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Morphological Variation in Fruit Shapes of *Adansonia digitata* L. From Blue Nile and North Kordofan States, Sudan.

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Abstract **- Morphological variation of fruits of *Adansonia digitata* L. (Baobab tree) from the Blue Nile and North Kordofan States, Sudan , was evaluated by sampling fruits from five locations from each state following a climatic gradient. Their morphological characteristics were assessed with the combination of morphometric criteria. The results indicated a high diversity in fruit shapes. Twelve shapes were observed in the studied locations (ellipsoid, high spheroid, ovate, obovate, oblong pointed, fusiform, globose, spheroid -emarginate , ellipsoid pointed, clavate, rhomboid and crescent shapes). Among them clavate and crescent shapes were found only in North Kordofan samples and rhomboid shape was found in the Blue Nile samples only. Analysis showed that there were significant differences in fruit morphometric characters: fruit length, width, length/width ratio and weight within and between the studied states. Oblong pointed, clavate and fusiform shapes have the largest L/W ratios (3.19-3.22) whereas the lowest ratio was found in the spheroid emarginate shape (1.12). It is concluded that there is considerable variability in fruit shapes of baobab, offering opportunities for cultivar selection.**

***Index items: Adansonia digitata*; Baobab.; Fruit variations; Domestication.**

I. INTRODUCTION

Adansonia digitata L., the Baobab tree belongs to the Bombacaceae family, is characterized by its massive size up to 25m high, trunk bottle shaped and 10m diameter, bark is smooth, reddish-brown to grey, soft and fibrous [1] .This tree species is one of the key species for domestication in the semi-arid regions of Africa. Rural populations (farmers) can use their own criteria to differentiate between different types of baobab with the colour of bark, and fruits shapes as a guide in collecting germplasm from trees [2].

It is a very important species in the economy of rural and urban people, contributing to their food, fodder, medicine and other uses. Its fruits are important source of cash income for the certain tribes living in Central and South Sudan [3,4]. Also it promotes biodiversity conservation through agroforestry systems which help in soil and water conservation to enhance high crop yield [5,6,7]. Baobab trees are classified as an endangered species, in their natural savannah ecosystem [8]. It is mostly regarded as fruit-bearing forest tree. Each mature tree produces more than an average of 250 capsules which may provide at least 30 kilograms of fruits[9].

Ecotypes from different areas in Sudan are widely known to have different fruits in terms of size, shape and sweetness. Fruits of baobab are very variable in size and shape [10,11] . El Amin [12] reported that the fruits are capsule, globose to ellipsoid in shape and they often irregular in shape, apex pointed or obtuse, covered by velvety yellowish hairs. Four types of baobab fruits distinguished in Kordofan only: fusiform, crescent shaped, globose and ventricose [13].
Most studies have been focused on the description of the baobab fruits. No further information on the diversity of baobabs and fruit shapes is available in the literature.

Classification of fruit shape is vital in evaluating agricultural production and increasing market value, and it is also helpful in planning packaging for conservation. In addition it is often necessary in horticultural research for arrangement of different purposes such as cultivar descriptions in applications for plant variety rights or cultivar registers [14, 15].
Therefore, the aims of this study were to morphologically describe and classify baobab fruits shapes in different locations of the Blue Nile and North Kordofan states with the combination of morphometric criteria.

II. MATERIALS AND METHODS

Site description

The study was performed on baobab (*Adansonia digitata* L.). Population established within five locations from each North Kordofan and Blue Nile states in Sudan. North Kordofan state located roughly between latitude 10.5˚ and 15˚ north and longitude 27.5˚ and 32˚ east, it occupies a total area of about 185302 km². Blue Nile state located between latitude 10˚ and 13˚ North and longitude 33˚and 36˚ east, and occupies a total area about 38500km²(**Fig.1&Table1**).

