

Variations in Fruit and seed Characteristics of Baobab (*Adansonia digitata* L) in Wild Stands in the Sudan

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ABSTRACT

Baobab is a multipurpose tree species, widespread throughout the hot, drier regions of tropical Africa. In Sudan, it forms belts in Centre of the country, extending through, Kordofan, Darfur and Blue Nile. The phenotypic variation in fruits traits of selected baobab trees in ten wild populations in Sudan was considered by sampling fruits and assessing their characteristics. Fruits were characterized from 130 trees, represented from two states distributed along a rainfall gradient (5 locations in each state). From each tree, six dry fruit were selected. For all the measured fruit shapes characters. The results showed highly significant differences between the two states, in fruit, pulp, and seed weight, number of seed, individual seed weight, seed length and width. Fruits from Blue Nile (wetter area) were heavier (large weight mean of capsules 209.22 ± 84.32 , pulp 30.8 ± 14.09 and seeds 90.25 ± 48.8) than those from North Kordofan, dry area (weight of capsules 153.18 ± 78.45 , pulp 24.54 ± 10.47 and seeds 61.23 ± 39.08), as well as mean number of seed per capsule from Blue Nile was found to be larger (192.3 ± 43.2) than those from North Kordofan (133 ± 34.2). According to the fruit types, the highest mean pulp weight (70.18 g) was measured in Taloba location (in Blue Nile State) from spheroid fruits. Whereas in North Kordofan state the highest mean (39.97g) was measured only in ellipsoid fruits from KorTaggats location.

It is concluded that environment and genetics play an important role in fruit shapes characters of baobab, and there is great phenotypic variability in fruit characters found between baobab population in studied area, offering opportunities for cultivar selection (domestication purpose and tree improvement).

1. Introduction

The African baobab (*Adansonia digitata* L.) is characterized by its massive size, reaching up to 25m in height. It has thick, angular, wide spreading branches and a short, stout trunk, which reaches 10-14 m or more in girth. The form of the trunk varies; in young trees it is conical while in mature trees it may be cylindrical, bottle shaped or tapering with branching near the base (Elamin 1990). Leaves are palmate in shape leaflet 5-7. Sidibe and Williams (2002) reported that Fruits are very variable, usually globose to ovoid but sometimes oblong cylindrical, covered by velvety yellowish hairs (sometimes greenish), Pericarp 8-10 mm thick, woody, enclosing a dry mealy pulp. Seed are reniform and embedded in the pulp, dark brown to reddish black. Generally, in Africa the species is indigenous in drier areas found in West Africa, East Africa, Southern Africa up to Transvaal covering about 26 countries (Munthali, et al, 2012). In Sudan, *Adansonia digitata* is most frequently found on sandy soils and seasonal streams, Khors, in low grassland Savannas. It forms belts in Central Sudan, in Kordofan, Darfur, Blue Nile, (El Amin, 1990). The tree is used in parkland agro-forestry system in low grassland Savannas of Sudan where it grows undistributed and survives until their natural death. The tree is also grown in courtyards of villages and cities of the Blue Nile and North Kordofan states.

Baobab is mostly regarded as a fruit-bearing forest tree; it is a multipurpose, widely-used species with medicinal properties, numerous food uses of various plant parts (Sidibe and Williams, 2002). Baobab fruit pulp has been identified as important material which carries a variety of uses (Buchmann et al. 2010), Baobab products significantly contribute to household income (Kristensen and Lykke 2003; Lockett et al., 2000 ; Gebauer et al., 2002).

There is a growing international interest for Baobab fruits pulp in food, pharmaceutical and cosmetics industries. This may lead to farmers being interested in planting a type of baobab tree that produces a large number of large fruits with high fruit pulp content. Therefore, potential 'desired' planting material would depend upon fruit characteristics. Baobab fruit is already the major baobab tree product produced in some countries, for example in Sudan, each mature tree produces more than an average of 250 capsules which may provide at least 30 kilograms of fruits (FAO, 1988).

