Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 8 Number 2 May 2009 pp 110 - 115
ISSN 1119-7455

INTRA- AND INTER- CORRELATIVE RESPONSES AMONG FRUITS PHYSICAL TRAITS, SEEDLING GROWTH PARAMETERS AND FRUIT AND NUT PROXIMATE QUALITIES OF THE NIGERIAN SHEA NUT TREE (*VITELLARIA PARADOXA* C. F. GAERTN)

Ugese[1], F D Baiyeri[2] K P and Mbah[2] B N
[1] Dept. of Crop Production, University of Agriculture, P M B 2373, Makurdi, Nigeria.
[2] Dept. of Crop Science, University of Nigeria, Nsukka, Nigeria.

ABSTRACT
Seedling growth of Vitellaria paradoxa C. F. Gaertn (shea nut tree) is extremely slow. Identification of any nut trait that shows positive and significant relationship with vigorous seedling growth could therefore, be an important selection index. Besides, fruit preferences among indigenous peoples are associated with high pulp proximate quality while highly valued nut has strong relationship with fat content. Thus, intra- and inter- correlative responses among fruits physical traits, seedling growth parameters and fruit and nut proximate qualities of V. paradoxa were studied. Agronomically important seedling characters of nine provenances across Nigeria's savanna zone were also examined with principal components analysis (PCA). Results indicated that the first three PCA axes retained explained 96.3% of total variability among seedling provenances, revealing that leaf area, seedling girth, plant height and number of leaves are more promising traits for shea seedling classification in Nigeria. Multiple correlation analysis showed that nut length had high and significant linkage with number of leaves, leaf width, leaf area and seedling girth. Nut width also correlated positively with leaf length, leaf area and seedling girth (P<0.05). Percent pulp weight had high positive significant correlation with carbohydrate and energy, but was negatively correlated with fibre. Similarly, nut diameter had positive significant relationship with fat but a negative one with carbohydrate. Correlations between percent testa weight and fat were positive. The correlative responses showed that choice of long nuts for planting could lead to vigorous seedling growth. Similarly, shea fruits with high percent pulp content could have high carbohydrate and energy contents while nuts with broader diameters may be selected for high fat content.

Keywords: Shea nut tree, Correlations, PCA, , Proximate traits, Seedling traits, ***Vitellaria paradoxa***

INTRODUCTION

Among the many trees in the family Sapotaceae, foremost economic species seem to be *Vitellaria paradoxa*, *Baillonella toxisperma* and *Madhuca longifolia* (Maranz *et al*., 2004), with *V. paradoxa* appearing to be of greater economic significance. The importance of the shea nut tree (*Vitellaria paradoxa*), most commonly called shea butter tree, on a global scale, is predicated on the usefulness of its seed fat in European and Japanese food and cosmetic industries (Umali and Nikiema, 2002). In Africa where the species occurs, the seed fat is used for cooking, in lighting of lamps, in soap and pomade preparations as well as for medicinal purposes (Awoleye, 1995; ICRAF, 2000; Hill, 1952). Other plant parts have been credited with various medicinal uses (Popoola and Tee, 2001).

In addition, caterpillars of *Cirina butyrospermi*, rich in protein and exclusive feeders on the leaves of the species, are considered a delicacy among some Nigerian ethnic groups such as the Yoruba and Nupe (Ande, 2004) and the Tiv of Central Nigeria (Ugese *et al.,* 2005). Sale of these caterpillars is said to contribute significantly to rural household incomes (Popoola and Tee, 2001). The wood of *V. paradoxa* is hard and termite proof and is useful in constructional works and in the production of household and farm items. The fruit pulp has excellent nutritional properties and is widely consumed among indigenous peoples (Maranz *et al*., 2004; Ugese *et al*., 2008).

Agroforestry species that show high potential in contributing to reduction of rural poverty, hunger and disease and enhancing environmental sustainability are considered priority species for domestication (Leakey *et al.*, 2005). The high rating of *V. paradoxa* in terms of the above potentials qualified it for inclusion among the 17

priority species that have been farmer-identified for domestication in four eco-regions of the tropics (Leakey, 1999). A key consideration in agroforestry tree domestication effort is the identification of genetic variability within the species, and the relationships between or among those traits as an aid towards selection of superior genotypes (Leakey *et al.*, 2005). According to Sanwo (1980), if an easily observable trait positively and significantly correlates with an obscure but useful trait, then the former could be used as a basis for selection for the latter. This indicator trait approach could become even more useful if the easily observable or measurable trait correlates with two or more traits of economic significance.

