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Variability in Seedling Growth of Seeds of Shea Butter Tree (*Vitellaria paradoxa* C. F. Gartn.) Sourced from Nine Locations in Nigeria

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ABSTRACT

Provenance evaluation is essential in identifying genotypes with superior seedling growth. The seedling performance of nine accessions of *Vitellaria paradoxa* obtained from Southern Guinea Savanna, Northern Guinea Savanna and the Sudan Savanna of Nigeria were investigated at two contrasting locations – Makurdi and Nsukka – between July 2006 and July 2007. Seedling emergence of the Makurdi trial was monitored while seedling growth at both sites was monitored at monthly intervals from the 6th to 12th month after sowing. Results of analysis of variance showed wide variation in emergence parameters with the Akwanga, Makurdi, Jalingo and Yola seed sources giving significantly higher emergence percentage (E %). Most accessions had emergence index (EI) values of 100 or more with corresponding high emergence rate index (ERI) scores. The main effect of location on seedling growth showed the superior performance of seedlings grown at Makurdi over those grown at Nsukka. There was a significant interaction between location and accession. Generally, while the Akwanga, Kachia and Yola provenances gave better seedling vigour at Makurdi, at Nsukka, it was Akwanga, Kachia and Jalingo suggesting the existence of genotype x environment interaction.

Keywords: accession, emergence, provenance, seedling vigour
Abbreviations: EI, emergence index; **E%**, emergence percentage; **ERI**, emergence rate index

INTRODUCTION

The shea butter tree, *Vitellaria paradoxa*, also known by its synonym *Butyrospermum parkii*, is indigenous to sub-Saharan Africa, occurring in a narrow 5000 km long stretch of vegetation from Senegal to Uganda and Ethiopia (FAO 2002). In Nigeria, the species occurs mainly in the Guinea and Sudan savanna zones (Keay 1989), with the nuts showing remarkable variation in physical and chemical attributes (Ugese *et al*. 2010a, 2010b). The nut of the tree produces a fat which is dominated by stearic and oleic acids (Maranz *et al*. 2004a). In Europe and Japan, much of the fat extract of the imported shea nuts is used in chocolate manufacture, while the unsaponifiable fraction which contains vitamin E, is highly prized in the cosmetic industry owing to its high therapeutic effect on the skin (FAO 2002). The nutritional value of the fruit pulp has also been emphasized (Maranz *et al.* 2004a; Ugese *et al*. 2008a), including a highlight of the traditional use of various parts of the species in human and veterinary medicine (ICRAF 2000; Umali and Nikiema 2002). The positive impact of the species on rural livelyhoods as well as national economies of some African producer nations has been documented (Boffa *et al*. 1996; FAO 2002).

Although the usefulness of the shea butter tree is not in doubt, the species is still considered wild (ICRAF 2000). Because of this, fruits and nuts for consumption, sale or processing are still collected from the wild, raising questions of full and sustained exploitation (Ugese *et al.* 2005). Serious concerns have also been expressed about the rapid disappearance of the species from the ecosystem. Reasons adduced to this unfortunate trend include aggressive deforestation for various uses (Okafor 1985), drought, mechanization, shortening of fallow periods and prevalence of the parasitic plant, *Tapinanthus* species (Boffa *et al*. 1996). The yearly savanna bushfires have been implicated in reduced tree growth and productivity (Jackson 1968; Irvine 1969).

The potential of *Vitellaria paradoxa* at improving rural livelihoods has compelled calls for its domestication (Popoola and Tee 2001; Ugese *et al*. 2005). The prevailing threats to its continued existence as a key species on the African Savanna landscape may serve to reinforce such calls. Interestingly, the shea tree is among the 17 agroforestry species that have been farmer identified for domestication in four eco-regions of the tropics (Leakey 1999). To ensure the success of such a noble effort, it is imperative to evaluate provenances to identify those with superior seedling growth especially that shea is known to be a slow growing species (Dianda *et al*. 2009; Ugese *et al*. 2009). If Nigeria's position as the world's leading producer of shea nuts (Umali and Nikiema 2002; Umobong 2006) is anything to go by, then such an exercise becomes even more pertinent considering its ultimate impact on world shea nut production and supply. We therefore embarked on the study to evaluate seedling growth of shea provenances across the savanna of Nigeria with a view to identifying those with more vigorous growth.