Variation in baobab fruit characteristics has been noted by several authors (Assogbadjo *et al.*, 2010; De Smedt, *et al.*, 2011; Gebauer and Luedeling, 2013). Gurashi and Kordofani (2014) reported that baobab have twelve different fruit shapes; Fusiform shaped, ellipsoid, ellipsoid pointed, obovate, ovate, globose, clavate, oblong pointed, rhomboid, spheroid emarginated, high spheroid, crescent shaped from Blue Nile and North Kordofan states, Sudan. Farmers in some countries have also noted variation in fruit characteristics, and locally recognised morphotypes on the whole populations. In Benin, Baobab trees are mainly distinguished by their fruit shape (Codija *et al.*, 2001) while in Mali farmers take into account pulp taste among other characteristics (Sidibé and Williams, 2002). Generally, Farmers are able to differentiate baobab by using their own criteria and guide researchers in collecting germplasm from superior species. In Sudan within the species it is widely known that local types from different areas have different fruits in terms of size, shape and sweetness (Gebauer *et al.*, 2002). No further information on the diversity of Sudanese baobabs is available in the scientific literature. The considerable size differences which exist between single trees of identical age suggest that the differences are mainly of genetic origin (Von Breitenbach 1985; Sidibe *et al.*, 1996). Predict the extinction of baobabs in Sudan, and therefore point out that information on baobabs in Sudan is urgently needed to develop utilization and conservation strategies (Gebauer and Luedeling, 2013), to our knowledge no recent data on tree regeneration and population structure is available for baobab populations in North Kordofan and Blue Nile state, Sudan. The baobab 's leaves, fruit, and seeds are all edible, all parts of baobab tree are used; fruits, leaves, bark, roots and seeds; in addition to an important source of cash income.

In order to provide information, help towards the effective domestication of this species, Buchmann *et al.*, (2010) reported that several studies have been carried out on baobab tree, morphological ecology, chemical and genetic characterisation, utilisation, and indigenous knowledge, mainly in West Africa. However, no or little information is available on baobab tree phenotypic variation within and between Blue Nile and North Kordofan state, Sudan in east Africa wild population. This is probably the first phenotypic variations on fruits of Baobab study on an indigenous tree species in Blue Nile and North Kordofan states, Sudan. The present study was carry out to determine and assesses fruit and seed morphological variation of baobab, occurring between and within Studied baobab populations.

2. Materials and Methods

2.1. Study area

The study was conducted in North Kordofan (NK) and Blue Nile (BN) states, Sudan (Fig. 1).

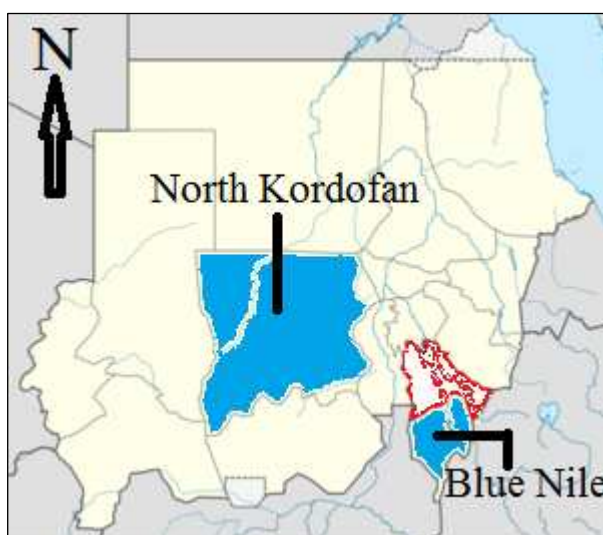


Figure 1. Study area (North Kordofan and Blue Nile state)

North Kordofan State locates between latitudes 10.5° and 15° North and longitudes 27.5° and 32° east; it occupies a total area of 185302 km². While Blue Nile State locates between latitudes 10° and 13° North and longitude 33° and 36° East, and occupies a total area of 38500 km² (Tab. 1).