In *Vitellaria paradoxa*, seedling growth is extremely slow (Jackson, 1968). Therefore, any nut trait that would have a positively significant correlative link with vigorous seedling growth could be an asset. Similarly, fruit preferences among indigenous peoples have been documented, with farmers showing preference for sweet, fleshy and ripe fruits (de Saint Sauveur, 1999). As far as fat extraction and its utilization are concerned, a key criterion for identifying a good nut is the fat content (Maranz *et al*., 2004). Working out the relationships between these set of traits will enable all kinds of useful selections to be done. Therefore, this study was undertaken to identify the nature, and then quantify the degree of relationship [i] between fruit and nut traits; [ii] between seedling traits and nut traits, and [iii] between fruit pulp and kernel proximate traits, of the shea nut tree across Nigeria's savanna ecology.

MATERIALS AND METHODS

Fresh fruits of the shea nut tree were collected across the guinea and sudan savanna of Nigeria in early July, 2006. The specific locations of collection were Ilorin, Lokoja, Makurdi, Akwanga, Minna (southern guinea savanna), Kachia, Jalingo (northern guinea savanna), Yola and Kano (sudan savanna). The fruits were depulped to obtain the seeds.

Fruits and nuts were divided into five groups of forty five, with each group representing a replicate. Metric traits of the fruits and nuts were then taken. Trait means resulting from the analysis of variance were used for this study.

A provenance evaluation trial was set up at the Teaching and Research Farm of the University of Agriculture, Makurdi (7^o 41′N, 8^o 37′E, 97m above sea level) on 26th July, 2006. Seeds were planted at 50 x 20 cm spacing in single row plots of ten seeds each. The experimental design was randomized complete block (RCBD) replicated four times. A replicate trial was set up at the farm of the Department of Crop Science, University of Nigeria, Nsukka (6^o 51′E, 7^o 29′N, 400 m above mean sea level). Makurdi is in the southern guinea savanna zone while Nsukka falls within the derived savanna zone of Nigeria.

Twelve (12) months after sowing, seedling growth characters were measured. Analysis of variance was carried out on the data as a 2 x 9 x 4 factorial in RCBD with location (2) and genotypes (9) as the factors. Means of seedling characters resulting from the main effects of the factors were utilized in the correlation analysis.

Oven dry weights of fruit pulp were subjected to proximate trait determinations based on laboratory procedures outlined by the Association of Official Analytical Chemists (AOAC, 1980). Energy was determined using the Atwater method (Joslyn, 1970). Similar procedures as above were employed for determination of seed kernel proximate traits. Means obtained from analysis of variance were used for the correlation study.

Seedling traits were examined with Principal Component Analysis (PCA) to identify those traits with greater promise for shea seedling classification in Nigeria. Furthermore, correlations among the seedling traits were also determined.

Fruit and nut means were correlated with seedling growth means, pulp proximate trait means and kernel proximate trait means. Statistical software employed for the correlation analysis was SPSS version 11 while GENSTAT Discovery edition 3, Release 7.2DE (GENSTAT, 2007) was used for the analysis of variance.

RESULTS

Results of Principal Components Analysis (PCA) performed on the data showed that the three principal axes retained explained 96.3% of the total variability among growth characters of seedlings of the various provenances (Table 1). The first axis (PRIN 1) accounted for 73.2% of the total variability and was loaded for leaf dimension parameters and plant girth. PRIN 2 which loaded highly for plant height explained about 15.6% of the total variability. It was observed that number of leaves per seedling could explain up to 7.5% (PRIN 3) variance found in shea seedling. Generally, PCA identified leaf area, leaf length, seedling girth, plant height and number of leaves as showing greater prospect as discriminant variables for shea seedling classification in Nigeria.

Intra-correlations among the seedling growth traits showed that number of leaves had positive significant relationship with leaf area and leaf width (Table 2). Similarly, length of leaf revealed

Table 1. Eigen vector values for principal components of seedling characters of nine accessions of the shea nut tree grown at Makurdi and Nsukka in Nigeria.