MATERIALS AND METHODS

Depulped seeds of shea butter tree obtained from the nine locations (Ilorin, Lokoja, Makurdi, Akwanga, Minna, Kachia, Jalingo, Yola and Kano), were planted at the Teaching and Research Farm of the University of Agriculture Makurdi in 2006. Depulping was effected by removing the fleshy part of the fruit (pulp) leaving only the seed with a shiny brown testa. Seeds were sown on 19th July, 2006 according to accession at a depth of 5 cm in single row plots of 10 seeds each. Intra row distance was 20 cm while inter

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Table 1 Site characteristics of experimental locations.

Characteristics	Makurdi	Nsukka
Soil properties		
Sampled depth (cm)	0 – 30 cm	0 – 30 cm
Sand (%)	67	62
Silt (%)	22	17
Clay (%)	11	21
Textural class	Sandy loam	Sandy clay loam
Organic carbon (%)	0.60	0.85
Organic matter (%)	1.03	1.46
Total nitrogen (%)	0.042	0.042
Phosphorus (ppm)	8.96	7.96
Sodium (mg/100 g)	0.50	0.40
Potassium (mg/100 g)	0.24	0.09
Calcium (mg/100 g)	3.2	5.8
Magnesium (mg/100 g)	1.4	9.6
CEC (%)	24.0	26.0
pH: H_2O	5.9	4.6
$CaCl_2$	5.2	3.9
Other variables		
Longitude	7.41°N	6.52°N
Latitude	8.37°E	7.24°E
Altitude (m above sea level)	97	200
Mean annual rainfall (mm)	1150	1500
Mean temp. (°C)	>27°C	
Vegetation zone	Southern Guinea savanna	Derived savanna

Table 2 Emergence parameters of *Vitellaria* seedlings of nine accessions grown at Makurdi, Nigeria, in 2006.

Accession	Emergence percentage (E%)	Emergence index (EI)	Emergence rate index (ERI)
Ilorin	38.8	108.8	268.5
Lokoja	40.0	103.5	260.8
Makurdi	65.0	96.8	157.6
Akwanga	68.8	100.2	149.8
Minna	40.0	102.6	256.6
Kachia	48.2	89.5	178.0
Jalingo	65.0	89.2	155.2
Yola	89.2	94.9	238.6
Kano	42.5	96.4	228.8
$LSD_{(0.05)}$	15.9	NS	55.1

NS – No significant difference

row distance was 50 cm. Distance between plots were also 50 cm. Mean seed weights of the various accessions were 12.5 g (Ilorin), 8.7 g (Lokoja), 10.1 g (Makurdi), 20.3 g (Akwanga), 13.8 g (Minna), 22.0 g (Kachia), 19.5 g (Jalingo), 11.8 g (Yola) and 12.0 g (Kano). The experimental design was randomized complete block (RCBD) replicated 4 times. A replicate trial was set up at the Crop Science Farm of the University of Nigeria Nsukka on 21st July, 2006. The site characteristics of the two locations are presented in **Table 1**.

Emergence of seedlings was monitored (for the Makurdi experiment only) when first seedling emergence was noticed. This was continued at 10-day intervals up to 117 days after sowing. Emergence parameters, namely, emergence percentage (E%), emergence index (EI) and emergence rate index (ERI) were then calculated from the emergence counts using formulae adopted by Fakorede and Ayoola (1980) as follows:

$$E\% = \frac{No\,of\ Seedlings\,emerged}{Total\ number\,of\,seeds\ planted} X100$$

$$EI = \frac{\sum\ (Number\ emerged)(DAP)}{Total\ seedlings\,emerged}$$

$$ERI = \frac{EI}{E\%(in\ decimal)}$$

where: E% = emergence percentage; EI = emergence index; ERI = emergence rate index; DAP = days after planting.