Table 1. The characteristics of the selected locations

State	Locations	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 (2013), Ministry of Agriculture of Blue Nile States (2013))

Sampling and design

In each state, five locations where baobab trees naturally distributed were randomly sampled as a group (Table 1). Geographical Information System (GIS) database and Geographic coordinates of each population were taken during the field survey using Global Positioning System (GPS). Baobab fruits were collected from 10 baobab locations. Five to twenty individuals' trees were sampled randomly within baobab population for the morphometric measurements. A baobab individual was randomly selected at a minimum distances of 100 m from one another in order to avoid the genetically related individuals sampling following (Assogbadjo *et al.*, 2006; Kouyate, 2005). In total 130 individuals were collected in both study areas.

Gurashi (2014) reported that twelve distinct fruit shapes were observed and were described through visual examination in the studied locations: ellipsoid, high spheroid, ovate, obovate, oblong pointed, fusiform, globose, spheroid-emarginate, ellipsoid pointed, clavate, rhomboid and crescent shapes. Fruit shape varied between trees but was consistent within each individual tree.

From each tree, six dry fruits without any damage were selected from different positions of tree crown and kept in labeled plastic bags. This corresponds to a total of 390 fruits sampled in each State for assessing and analyzing morphometric data for baobab populations.

The capsule shell was opened and separated from shell content (pulp plus seeds) and weighted (Fig. 2). Fruits pulp and seeds were separated by dissolving the dry powdery pulp in water for five minutes and then the seeds were weighted and the pulp weight was calculated by subtraction (pulp + seed - seeds weight). The individual seeds were weighted and seed length was measured, according to the method described by De Smedt *et al.* (2011).

**Figure 2.** Fruit characters of Baobab

Statistical analysis

A univariate analysis of variance on each morphological trait variance component analysis was applied. SPSS software was used for analysis. Correlation analysis was employed using Spearman Rank order coefficient and analysis of variance.

3. Results and Discussion

Generally, the study results indicated that there were significant differences ($P \leq 0.05$) within and between the two states in relation to fruit weight, pulp weight and seeds weight. Fruits from Blue Nile were heavier (large weight of capsules, pulp and seeds) than those from North kordofan state. The seeds number per fruits from Blue Nile state was higher than those from North Kordofan state (Tab. 2).

Table 2. Variation of Baobab Fruit traits between the studied locations

Characters location	Stalk Length (cm)	Fruit weight (g)	Epicarp thickness (mm)	Seeds weight (g)/ capsule	Pulp weight (g)/ capsule	Number of seeds/ capsule
Blue Nile	10.83±3.06 ^a	209.22±84.32 ^a	5.09 ±1.17 ^a	90.25±48.8 ^a	30.8±14.09 ^a	192.3 ±43.2 ^a
North Kordofan	11.44±3.04 ^a	153.18±78.45 ^b	4.77±0.91 ^a	61.23±39.08 ^b	24.54±10.47 ^b	133 ±34.2 ^b

Means ±SD followed by the same letter within a column are not significantly different at $P \leq 0.05$

Fruit characteristics for the different locations are summarized in Table 3. Within Blue Nile state, spheroid emarginated fruit shape scored the highest measures (weight of fruit and pulp and thickness of epicarp) were found to be highly significant ($P \leq 0.05$) in Taloba.

Whereas fruits weights from obovate fruit shape in Elgerri were found to be significantly low (Table 3). The results in the same table illustrated that pulp weight was lower in Agadi and Elgerri from obovate fruit shape. Table 3 also demonstrated that the thickness of epicarp related to ovate, globose, spheroid emarginated and rhomboid fruit shapes in Shenisha and Taloba were highly significant ($P \leq 0.05$), whereas, the thinnest ones were found to be oblong pointed shape in Elgerri.

Within North Kordofan state, the fruits weight were significantly higher ($P \leq 0.05$) from ellipsoid in Khortaga, globose in Elkhuei, spheroid emarginated in Elkhuei and ellipsoid pointed in Derrira. Whereas, crescent fruit shape from Derrira was the lowest one in the study area (Table 3). In the same table the study findings revealed that the obovate fruit shape from Elkhuei was the thinnest among the other fruit shapes. The study results also explained that the pulp weight was highly significant from KorTagat and Elkhuei. While obovate and oblong pointed fruit shapes from Derrira and Elkhuei were significantly low.