Principal Axis	Leaf area	Leaf Length	Leaf width	Number of leaves	Plant height	Seedling girth	Latent roots	Percentage of total variation explained
PRIN 1	**-0.45715**	**-0.45670**	-0.38860	-0.34357	-0.31552	**-0.46242**	4.392	73.20
PRIN 2	0.28416	0.03447	0.52561	-0.52537	**-0.60312**	0.04518	0.935	15.58
PRIN 3	-0.05421	-0.18383	0.16731	**-0.66263**	0.69539	0.11238	0.451	7.52

Table 2. Correlations among seedling characters of nine accessions of the shea nut tree grown at Makurdi and Nsukka in Nigeria

	No. of leaves	Leaf length	Leaf width	Leaf area	Petiole Length	Plant height	Seedling girth	Leaf shape index
Leaf shape index	0.652	0.954**	0.754	0.833**	0.801*	0.669	0.885**	-
Seedling girth	0.831*	0.834*	0.915**	0.920**	0.656	0.709	-	
Plant height	0.641	0.532	0.444	0.502	0.503	-		
Petiole length	0.387	0.833*	0.490	0.557	-			
Leaf area	0.837*	0.772*	0.986**	-				
Leaf width	0.881**	0.698	-					
Leaf length	0.559	-						
No of leaves	-							

*, ** - Correlation is significant at the 5% and 1% levels of probability respectively

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Table 3. Correlations between metric traits of fruits and nuts and seedling growth traits of the shea nut tree from the savanna of Nigeria.

Seedling growth traits	**Metric traits of fruits and nuts**											
	FRLT	FRDM	FSI	FRWT	PUPWT	%PUPWT	NTWT	NTLT	NTDM	NSI	KNWT	%TSWT
No of leaves	0.805*	0.695	0.490	0.706	0.599	-0.226	0.714	0.777*	0.493	0.064	0.650	-0.060
Leaf length	0.169	0.022	0.114	0.171	-0.110	-0.860*	0.605	0.678	0.808*	-0.649	0.657	0.423
Leaf width	0.623	0.677	0.198	0.786*	0.615	-0.419	0.884**	0.798*	0.703	-0.307	0.680	-0.126
Leaf area	0.526	0.553	0.196	0.687	0.495	-0.528	0.846*	0.771*	0.727	-0.407	0.674	-0.093
Plant height	0.395	0.04	0.776*	0.034	-0.089	-0.504	0.234	0.503	0.275	-0.014	0.543	0.169
Seedling girth	0.496	0.398	0.365	0.540	0.312	-0.673	0.794*	0.838*	0.765*	-0.434	0.797	0.097

FRLT = Fruit length; FRDM = Fruit diameter; FSI = Fruit shape index; FRWT = Fruit weight; PUPWT = Pulp weight; PUPWT(%) = Percentage pulp weight; NTWT = Nut weight; NTLT = Nut length; NTDM = Nut diameter; NSI = Nut shape index; KNWT = Kernel weight; %TSWT = Percentage testa weight.

*, ** - Correlation is significant at the 5% and 1% levels of probability respectively

positive statistical linkage with leaf shape index, seedling girth, petiole length and leaf area ($P < 0.05$). In addition to having high and significant relationship with number of leaves and leaf length, leaf area also maintained such relationship with leaf shape index and seedling girth. Plant height had positive but non-significant relationships with all the other seedling growth traits. Seedling girth recorded high positive correlations with leaf dimensions parameters.

The inter-correlation among fruits and nuts metric traits and seedling traits are shown in Table 3. Fruit length exhibited high significant linkage with number of leaves while fruit weight maintained such relationship with leaf width. Percentage pulp weight had a negative relationship with leaf length ($P < 0.05$). Among all the fruit and nut traits, only fruit shape index had positive significant relationship ($r = 0.776*$) with plant height.

Among nut metric traits, nut weight correlated positively with leaf length, leaf area and seedling girth. Nut length had the highest number of significant linkages with seedling characters as it maintained such relationship with number of leaves, leaf width, leaf area and seedling girth. Nut diameter was also positively correlated with leaf length and seedling girth. Kernel weight similarly

Table 4. Correlations between physical traits of fruits and nuts and pulp proximate traits *Vitellaria paradoxa* sourced from the savanna of Nigeria.

