product moment correlation showing relationships between weight and diameter; weight and length and diameter and length of *V. paradoxa* seeds

Variables	Number of cases	Means	Standard deviation	R
Weight	50	12.40	2.47	0.60
Diameter	50	36.14	2.38	
Weight	50	12.40	2.47	0.74
Length	50	47.17	3.92	
Diameter	50	36.14	2.38	0.56
Length	50	47.17	3.92	

$P < 0.05$

Effects of Seed Size on Germination and Early Seedling Growth of V. paradoxa

Germination in the seeds varied with sources and seed sizes ranging between 65.3% and 84.4%. The highest mean germination was recorded for the large-sized seeds from Saki with 84.4%. This was followed by small-sized seeds from New-Bussa (84.1%) while small-sized seeds from Saki had the least germination with 65.3%. However, the highest mean cumulative germination was recorded for the large seeds with 81.3% while small-sized seeds had the least of 75.8%. The overall highest mean germination was recorded for New-Bussa with 81.9%, followed by Eruwa (77.6%) while Saki had the least of 74.9% (Table 3). There is variation in the degree of germinability of seeds between and within populations and between and within individuals (Mkonda *et al*., 2003; Loha *et al*., 2006). Tripathi and Khan (1990) reported that large seeds showed greater germination percentage than smaller diameter and light seeds as observed in large seeded species such as *Quercus* spp. Bigger seeds are the best for selection for early seedling growth and development (Kadu *et al*., 2006; Mkwezalamba *et al*., 2015) while Colombo *et al.* (2015) stated that seeds with bigger mass present better germination capacity, standardization and seedling emergence.

Table 3: Effect of seed size on mean percentage germination of seeds of V. paradoxa collected from Eruwa, New-Bussa and Saki

Seed size classes (cm)	Seed sources/ germination percentage			
	Eruwa	New-Bussa	Saki	Cumulative germination
Large (>45.00)	78.2	81.3	84.4	81.3
Medium (40.00-45.00)	76.8	80.4	74.9	77.4
Small (<40.00)	77.9	84.1	65.3	75.8
Mean source cum. Germination	77.6	81.9	74.9	

Total Seedling Height (cm)

Seedlings had mean height growth ranging from 4.81 cm to 6.72 cm. Heights for seedlings from small, medium and large seeds were 4.81 cm, 5.08 cm and 6.72 cm respectively while Eruwa and New-Bussa had 4.8 cm each while Saki had 5.53 cm. However, seed mass had no significant influence on total height of the seedlings ($p \leq 0.05$) (Tables 4). Cicek and Tilki (2007) reported that large-sized seeds of *Castanea sativa* had the highest seedling height which was not significantly different from the medium and small-sized seeds.

Stem Diameter (mm)

The highest mean growth in stem diameter was recorded from the small-sized seeds (4.69 mm), followed by large seeds with 4.32 mm while seedlings from medium-sized seeds had the least (3.30 mm) radial growth. Seed size had significant effect ($p \leq 0.05$) on early seedling diameter growth although, stem diameter growth of seedlings from large and small seeds were not significantly different from each other but differed from the seedlings from small seeds (Tables 4). There was however no significant difference among the seed sources and no significant interaction between seed size and source. However, Eruwa, Saki and New-Bussa had 4.0 mm, 4.1 mm and 4.3 mm mean stem diameter respectively (Table 4).

Leaf Production

The number of leaves produced by the seedlings varied according to seed size from 2.6 to 3.9. The mean leaf production from the three size classes was significantly different from one another, from medium (2.6), large (3.4) and small (3.9). Seed size and sources had significant effects ($P \leq 0.05$) on leaf production of the seedlings (Table 4). Although, the mean leaf production from Eruwa and Saki sources were not significantly different from one another (2.9 and 3.0) respectively, they differed from leaf production of New-Bussa seedlings (3.9) (Table 6) while there was no significant difference in the interaction between seed size and sources (Table 4).

Leaf Area (cm^2)

Leaf expansion of the seedlings varied with sizes and sources. The mean leaf area values were 48.7 cm^2, 48.6 cm^2 and 47.0 cm^2 for seedlings from small, large and medium seed sizes respectively. However, mean leaf area from Eruwa, Saki and New Bussa were significantly different ($P \leq 0.05$) with mean leaf area values of 52.82 cm^2, 47.48 cm^2 and 43.96 cm^2 respectively (Table 4). The effects of seed size and source on leaf expansion were significant ($P \leq 0.05$) on the growth of the seedlings. The large and medium-sized seeds were however, not significantly different from each other but differed from the small-sized seeds (Table 4).