With the comparison of the two states (BN and NK), the study findings revealed that spheroid emarginated fruit shape from Toloba was highly significant in relation to fruit weight, fruit pulp and epicarp thickness, while obovate and oblong pointed fruit shapes from Derrira and Elgarri, respectively, were significantly low in relation to fruit weight, fruit pulp and epicarp thickness (Table 3). In Blue Nile, the highest mean pulp weight (70.18 g) was measured in Taloba location from spheroid emarginated fruits shape. While in North Kordofan the highest mean (39.97g) was linked to ellipsoid fruits shape from KorTaggat location (Tab. 3). The high pulp mean of spheroid emarginated and ellipsoid fruits suggests that fruit shape could be a verifiable tool in selecting for trees with high pulp weight under field conditions in Sudan. In Mali, mean pulp weight reached 77 g in Katon, while in Benin the highest mean value observed was only 54 g in the Southern part (Assogbadjo et al., 2005). While in Blue Nile state the mean total fruit pulp was found to be 30.8g, whereas in North Kordofan reached 24.54 g (Tab. 3).

Fruits from the Blue Nile (wetter areas) were larger and had more pulp than fruits from the North Kordofan (drier area). Assuming that fruit characteristics are under relatively environmental and strong genetic control, however, more areas where baobab is found should be sampled to identify location with useful fruit characteristics for cultivar development. Population characteristics give an indication of overall baobab population properties, these values give information about the properties of individual trees, population contain different morphotype differing in fruits leaves bark color, this agreed with Gebauer et al. (2002) who reported the existence of different ecotypes with different fruits in terms of size, shape and sweetness. The very pronounced tree-to-tree variation in fruit characteristics within each population was clear.