Proximate Traits of Fruit Pulp	Physical Traits of Fruits and Nuts											
	FRLT	FRDM	FSI	FRWT	PUPWT	%PUPWT	NTWT	NTLT	NTDM	NSI	KNWT	%TSWT
Moisture	0.003	-0.214	-0.020	-0.280	-0.354	-0.288	-0.087	-0.067	0.054	-0.055	-0.196	0.223
Carbohydrate	-0.269	0.118	-0.618	0.044	0.285	0.798*	-0.376	-0.606	-0.514	0.288	-0.723	-0.508
Protein	-0.057	-0.302	0.346	-0.218	-0.335	-0.417	0.033	0.399	0.343	-0.249	0.490	0.559
Fat	0.711	0.608	0.565	0.542	0.529	0.053	0.432	0.396	0.042	0.390	0.422	-0.227
Fibre	0.311	-0.078	0.675	0.000	-0.230	-0.779*	0.390	0.625	0.502	-0.262	0.739	0.436
Ash	-0.134	-0.097	-0.213	-0.084	-0.163	-0.229	0.071	-0.133	0.048	-0.196	-0.088	0.027
Energy	-0.241	0.136	-0.560	0.066	0.314	0.829*	-0.372	-0.544	-0.497	0.315	-0.653	-0.468

FRLT = Fruit length; FRDM = Fruit diameter; FSI = Fruit shape index; FRWT = Fruit weight; PUPWT = Pulp weight; %PUPWT = Percentage pulp weight;
NTWT = Nut weight; NTLT = Nut length; NTDM = Nut diameter; NSI = Nut shape index; KNWT = Kernel weight; %TSWT = Percentage testa weight.
*- Correlation is significant at the 5% level of probability.

Table 5. Correlations between physical traits of fruits/nuts and proximate traits of kernels of *Vitellaria paradoxa* sourced from the savanna of Nigeria.

Proximate Traits of Kernel	Physical Traits of Fruits and Nuts											
	FRLT	FRDM	FSI	FRWT	PUPWT	%PUPWT	NTWT	NTLT	NTDM	NSI	KNWT	%TSWT
Moisture	0.145	0.207	0.161	0.126	0.324	0.639	-0.242	-0.102	-0.369	0.508	-0.129	-0.234
Carbohydrate	0.005	-0.141	0.346	-.314	-0.069	0.519	-0.654	-0.733	-0.905**	0.698	-0.745	-0.718
Protein	0.063	-0.241	0.398	-.382	-0.270	0.246	-0.479	-0.174	-0.382	0.485	-0.209	0.158
Fat	-0.129	-0.055	-.396	0.080	-0.169	-0.575	0.483	0.528	0.777*	-0.678	0.542	0.767*
Fibre	0.058	0.363	-.248	0.584	0.423	-0.413	0.713	0.482	0.640	-0.655	0.509	-0.182
Ash	0.408	0.553	0.278	0.481	0.671	0.630	0.039	-0.046	-0.379	0.568	-0.047	-0.650
Energy	-0.186	-0.222	-.334	-.143	-0.366	-0.546	-0.271	0.359	0.606	-0.551	0.368	0.818*

FRLT = Fruit length; FRDM = Fruit diameter; FSI = Fruit shape index; FRWT = Fruit weight; PUPWT = Pulp weight; %PUPWT = Percentage pulp weight;
NTWT = Nut weight; NTLT = Nut length; NTDM = Nut diameter; NSI = Nut shape index; KNWT = Kernel weight; %TSWT = Percentage testa weight.
*, ** - Correlation is significant at the 5% and 1% levels of probability respectively.

recorded high positive relationship with seedling girth ($P < 0.05$).

There were few significant relationships between physical traits of fruits and nuts and pulp proximate characters (Table 4). Percentage pulp weight significantly correlated positively with carbohydrate and energy, but negatively with fibre. Apart from percent pulp weight, other physical attributes did not show significant relationship with any of the pulp proximate qualities. However, the relationship between fibre and kernel weight was positive ($r = 0.739$). Similarly, proportion of fat in the fruit pulp was associated ($r = 0.711$) with increasing fruit length.

A few significant relationships were observed between fruit and nut physical traits and proximate traits of kernel (Table 5). The nut diameter was negatively but significantly correlated with carbohydrate ($r = -0.905^{**}$). However, nut diameter had positive significant relationship ($r = 0.777^{*}$) with fat. The percent testa weight was positively correlated with fat and energy ($P < 0.05$).