The experiment was maintained by weeding according to need. Starting from 28 weeks after planting (WAP), seedling growth parameters were measured at 4-weekly intervals up to 48WAP. Leaf area was calculated based on the model developed by Ugese *et al.* (2008b) as shown below.

$$LA = 4.41 + 1.14LW$$

where LA = leaf area and LW = the product of linear dimensions of the length and width at the broadest part of the leaf. Leaf shape index (LSI) was estimated as the ratio of length to width of leaves at the widest point.

Data collected were subjected to analysis of variance and by use of GENSTAT Discovery edition 3, Release 7.2DE (GENSTAT 2007).

RESULTS

Emergence parameters varied widely among the accessions (**Table 2**). E % values were highest for Akwanga but lowest for the Lokoja, Minna and Yola accessions. Most of the accessions had EI values of 100 or more but these were not statistically different from each other. Corresponding ERI scores were higher, representing poorer performance.

The main effect of location on seedling growth characters is presented in **Table 3**. It was interesting that all the parameters except LSI at 28 and 32 WAP showed significant variation. Consistently, performance of seedlings was better at the Makurdi location except for LSI at 36WAP where Nsukka trial location did better. There was as expected a general increase in values of parameters measured with time.

Similarly, accession main effect influenced seedling growth remarkably (**Fig. 1A, 1B**). Kachia and Akwanga