Table 3. Fruit characters' variation within and between studied states

Fruit shape	States	Locations	Fruit weight (g)	Epicarp thickness (mm)	Pulp weight (g)
Ellipsoid	BN	Taloba	217.97 ± 86.48 ^{ab}	5.03 ± 0.56 ^d	26.55 ± 12.34 ^b
		Elgerri	192.17 ± 28.18 ^{bc}	5.73 ± 1.08 ^c	29.67 ± 5.58 ^b
		AbuGudaf	286.6 ± 42.57 ^{ab}	4.33 ± 0.49 ^{fg}	28.72 ± 7.43 ^b
		Agadi	136.45 ± 10.26 ^{bc}	5.35 ± 0.08 ^{cd}	20.65 ± 5.05 ^c
	NK	Elkhuwei	154.89 ± 62.86 ^{cd}	4.58 ± 0.63 ^f	25.31 ± 7.37 ^b
		WadBanda	118 ± 43.07 ^e	5.09 ± 0.41 ^d	27.05 ± 7.30 ^b
		KorTaggat	226.42 ± 9.34 ^{ab}	4.30 ± 0.32 ^{fg}	39.97 ± 1.83 ^{ab}
		Derrira	90.38 ± 30.69 ^{de}	5.09 ± 0.41 ^e	17.82 ± 5.58 ^{de}
High Spheroid	BN	Saata	158.04 ± 55.56 ^{cd}	4.35 ± 0.47 ^{fg}	22.50 ± 7.25 ^c
		Agadi	290.70 ± 28.87 ^{ab}	5.33 ± 0.39 ^{cd}	27.30 ± 4.21 ^b
		Shenisha	237.30 ± 67.4 ^{ab}	4.91 ± 1.16 ^{de}	40.58 ± 3.72 ^{ab}
	NK	Elgerri	115.24 ± 64.92 ^{de}	4.74 ± 1.32 ^e	21.34 ± 9.26 ^c
		Elkhuwei	86.80 ± 7.41 ^f	4.01 ± 0.29 ^{hi}	15.95 ± 2.86 ^e
		KorTaggat	144.41 ± 81.09 ^{bc}	4.07 ± 0.59 ^{hi}	23.16 ± 8.74 ^{bc}
Ovate	BN	Derrira	155.62 ± 27.27 ^{cd}	5.46 ± 0.28 ^{cd}	20.25 ± 2.64 ^{cd}
		Saata	187.68 ± 14.51 ^{bc}	4.90 ± 0.39 ^{de}	23.52 ± 3.94 ^{bc}
		Agadi	271.23 ± 34.23 ^{ab}	5.83 ± 0.22 ^{bc}	29.98 ± 4.82 ^b
	NK	Shenisha	156.75 ± 42.37 ^{cd}	6.61 ± 0.40 ^a	36.55 ± 8.81 ^{ab}
		Elgerri	197.61 ± 53.39 ^{bc}	4.20 ± 0.83 ^{gh}	35.44 ± 12.23 ^{ab}
		Agadi	270.48 ± 28.72 ^{ab}	5.55 ± 0.34 ^{cd}	26.88 ± 1.47 ^b
Obovate	BN	WadBanda	105.27 ± 30.27 ^e	4.38 ± 1.08 ^{fg}	19.83 ± 8.83 ^{cd}
		KorTaggat	205.84 ± 98.38 ^{cd}	5.24 ± 0.77 ^{cd}	28.09 ± 9.67 ^b
		Elkhuwei	74.16 ± 11.03 ^{fg}	3.38 ± 1.08 ^j	11.90 ± 5.94 ^{fg}
	NK	Agadi	112.56 ± 24.03 ^{de}	5.11 ± 0.40 ^d	18.06 ± 3.49 ^{de}
		Elgerri	110.05 ± 28.93 ^{de}	6 ± 0.32 ^b	18.58 ± 4.25 ^d
		KorTaggat	159.14 ± 73.53 ^{cd}	3.91 ± 0.38 ^{ij}	36.40 ± 12.53 ^{ab}
Oblong Pointed	BN	Derrira	40.47 ± 6.78 ^{gh}	3.31 ± 0.17 ^{dj}	6.40 ± 2.07 ^h
		Elkhuwei	195 ± 44.55 ^{bc}	5.02 ± 0.35 ^d	33.83 ± 7.74 ^b
		Taloba	236.68 ± 59.65 ^{ab}	5.13 ± 0.52 ^d	32.83 ± 8.25 ^b
	NK	Elgerri	210.95 ± 26.82 ^b	3.24 ± 0.19 ^{kj}	34.85 ± 8.57 ^{ab}
		Agadi	232.28 ± 59.65 ^{ab}	4.03 ± 0.38 ^{hi}	22.93 ± 6.86 ^c
		AbuGudaf	206.37 ± 25.39 ^b	3.30 ± 0.24 ^j	25.23 ± 1.93 ^b
Fusiform	BN	Shenisha	220.00 ± 31.67 ^{ab}	5.13 ± 0.44 ^d	41.81 ± 6.14 ^{ab}
		Elkhuwei	70.00 ± 22.14 ^{fg}	6.07 ± 0.43 ^b	6.92 ± 3.09 ^g
		Elgerri	196.11 ± 36.38 ^{bc}	4.61 ± 0.43 ^{ef}	26.48 ± 10.83 ^b
	NK	AbuGudaf	147.17 ± 21.68 ^{cd}	4.17 ± 0.64 ^h	20.85 ± 3.96 ^c
		Taloba	219.13 ± 40.5 ^{ab}	6.27 ± 0.55 ^{ab}	34.37 ± 7.34 ^b
		Elkhuwei	147.13 ± 23.11 ^{cd}	5.42 ± 0.31 ^{cd}	22.1 ± 3.45 ^c
Globose	BN	Elkhuwei	318.09 ± 105.5 ^{ab}	6.84 ± 0.87 ^a	50.35 ± 18.81 ^{ab}
		AbuGudaf	161.92 ± 85.4 ^{cd}	4.52 ± 0.34 ^{de}	24.91 ± 12.53 ^b
	NK	Elkhuwei	311.6 ± 55.6 ^{ab}	7.31 ± 1.03 ^a	35.5 ± 7.09 ^{ab}
		KorTaggat	62.80 ± 16.81 ^g	3.48 ± 0.22 ^{ij}	19.77 ± 5.82 ^{cd}
Spheroid	BN	Taloba	407 ± 35.17 ^a	7.05 ± 0.25 ^a	70.18 ± 6.23 ^a
Emarginate	NK	Elkhuwei	212.17 ± 49.46 ^{ab}	5.05 ± 0.22 ^d	32.95 ± 7.88 ^b
Clavate	NK	Elkhuwei	187.47 ± 25.99 ^{bc}	5.21 ± 0.23 ^c	31.50 ± 6.34 ^b
Rhomboid	BN	Shenisha	232.8 ± 29.69 ^{ab}	7.12 ± 0.28 ^a	37.55 ± 11.42 ^{ab}
Ellipsoid pointed	NK	Derrira	278.4 ± 77.48 ^{ab}	4.32 ± 0.40 ^{fg}	21.21 ± 5.08 ^c
	BN	Taloba	173.16 ± 54.53 ^c	5.01 ± 0.56 ^d	34.68 ± 4.6 ^{ab}
Crescent Shape	NK	Saata	118.42 ± 31.03 ^d	5.80 ± 0.69 ^c	14.52 ± 3.26 ^{ef}
		Derrira	59.28 ± 11.64 ^g	5.36 ± 0.32 ^c	13.68 ± 4.58 ^f