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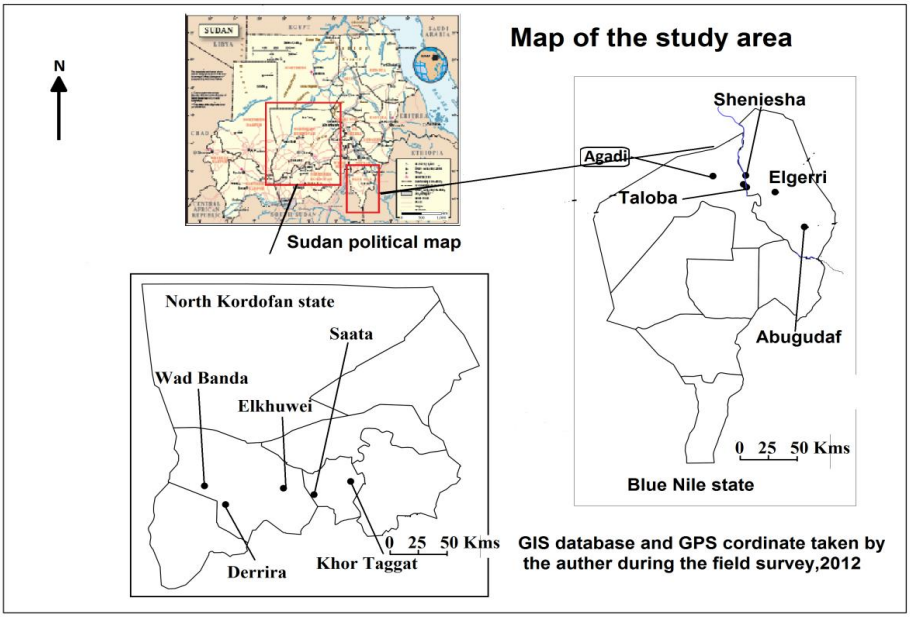

Figure 1. Map of Blue Nile and North Kordofan states.

Table1

The characteristics of the selected locations of study from the two states

State	Location	Altitudes (m)	Soil	Lat. N	Long. E	Average Rainfall (mm)
North Kordofan	KorTaggat	560	Sandy loamy	13° 11′	30° 18′	350
	Saata	512	Sandy	12° 58′	29° 52′	350
	Elkhuwei	530	Sandy loamy	13° 04′	29° 13′	350
	Derrira	565	Sand	12° 47′	28° 16′	350
	WadBanda	623	Sandy loamy	13° 06′	27° 56′	350
Blue Nile	Taloba	474	Stony hill side	11° 49′	34° 23′	700
	Shenisha	465	Silty	11° 57′	34° 22′	700
	Elgerri	538	Stony hill side	11° 49′	34° 36′	700
	AbuGuduf	550	Clay	11° 31′	34° 50′	700
	Agadi	522	Stony hill side	11° 57′	34° 06′	700

Sources: Ministry of Agriculture of North Kordofan and Blue Nile States (2013).

Fruits morphological characteristics (fruit measurements)

Six mature fruits without any damage or defects by careful visual inspection were picked up randomly from different positions in the crown and put in labeled plastic bags. The total number of fruits sampled was 486 from 81 trees from the studied areas. Fruits were harvested by climbing, or by throwing wooden sticks. After transport to the laboratory, fruit length, width (at widest part) were measured by using callipers (least count 1mm), and ruler and length /width ratio was calculated, to show the degree of relationship with fruit shapes and morphometric traits. In addition, fruits were weighed to the nearest 0.5 g.

Statistical analysis

Statistical analyses were carried out using Minitab 16, significant differences in variables fruits length (FL), fruits width (FW), fruits ratio (FR) and fruit weigh (FW) between and within North Kordofan and Blue Nile states tree population. These parameters, were assessed using analysis of variance (ANOVA). Tukey's honestly significant difference (HSD) was used to compare the means.

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III. RESULTS AND DISCUSSION

Results indicated high significant differences in fruit morphology in the two studied States (**Table 2**). Twelve distinct fruit shapes were observed and were described through visual examination: ellipsoid, high spheroid, ovate, obovate, oblong pointed, fusiform, globose, spheroid-emaginate, ellipsoid pointed, clavate, rhomboid and crescent shaped, (**Fig.2**). Fruit shape varied between trees but was consistent within each individual tree.

Figure 2. Diversity in fruit shape of (*A. digitata* L.) from North Kordofan and Blue Nile states, Sudan.

In this study morphometric attributes of baobab namely: fruit length and width were analyzed to detect the degree of variation. Ellipsoid, obovate, and globose shapes characterized by having large measurements in NK than BN, whereas high spheroid, oblong pointed and fusiform shapes have larger measurements in BN than NK. In addition to that, ellipsoid type has a round apex, and spheroid has emarginated apex, not like the others which characterized by having pointed apex.