DISCUSSION

The vector loadings of the three principal axis retained in the PCA conducted suggested that leaf parameters (number of leaves, leaf area, leaf length) and seedling girth are the most important selection indices for shea seedlings in Nigeria. The significant intra- and inter-correlations among several parameters as obtained in this study corroborate earlier report of Ugese *et al*. (2005). However, in the present study, an important contrast was the non-significant relationship between plant height and other seedling growth parameters. It could be due to the influence of genotype x environment (g x e) interaction on this particular trait as nine genotypes were assessed over two contrasting environments. In the earlier study under reference, only one seed source, planted in a single location was involved, thereby precluding any possibility of g x e interaction.

Some key nut traits correlated positively and significantly with one or more aspects of seedling growth. This implies that selecting

seeds for planting on the basis of the indicator traits could boost seedling growth attributes. For instance, if seeds of longer length are planted this will lead to seedlings with high number of leaves, broader leaf width, larger leaf area and bigger stem girth. The positive significant correlations among these seedling traits (Table 2) reinforces the idea that planting
suitable seeds will produce seedlings that will show vigour in many aspects of seedling growth. For instance, nut length did not show any significant relationship with leaf width (Table 3). However, stem girth did (Table 2). Thus planting long seeds could lead to seedlings with larger stem girth and consequently larger leaf width as well.

It is highly advantageous that nut length recorded the highest number of significant correlations with seedling growth traits. This is because even when nuts are bulked together under post harvest conditions, it might be easier to undertake selection on the basis of nut length rather than nut width or weight.

An important practice in agroforestry tree domestication is the use of various vegetative propagation techniques to disseminate germplasm of superior individuals (Leakey *et al.*, 2005). In *Vitellaria*, this has started happening (Maranz *et al.*, 2004). However, the method that has been found successful is grafting in which young saplings are used as the root stock (Spore 2008). Since growth of shea seedlings is extremely slow (Jackson, 1968), any choice of seed that could accelerate seedling growth would be a positive development. This could reduce the age at which saplings are grafted, thereby helping to reduce further the age of fruiting occasioned by the technique.

The significant positive correlation between percentage pulp weight and carbohydrate showed that this class of food was dominant in such fruit pulps. Ugese *et al.* (2008) reported that shea fruits in the wetter savanna zone of Nigeria had more percentage pulp and carbohydrate contents than those in the drier zone. They attributed this to more favourable environmental conditions that enhance optimal rates of photosynthesis. Stress conditions may result in low percentage pulp content that could be more fibrous as correlation analysis also indicated in this study.

The positive significant correlation between nut diameter and kernel fat content may be an indication that wider seeds could contain more fat than narrower ones. The carbohydrate content of such seeds could be less as this character (nut diameter) was negatively correlated with carbohydrate content. From the description of cellulose or lingo-cellulose by Roberts (1976), it seems likely that the testa is made up of this material. If this is the case, it implies that part of the carbohydrate was used in forming the testa. This, therefore, could have the effect of reducing the amount of carbohydrate inside the kernel thereby indirectly increasing that of fat and other components. Thus, seeds with higher percentage testa weight would invariably maintain high amount of fat which is the dominant kernel content. This feature may explain the significant positive linkage between percentage testa weight and carbohydrate content (Table 4). Since fat is apparently the major determinant of kernel energy content, the relationship between energy and percent testa weight was equally positive.

Generally, the nature of relationships observed between physical traits of fruits and nuts and also between proximate traits of kernel and fruit pulp corroborates the findings of Leakey *et al.* (2005), in three key agroforestry species – *Dacryodes edulis*, *Irvingia gabonensis* and *Sclerocarya birrea* who noted that high values of one trait may not necessarily be associated with high values of another trait. In other words, large fruits, for instance, may not necessarily be sweet or contain large nuts or kernels. In this study, large fruits, for instance, did not record high percentage pulp content and fruit weight did not also exert any appreciable influence over any of the pulp proximate qualities. In cashew, Sanwo (1980) obtained negligible number of significant correlations between fruit and nut physical characters and fruit chemical attributes.

Based on the results of the study, the following conclusions and recommendations are stated below:

(i). Principal components analysis identified leaf area, leaf length, seedling girth, plant height and number of leaves as more promising traits for shea seedling classification. This suggests that leaf dimension and stem growth are key selection indices for identification of vigorous accessions at seedling growth stage of shea;

(ii). Nuts that were long were significantly associated with vigorous seedling growth. This implies that initial selection of long nuts for nursery planting will invariably produced vigorous and healthy seedlings;

(iii). Shea fruits with high percentage pulp contents are associated with higher carbohydrate and energy content;

(iv). Nuts with wider diameters may contain more fat than those with narrower diameters.

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