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$

Presently, pulp weight has important economic value (Gruenwald and Galiza, 2005). However the current results showed that selection of pulp weight according to fruit weight may end up with good luck, because some fruits with high fruit weight have significantly different fruit pulp than relatively bigger fruits as shown by different degree of trees within locations (Tab. 3), this disagree with De Smedt et al. (2011) who reported that the shell was the heaviest part of the fruit (overall mean: 47% of total fruit weight), followed by the seeds (overall mean: 33% of total fruit weight), so the selection of weight according to fruit weight may end up with a big error.

There were differences in climatic factors which may be linked to differences in fruit and leaves characters related parameters observed, as the mean weight of fruits pulp (30.8 ± 14.09 g) in Blue Nile state having higher rainfall was greater than those from North Kordofan state having low rainfall (24.54 ± 10.47 g). Moreover, [Katsvanga et al. \(2007\)](#) reported that weight of pulp is influenced by environmental factors largely by the amount of rainfall.

This suggests that selection of superior trees to improve pulp production should be done following several seasons of data collection of pulp production.

Within Blue Nile State, table (4) revealed that ellipsoid (from Abugudaf), ovate (from Taloba and Agadi), globose (from Taloba) and spheroid emarginated (from Taloba) fruit shapes were highly significant in relation to seed weight. Whereas, obovate fruit shape from Elgari was found to be the lightest one. The same table indicated that high spheroid (from Agadi and Shenisha), Globose (Taloba) and spheroid emarginated (from Taloba) contained high number of seeds. Whereas, obovate fruit shape (from Elgari) was found to be the lowest one.

Within North Kordofan State, high spheroid and globose (from Elkhwei) were highly significant in relation to seeds. Whereas, obovate (from Derrira) was the lightest one (Table 4). The same table illustrated that ellipsoid pointed (from Derrira) contained a high number of seeds, whereas, crescent fruit shape contained a lower number of seeds.

Table (4) explained that seeds length and seeds width were significantly different ($P \leq 0.05$) in relation to studied fruit shape between locations. Generally, the same table indicated that mean seeds length from Blue Nile State was longer than that from North Kordofan State. Whereas, there were three fruit shapes (ellipsoid, ovate and spheroid emarginated) with wider seeds width (Tab. 4).

In the studied locations, the mean seed weight was significantly higher in Blue Nile state (90.25 ± 25 g) than in North Kordofan state (61.23 ± 23 g). However, [Cuni, \(2010\)](#) argued that in Mali the mean seed weight was (87 ± 7 g), (52 ± 5 g) and (55 ± 10 g) from Bendjiely, Seribougou and Massadji, respectively. In fact seeds from Blue Nile state (wetter sites) were found to be larger than those from North Kordofan state (drier sites), this finding is similar with [Assogbadjo et al. \(2010\)](#) who reported that differences between study sites in one country, with baobab seeds from wetter sites being larger than those from drier sites in Benin. [Parker et al. \(2006\)](#) also reported a positive influence of large seed size and seed reserve on the establishment and early growth of seedlings.