Table 4: Mean effects of seed size and sources on early growth of *V. paradoxa*

Variables	Height (cm)	Stem Diameter (mm)	Leaf Production	Leaf area (cm^2)
Seed sizes				
Large	6.72	4.32	3.39	48.56
Medium	5.08	3.31	2.57	47.00
Small	4.81	4.69	3.85	48.70
LSD	ns	0.54	0.41	1.46
Seed sources				
Eruwa	ns	ns	2.94	52.82
Saki	ns	ns	3.00	43.96
New-Bussa	ns	ns	3.88	47.48
LSD			0.41	1.46

Relative Growth Rate (RGR)

The Relative Growth Rate (RGR) for seedlings from the three seed sizes followed the normal growth pattern. However, highest RGR value was recorded in seedlings from large-sized seeds (6.3×10^{-2} g/g/month) from Eruwa source while the least value (4.9×10^{-2} g/g/month) was recorded for seedlings from small-sized seeds both from Eruwa and New Bussa (Table 5).

Khurana and Singh (2000) reported a higher relative growth rate in larger seeds of *Albizia procera* compared to its smaller seeds. Also Awodoyin *et al*. (2001) reported the same trend in *Irvingia wombulu* while Agboola (1996) reported higher relative growth rate from smaller seeds of *Gmelina arborea* compared to the large seeds. Conversely, Owoh *et al.* (2011) reported higher relative growth rate for seedlings of large seeds compared to the smaller seeds seedlings of *G. arborea*.

Absolute Growth Rate (AGR)

Seedlings from large-sized seeds from Eruwa source had the highest Absolute Growth Rate (AGR) ($6.5x10^{-1}$ g/g/month) between the 5th and 6th month of assessment. The least AGR value of $4.9x10^{-1}$ g/g/month was recorded in the medium-sized seeds from New Bussa (Table 6). However, the seedlings from all the sizes and sources followed normal growth trend for all seed sources and sizes. The results agree with Owoh *et al.* (2011) who reported higher absolute growth rate for seedlings of large seeds compared to the smaller seeds seedlings of *G. arborea.*

Net Assimilation Rate (NAR)

Net Assimilation Rate computed for seedlings from the three seed weight classes revealed that highest value of $6.3x10^{-3}$ g/cm^2/month was recorded in the 3rd harvest from large-sized seeds from New Bussa. However, the least NAR value was obtained from small-sized seeds from Saki ($4.8x10^{-3}$ g/cm^2/month) (Table 7). The result is in line with Agboola (1996) who reported a higher net assimilation rate from smaller seeds of *Gmelina arborea* compared to the large seeds.

Effect of Seed-size Classes on Shoot to Root Ratio

At 1st harvest in the 1st month of assessment, all seed sources (Eruwa, New-Bussa and Saki) and size classes (large, medium and small) had uniform shoot: root ratio of 1:4 (Table 8). At the 2nd harvest, seedlings from Eruwa in the three size classes; large size from New-Bussa and medium from Saki had shoot: root of 1:3. However in the 3rd harvest, all the sources and size classes had 1:3 shoot: root ratio with the exception of the large and medium from Eruwa (Table 8).

Table 5: Relative growth rate (g/g/month) of seedlings of *V. paradoxa* from three sources of three seed-size classes

Sources	Seed size	RGR_1	RGR_2	RGR_3
Eruwa	Large	$3.4 x10^{-2}$	$4.3 x10^{-2}$	$6.3 x10^{-2}$
	Medium	$3.1 x10^{-2}$	$4.1 x10^{-2}$	$5.2 x10^{-2}$
	Small	$2.9 x10^{-2}$	$4.0 x10^{-2}$	$4.9 x10^{-2}$
New-Bussa	Large	$3.5 x10^{-2}$	$4.8 x10^{-2}$	$5.6 x10^{-2}$
	Medium	$3.4 x10^{-2}$	$4.1 x10^{-2}$	$5.9 x10^{-2}$
	Small	$2.7 x10^{-2}$	$4.0 x10^{-2}$	$4.9 x10^{-2}$
Saki	Large	$3.2 x10^{-2}$	$4.3 x10^{-2}$	$6.0 x10^{-2}$
	Medium	$3.3 x10^{-2}$	$3.9 x10^{-2}$	$5.2 x10^{-2}$
	Small	$3.1 x10^{-2}$	$4.0 x10^{-2}$	$5.4 x10^{-2}$