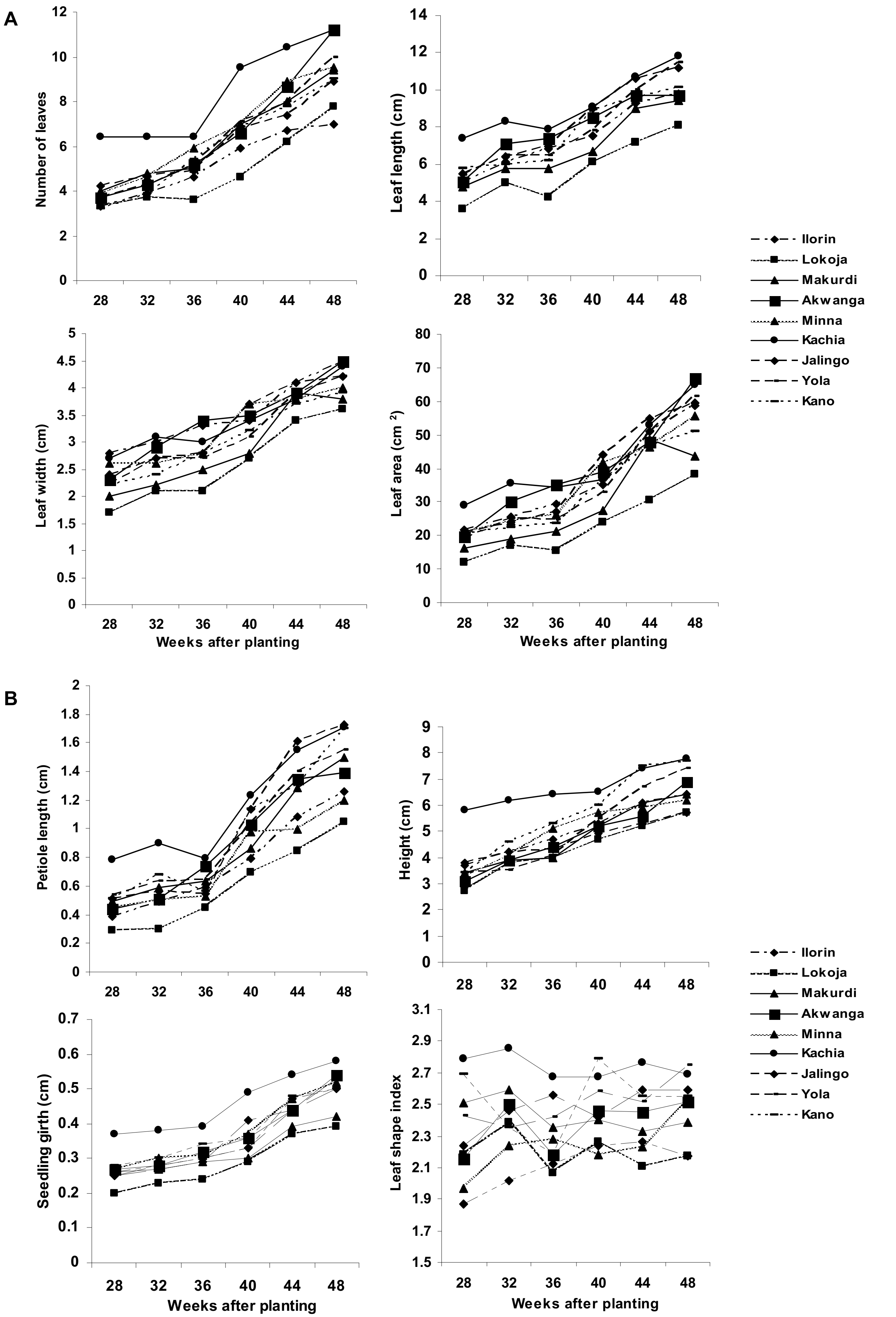

Fig. 1 (**A**) Growth of *Vitellaria* seedlings of nine accessions in terms of leaf number, leaf length, leaf width and leaf area at Makurdi and Nsukka, Nigeria. (**B**) Growth of *Vitellaria* seedlings of nine accessions in terms of petiole length, seedling height, seedling girth and leaf shape index at Makurdi and Nsukka, Nigeria.

Table 3 The main effects of location on *V. paradoxa* seedling characters taken at the sixth month of measurement.

Month	Location	No of leaves	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Petiole length (cm)	Plant height (cm)	Stem girth (cm)	Leaf shape index
1	Makurdi	5.6	6.3	2.6	24.4	0.62	4.4	0.31	2.37
	Nsukka	2.4	4.4	2.0	15.5	0.34	2.9	0.22	2.26
	$LSD_{(0.05)}$	0.1	0.3	0.1	1.2	0.04	0.3	0.02	NS
2	Makurdi	5.9	7.3	3.0	30.4	0.72	5.1	0.33	2.49
	Nsukka	3.1	5.2	2.3	19.2	0.43	3.5	0.25	2.34
	$LSD_{(0.05)}$	0.2	0.2	0.1	2.7	0.02	0.3	0.01	NS
3	Makurdi	5.9	7.1	3.0	30.1	0.73	5.6	0.35	2.25
	Nsukka	4.3	5.7	2.6	22.8	0.49	3.8	0.26	2.38
	$LSD_{(0.05)}$	0.5	0.2	0.2	1.5	0.03	0.3	0.01	0.1
4	Makurdi	8.3	9.0	3.5	42.0	1.36	6.7	0.43	2.57
	Nsukka	5.3	6.9	3.0	29.6	0.61	4.1	0.28	2.32
	$LSD_{(0.05)}$	0.5	0.3	0.2	1.8	0.09	0.4	0.01	0.1
5	Makurdi	9.9	11.4	4.4	62.5	1.83	8.0	0.58	2.57
	Nsukka	6.1	7.5	3.3	33.1	0.71	4.5	0.32	2.27
	$LSD_{(0.05)}$	0.6	0.4	0.2	2.0	0.08	0.3	0.02	2.26
6	Makurdi	12.0	12.3	4.6	70.8	2.13	8.4	0.66	2.66
	Nsukka	6.6	8.4	3.6	40.3	0.78	4.9	0.34	2.33
	$LSD_{(0.05)}$	0.6	0.5	0.2	2.1	0.08	0.4	0.03	0.14

NS – No significant difference

Table 4 Interaction effects of location and accession on *V. paradoxa* seedling characters taken at the sixth month of measurement.