The means of seed size found in the present study results has revealed slight variation in seeds traits (length and width of seed), from Blue Nile (1.18 cm length; 0.67 cm width) and North Kordofan (1.16 cm length, 0.67 cm width) in the different fruit types. These results of seed size in line with those reported by [Owen \(1999\)](#) which indicated that seed size recorded 0.5 cm width, in Niger. [Msanga \(1998\)](#) reported seed dimensions of 1.2 cm in length and 0.8 mm width in Tanzania. The differences in recorded results showed importance of studying variation at regional scale. [Chapman et al. \(2000\)](#) reported that seed characteristics may also strongly depict species adaptability.

The participating factor could be difference in climate especially higher available moisture and short period of moisture stress. [Katsvanga et al. \(2007\)](#) reported that it is not surprising that, due to low water stress, the seed is the lightest and smallest which may imply that trees do not need to reserve much substrate for the seedlings to survive in the environment.

Blue Nile state has a highly hard climate such as heavy rainfall, and long moisture stress. Thus, most seeds are heavy and large than those from North Kordofan due to stored reserves (substrates) perhaps adequate for the seedlings to survive well. These results are similar to the findings on *Pterocarpus angolensis* ([Munthali, 1999](#)) where it was reported that rainfall strongly influenced seed size.

Table 4. Seed characters variation of baobab within studied locations

Fruit Shape	States	Locations	Seeds weight(g)	Number of seeds	Seed length (cm)	Seed width (cm)
Ellipsoid	BN	Taloba	97.24 ± 50.15 ^{ab}	160.08 ± 67.64 ^c	1.29 ± 0.19 ^a	0.71 ± 0.04 ^a
		Elgerri	75.00 ± 16.15 ^{cd}	150 ± 34.08 ^c	1.25 ± 0.07 ^a	0.75 ± 0.04 ^a
		AbuGudaf	141.37 ± 35.28 ^a	221.50 ± 53.59 ^{ab}	1.12 ± 0.16 ^a	0.64 ± 0.06 ^a
		Agadi	53.62 ± 5.3 ^d	114.17 ± 12.86 ^e	1.26 ± 0.28 ^a	0.71 ± 0.05 ^a
	NK	Elkhuwei	65.88 ± 37.33 ^d	144.44 ± 92.68 ^c	1.15 ± 0.07 ^a	0.69 ± 0.05 ^a
		WadBanda	42.49 ± 29.62 ^{de}	98.92 ± 57.61 ^{ef}	1.08 ± 0.07 ^b	0.68 ± 0.04 ^a
		KorTaggat	84.12 ± 3.52 ^c	191.83 ± 6.49 ^b	1.27 ± 0.22 ^a	0.61 ± 0.04 ^c
		Derrira	38.33 ± 14.53 ^e	77.17 ± 29.86 ^f	1.16 ± 0.03 ^a	0.73 ± 0.04 ^a
High Spheroid	NK	Saata	74.66 ± 36.56 ^{cd}	154.72 ± 74.28 ^c	1.15 ± 0.07 ^a	0.68 ± 0.05 ^a