Note: RGR 1 = RGR between the 1st and 2nd month of assessment
RGR 2 = RGR between the 3rd and 4th month of assessment
RGR 3 = RGR between the 5th and 6th month of assessment

Table 6: Absolute growth rate (g/g/month) (AGR) of seedlings *V. paradoxa* from three sources of three seed-size classes

Sources	Seed sizes	AGR 1	AGR 2	AGR 3
Eruwa	Large	2.9×10^{-1}	4.3×10^{-1}	6.5×10^{-1}
	Medium	2.6×10^{-1}	3.8×10^{-1}	5.1×10^{-1}
	Small	2.4×10^{-1}	4.1×10^{-1}	5.4×10^{-1}
New-Bussa	Large	3.1×10^{-1}	3.9×10^{-1}	5.1×10^{-1}
	Medium	3.3×10^{-1}	4.1×10^{-1}	4.9×10^{-1}
	Small	3.0×10^{-1}	3.6×10^{-1}	5.0×10^{-1}
Saki	Large	3.2×10^{-1}	4.3×10^{-1}	6.2×10^{-1}
	Medium	3.3×10^{-1}	4.5×10^{-1}	6.1×10^{-1}
	Small	3.5×10^{-1}	4.8×10^{-1}	5.9×10^{-1}

Note: AGR 1 = AGR between the 1st and 2nd month of assessment
AGR 2 = AGR between the 3rd and 4th month of assessment
AGR 3 = AGR between the 5th and 6th month of assessment

Table 7: Net assimilation rate (g/cm^2/month) of seedlings of *V. paradoxa* from three sources of three seed-size classes

Source	Seed size	NAR 1	NAR 2	NAR 3
Eruwa	Large	3.1×10^{-3}	3.9×10^{-3}	5.3×10^{-3}
	Medium	3.3×10^{-3}	5.1×10^{-3}	6.0×10^{-3}
	Small	3.0×10^{-3}	4.6×10^{-3}	5.2×10^{-3}
New-Bussa	Large	3.2×10^{-3}	4.1×10^{-3}	6.3×10^{-3}
	Medium	3.1×10^{-3}	4.4×10^{-3}	5.8×10^{-3}
	Small	2.9×10^{-3}	3.7×10^{-3}	4.90×10^{-3}
Saki	Large	4.0×10^{-3}	5.1×10^{-3}	6.1×10^{-3}
	Medium	3.1×10^{-3}	4.3×10^{-3}	5.4×10^{-3}
	Small	3.0×10^{-3}	3.8×10^{-3}	4.8×10^{-3}

Note: NAR 1 = NAR between the 1st and 2nd month of assessment
NAR 2 = NAR between the 3rd and 4th month of assessment
NAR 3 = NAR between the 5th and 6th month of assessment

Table 8: Shoot: Root ratio for seedlings of *V. paradoxa* collected from three sources of three seed-size classes

Source	Seed size	HARV 1	HARV 2	HARV 3
Eruwa				
Large	1:4	1:3	1:2	
Medium	1:4	1:3	1:2	
Small	1:4	1:3	1:3	
New-Bussa				
Large	1:4	1:3	1:3	
Medium	1:4	1:4	1:3	
Small	1:4	1:4	1:3	
Saki				
Large	1:4	1:4	1:3	
Medium	1:4	1:3	1:3	
Small	1:4	1:4	1:3	

Note: HARV = Harvests 1, 2 and 3 during the period of assessment

Conclusion

The resultant effect of the morphological characteristics of *V. paradoxa* seeds on its germination and early growth was examined. Seeds collection from different agroclimatic zones exhibited variable morphological characteristics. Seedlings growth is highly linked to seeds sizes; larger seeds had higher germinability and growth rate than the smaller seeds, therefore, large seeds can be used to raise vigorous seedlings.

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