Moreover, rhomboid shape found only in the BN (Shenisha population) and clavate and crescent shapes found only in the NK. (**Table2**).

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Table 2
Fruit characteristics of *Adansonia Digitata*, from North Kordofan (NK) and Blue Nile (BN) States.

Fruitsshape	Site	Fruit length (cm)	Fruit width (cm)	Fruit shape L/W	Fruit weight (g)
Ellipsoid	NK	16.35 ± 2.04 a	7.66 ± 1.17 a	2.16 ± 0.23 a	146.43 ± 59.67 b
	BN	16.2 ± 2.87 a	8.13 ± 1.04 a	2.01 ± 0.41 a	210.25 ± 75.71 a
High Spheroid	NK	12.69 ± 1.76 a	8.33 ± 1.43 b	1.55 ± 0.27 a	151.10 ± 5±8.6 b
	BN	12.93 ± 2.94 a	9.14 ± 1.73 a	1.42 ± 0.16 b	199.16 ± 93.35 a
Ovate	NK	14.94 ± 3.06 a	7.54 ± 2.03 b	2.006 ± 0.48 a	157.92 ± 94.11 b
	BN	15.6 ± 1.96 a	9.06 ± 1.16 a	1.72 ± 0.22 b	206.86 ± 62.28 a
Obovate	NK	14.32 ± 1.82 a	7.78 ± 1.89 a	1.95 ± 0.51 a	149.75 ± 78.53 a
	BN	12.41 ± 1.08 b	7.55 ± 0.55 a	1.64 ± 0.08 b	111.72 ± 24.92 a
Oblong Pointed	NK	16.37 ± 3.11 b	4.88 ± 0.61 b	3.34 ± 0.36 a	70 ± 22.14 b
	BN	25.38 ± 3.72 a	7.59 ± 0.75 a	3.36 ± 0.53 a	225.92 ± 53.29 a
Fusiform	NK	20.48 ± 1.03 a	6.87 ± 0.52 b	3.19 ± 0.42 a	147.13 ± 23.11 a
	BN	21.75 ± 2.39 a	7.94 ± 0.87 a	2.73 ± 0.34 b	181.14 ± 42.8 a
Globose	NK	13.29 ± 3.45 a	8.33 ± 2.49 b	1.64 ± 0.22 a	187.2 ± 135.7 a
	BN	12.53 ± 3.18 a	10.24 ± 2.45 a	1.23 ± 0.14 b	250.2 ± 123.1 a
Spheroid Emarginate	NK	13.35 ± 1.19 a	8.82 ± 0.72 b	1.51 ± 0.07 a	212.17 ± 49.46 b
	BN	14.07 ± 0.77 a	12.57 ± 0.95 a	1.12 ± 0.06 b	407 ± 35.1±7 a
Ellipsoid pointed	NK	20.7 ± 3.47 a	9.45 ± 0.83 a	2.16 ± 0.3 a	279.98 ± 69.4 a
	BN	16.67 ± 1.17 b	7.33 ± 0.51 b	2.28 ± 0.23 a	154.08 ± 22.66 b
Clavate	NK	22.12±2.31	6.88 ± 0.34	3.22 ± 0.42	187.5 ± 26.0
Rhomboid	BN	16.68± 0.85	9.233 ± 0.52	1.81 ± 0.09	232.8 ± 29.7
Crescent shape	NK	11.49 ± 3.15	7.392 ± 0.62	1.55 ± 0.34	88.9 ± 38.1

Means ± standard deviation, Means followed by the same letter within Colum are not significantly different from each other at P< 0.05 (n = 20)