Location	Accession	No of leaves	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Petiole length (cm)	Plant height (cm)	Stem girth (cm)	Leaf shape index
Makurdi	Ilorin	8.3	11.9	5.1	77.2	1.90	7.9	0.63	2.36
	Lokoja	10.2	8.5	3.6	40.5	1.50	6.3	0.45	2.37
	Makurdi	12.4	10.1	4.1	51.2	2.10	8.2	0.53	2.47
	Akwanga	14.4	13.6	5.2	83.5	1.90	9.0	0.70	2.73
	Minna	13.0	13.2	5.0	82.1	1.87	7.3	0.70	2.72
	Kachia	15.4	14.0	4.9	82.3	2.60	10.2	0.85	2.85
	Jalingo	9.9	13.2	4.6	73.5	2.57	6.5	0.66	2.82
	Yola	13.4	14.1	4.8	82.7	2.20	10.2	0.75	2.92
	Kano	11.5	11.8	4.4	63.9	2.50	10.4	0.68	2.67
Nsukka	Ilorin	5.6	7.6	3.9	40.6	0.65	4.9	0.37	2.90
	Lokoja	5.5	7.7	3.6	36.1	0.60	5.1	0.34	2.16
	Makurdi	6.3	7.7	3.4	36.2	0.90	4.7	0.32	2.31
	Akwanga	8.1	9.2	4.0	50.1	0.87	4.8	0.38	2.31
	Minna	5.9	7.0	3.0	28.8	0.53	4.4	0.34	2.31
	Kachia	7.0	9.7	3.9	47.5	0.83	5.4	0.31	2.53
	Jalingo	8.0	9.2	3.9	45.5	0.86	4.9	0.34	2.35
	Yola	6.7	8.8	3.4	39.9	0.90	4.6	0.30	2.59
	Kano	6.6	8.5	3.5	38.3	0.90	5.1	0.33	2.43
	$LSD_{(0.05)}$	1.9	1.5	0.7	6.2	0.23	1.1	0.09	Ns

NS – No significant difference

seed sources recorded significantly higher leaf number compared to the rest. However, while Kachia had high leaf numbers from the beginning those of Akwanga were lower but increased relatively faster to catch up with the former at the last recorded interval. Lokoja and Ilorin seedlings maintained fewer leaf numbers. Other accessions seemed to occupy an intermediate position. The leaves produced by seedlings of Kachia, Yola and Jalingo sources were also longer while those of Lokoja were shorter. Leaf width also varied with accession ($P < 0.05$). In this case however, Ilorin together with Akwanga and Kachia had broader leaves at the final stage of growth. Makurdi and Lokoja leaves were narrower, a trend that was evident right from the early stage of seedling growth. Leaf area also showed similar pattern.

In terms of petiole length, three of the accessions (Kachia, Jalnigo and Kano) had leaves with long petioles, three (Ilorin, Lokoja and Minna) had short petioles. The remaining three accessions (Makurdi, Yola and Akwanga) had values that could be considered intermediate. Seedlings from seeds sourced from kachia, Yola and Kano ended up taller than the rest with those of Lokoja and Jalingo being the shortest. In terms of leaf shape index, Kachia took the lead while Markurdi and Lokoja came last.

All seedling characters except LSI showed significant response to interaction between location and accession (**Table 4, Fig. 2A, 2B**). Generally, best performers at Makurdi were Kachia, Yola and Akwanga. Seedlings of Ilorin, Lokoja and Markudi seed sources were consistently inferior in most traits considered. There was a slightly different response of seedlings at the Nsukka location where the best three performers were Akwanga, Kachia and Jalingo. It however appeared that the Lokoja, Makurdi, Ilorin and Minna seed sources produced seedlings of less vigour even though the leaf width and area of Ilorin seedlings appeared better than those of the other accessions in question. On a general note, the Makurdi environment evidently favoured shea seedling growth much better than Nsukka.