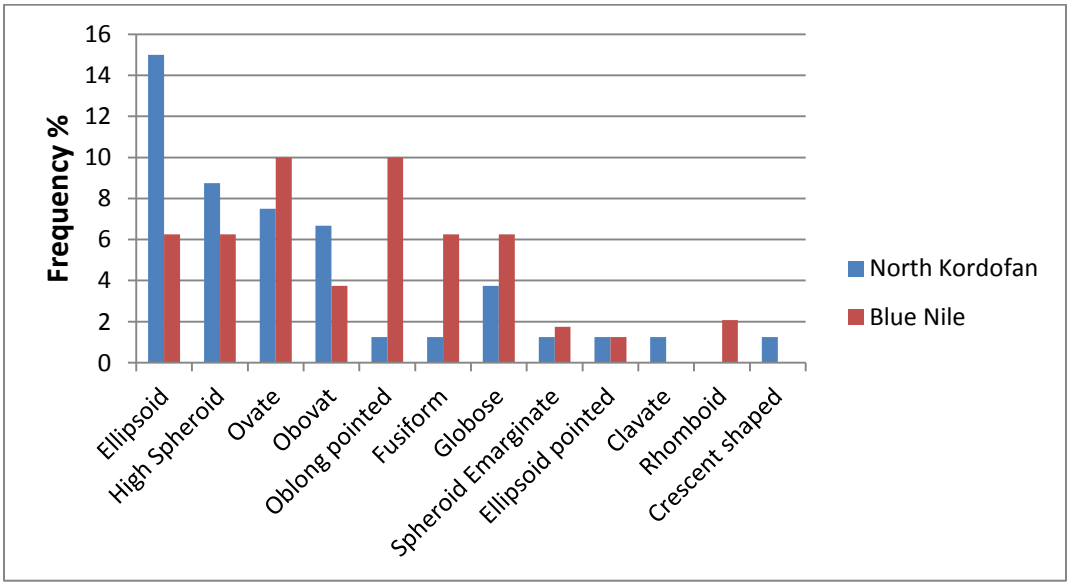

Figure 3. Frequency distribution of fruit shapes within *Adansonia digitata* tree populations at Blue Nile (BN) and North Kordofan (NK) States

Frequencies of fruit shapes

It is clear that fruit type ellipsoid was the most abundant (15% at NK, 6.25% at BN), followed by the high spheroid type (8.75% at NK, 6.25% at BN). Oblong pointed was least abundant in North Kordofan, but it was together with the ovate type most abundant in the Blue Nile state (10%)), whereas clavate, rhomboid, ellipsoid pointed and crescent types were the least frequent (1.25% at NK only, 2.08% at BN only, 1.25% at NK and BN, 1.25% at NK respectively) (**Figure 3**).

Establishing phenotypic characters of fruit shapes is the most important first step in characterization and assessing variability for plant species exchange and conservation.

In this study an impressive morphological variability in fruit shapes of Sudanese Baobab tree was observed among North Kordofan and Blue Nile states.

Fruit shape did not vary within individual baobab trees. This conform with the results of Assogbadjo *et al.* [16] who observed low morphological variability within-tree in capsule shape of baobabs in Benin and suggested a high heritability of this trait.

For all the African continent overall baobab fruit size was found to be in the general range (7.5–54 cm length, 7.5–20cm width)[10]. Fruits from Mali were found to be within the range reported by Soloviev *et al.* [17]: in Senegal (16.8 - 26 cm length, 167 - 348 g weight) and Assogbadjo *et al.* [18]. In Benin (16.8-20.7 cm length, 203-275 g weight). In this study, fruits from North Kordofan and Blue Nile states were observed to be greater than those of Benin, Mali and Senegal. In Nigeria fruit weight recorded as up to 496 g [19]. This exceeds the records from Sudan (up to 436 g) in the present study.

In general, the variation of measurable characters of fruits between and within the two studied states may be attributed to the different environmental factors and climatic gradients.

Four types of fruits were reported before only in North Kordofan [13]: ventricose, crescent-shaped, globose and fusiform types. In this study, eight more types were observed.

Current results help to suggest considerable opportunities for baobab fruit phenotypic diversity characteristics for selection and have important implication for domestication of baobab trees.

IV. CONCLUSIONS

Primary investigation of fruit shapes were distinguished and described through visual examination of 480 fruits for 81 trees. [Length and width of the fruit were measured. The length /width ratio was calculated for the fruit . Twelve fruit shapes have been identified. Therefore this study is a first step in fulfilling the criteria of different fruits in terms of size and shape of baobab tree, a promising unexplored species in hot, drier regions of Tropical Africa. It will help in the assessment of differences or variability which will facilitate selection or breeding for better quality, higher yielding cultivars, germplasm characterization and exchange. This may help to protect the species needs, to screen more material to get super-trees as well as enhance the food supply and income generation for the local population.

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