DISCUSSION

The consistent superiority of the Makurdi location in seedling growth over Nsukka could be ascribed to differences in soil and climatic conditions of the two sites. For instance, the amount of K was higher at Makurdi compared to Nsukka. This element is known to promote root growth (Ngeze 1993), a very important consideration in *Vitellaria.*

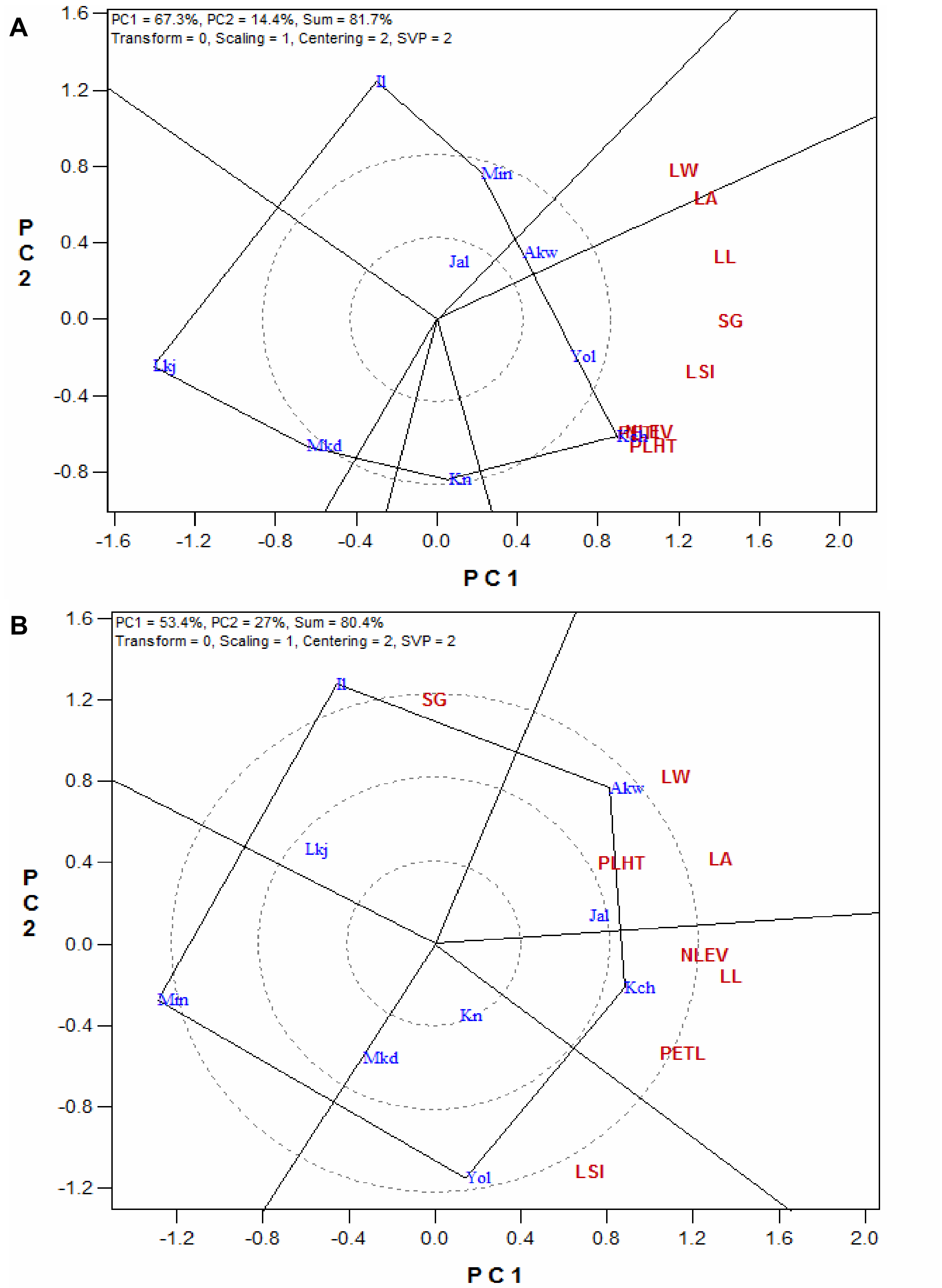

Fig. 2 (**A**) Biplot of *Vitellaria* seedling characters of nine accessions grown at Makurdi, Nigeria. Accessions code: Akw: Akwanga; Il: Ilorin; Jal: Jalingo; Kch: Kachia; Kn: Kano; Lkj: Lokoja; Mkd: Makurdi; Min: Minna and Yol: Yola. Seedling character code: LA: Leaf area; LL: Leaf length; LSI: Leaf shape index; LW: Leaf width; NLEV: Number of leaves; PETL: Petiole length; PLHT: Plant height and SG: Seedling girth. (**B**) Biplot of *Vitellaria* seedling characters of nine accessions grown at Nsukka, Nigeria. Accessions code: Akw: Akwanga; Il: Ilorin; Jal: Jalingo; Kch: Kachia; Kn: Kano; Lkj: Lokoja; Mkd: Makurdi; Min: Minna and Yol: Yola. Seedling character code: LA: Leaf area; LL: Leaf length; LSI: Leaf shape index; LW: Leaf width; NLEV: Number of leaves; PETL: Petiole length; PLHT: Plant height and SG: Seedling girth.

Besides, the pH of Nsukka site was more acidic. Generally, Nsukka soils are associated with high level of acidity (Tenkouano and Baiyeri 2007), a condition that limits the amount of nutrients available to the plant (Baiyeri and Mbah 2006). As such, seedlings grown at Markudi are expected to suffer less from nutrient inhibition than those grown at Nsukka. Their performance will therefore be superior.

The climatic factor of rainfall could also have played an important role in the differential performance of the two locations. *Vitellaria* is known to thrive best in areas with mean annual rainfall of 900-1400 mm (Umali and Nikiema 2002). The lower limit of rainfall could even be 600 mm per annum (ICRAF 2000). The reported 1500 mm mean annual rainfall for Nsukka (Tenkouano and Bayeri 2007) appears slightly above the upper limit of rainfall and could constitute an impediment to optimal performance of the species at this location.

Observed differences in performance of the accessions could be linked to differences in place of origin. It is generally understood that differences arising from place of origin could be many times greater than those among individual trees in the same stand (Wright 1976). This forms a basic justification for seed source testing. Those differences may arise due to adaptation of the species to certain climatic elements prevalent in those locations. These climatic elements may vary to some degree across the distribution range of such species.

For instance, in *Vitellaria*, as in other species, certain climatic factors may lead to the production of fruits or seeds that are bigger and which may contain more fat or so (Maranz *et al.* 2004). This factor (seed size) alone may lead to differential seedling growth of the accessions. An earlier study using seed of one source was still able to detect variation in seedling growth based on seed size (Ugese *et al.* 2007)

Results obtained here corroborate earlier reports (Ugese *et al.* 2008c, 2010c) in which seeds of various provenances in Nigeria showed significant variation in growth and dry matter attributes, with heavier seeds recording comparatively better performance Generally, there are significant differences in physical attributes of the nuts of shea tree across the distribution range in Nigeria (Ugese *et al.* 2010a), with serious implication for seedling growth performance as demonstrated by the present study. Awoleye (1995) also found differences in emergence and seedling growth of three *Vitellaria* accessions from Kwara and Niger States in Nigeria. The only marked deviation with results reported here is that in his case, the Ilorin seed source gave superior growth at the Ilorin experimental site suggesting strong local adaptation. In this case however, seeds obtained from Makurdi could not grow more vigorous than other seed origins at Makurdi. On the contrary, the Makurdi seed source was among the most inferior in seedling vigour. This is suspected to be due to the small size of the nuts as seed size has been adjudged a key determinant of seedling growth (Ugese *et al.* 2007). It is not clear whether this issue was considered by Awoloye (1995).

An interesting point in observed results is that while Kachia, Yola and Akwanga recorded superior seedling growth at Makurdi, Jalingo, Akwanga and Kachia gave the best seedling growth at Nsukka. A factor that may have given these accessions (except perhaps, Yola) advantage over others could be the large size of their seeds. But the pattern of performance stated above cannot rule out some degree of genotype and environment interaction. However, the Akwanga and Kachia seed sources that performed comparatively well at both locations could be said to be more stable over the two locations. Similar inference seems to hold in the case of accessions like Ilroin, Lokoja and Makurdi which maintained a consistently lower performance across the two locations.

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