		Elkhuwei	144.57 ± 17.38 ^a	87.33 ± 8.16 ^f	1.06 ± 0.03 ^{cd}	0.65 ± 0.06 ^a
		KorTaggat	104.47 ± 33.57 ^{ab}	97.49 ± 26.25 ^{ef}	1.16 ± 0.04 ^a	0.67 ± 0.08 ^a
		Derrira	44.63 ± 30.52 ^d	119.33 ± 25.19 ^e	1.27 ± 0.05 ^a	0.74 ± 0.03 ^a
	BN	Saata	33.60 ± 3.04 ^{ef}	161.67 ± 31.33 ^c	1.12 ± 0.06 ^a	0.62 ± 0.02 ^b
		Agadi	43.36 ± 22.23 ^{de}	323.33 ± 48.85 ^a	1.04 ± 0.04 ^d	0.64 ± 0.05 ^a
		Shenisha	65.75 ± 14.31 ^d	281.75 ± 69.35 ^a	1.08 ± 0.06 ^{bc}	0.65 ± 0.04 ^a
		Elgerri	87.08 ± 12.37 ^{bc}	112.83 ± 84 ^e	1.07 ± 0.04 ^{bc}	0.72 ± 0.06 ^a
Ovate	BN	Taloba	141.48 ± 18.79 ^a	267.5 ± 28.7 ^{ab}	1.31 ± 0.21 ^a	0.73 ± 0.04 ^a
		Shenisha	42.38 ± 13.1 ^{de}	124.92 ± 21.87 ^{df}	1.09 ± 0.06 ^{ab}	0.66 ± 0.05 ^a
		Elgerri	91.05 ± 39.63 ^{ab}	193.44 ± 97.38 ^b	1.15 ± 0.08 ^a	0.60 ± 0.13 ^a
		Agadi	143.87 ± 21.46 ^a	263.17 ± 24.77 ^{ab}	1.31 ± 0.21 ^a	0.73 ± 0.04 ^a
	NK	WadBanda	30.81 ± 8.93 ^f	79.53 ± 24.07 ^f	1.18 ± 0.14 ^a	0.59 ± 0.09 ^{cd}
		KorTaggat	81.16 ± 55.53 ^c	176 ± 111.31 ^{bc}	1.09 ± 0.06 ^{ab}	0.67 ± 0.05 ^a
		Elkhuwei	25.08 ± 8.45 ^g	60.62 ± 25.45 ^{gf}	1.28 ± 0.14 ^a	0.52 ± 0.09 ^d
		Agadi	28.49 ± 9.2 ^f	56.75 ± 20.19 ^{gf}	1.15 ± 0.07 ^a	0.67 ± 0.06 ^a
Obovate	BN	Elgerri	26.38 ± 9.93 ^{fg}	55.67 ± 24.15 ^{gf}	1.21 ± 0.05 ^a	0.72 ± 0.01 ^a
		KorTaggat	59.61 ± 28.11 ^d	140.83 ± 55.01 ^{cd}	1.09 ± 0.06 ^a	0.68 ± 0.04 ^a
	NK	Derrira	14.88 ± 3.24 ⁱ	33.67 ± 7.81 ^g	1.09 ± 0.04 ^a	0.69 ± 0.03 ^a
		Elkhuwei	76.65 ± 17.6 ^{cd}	158.01 ± 60.60 ^c	1.03 ± 0.27 ^{de}	0.69 ± 0.08 ^a
		Agadi	100.5 ± 47.13 ^{ab}	181.33 ± 104 ^b	1.22 ± 0.06 ^a	0.75 ± 0.04 ^a
Oblong Pointed	BN	Taloba	100.5 ± 47.13 ^{ab}	181.33 ± 104 ^b	1.22 ± 0.06 ^a	0.75 ± 0.04 ^a
		Elgerri	81.75 ± 31.29 ^c	214.50 ± 70.55 ^{ab}	1.09 ± 0.09 ^c	0.62 ± 0.05 ^{bc}
		Agadi	125.31 ± 44.1 ^{ab}	248.78 ± 84.73 ^{ab}	1.12 ± 0.06 ^c	0.67 ± 0.07 ^a
	NK	AbuGudaf	85.72 ± 34.81 ^{bc}	226.83 ± 28.62 ^{ab}	1.22 ± 0.04 ^a	0.63 ± 0.04 ^{ab}
		Shenisha	55.58 ± 6.99 ^d	111.83 ± 15.97 ^e	1.32 ± 0.09 ^a	0.63 ± 0.02 ^{ab}
		Elkhuwei	22.42 ± 7.84 ^{gh}	56.5 ± 19.89 ^{gf}	1.07 ± 0.04 ^c	0.64 ± 0.03 ^a
Fusiform	BN	Elgerri	92.42 ± 20.73 ^{ab}	246.92 ± 48.65 ^{ab}	1.09 ± 0.06 ^b	0.69 ± 0.05 ^a
		AbuGudaf	64.11 ± 10.6 ^d	159 ± 28.08 ^c	1.08 ± 0.16 ^b	0.60 ± 0.07 ^a
		Taloba	71.57 ± 13.24 ^{cd}	138.17 ± 33.8 ^d	1.22 ± 0.05 ^a	0.68 ± 0.02 ^a
	NK	Elkhuwei	56.17 ± 11.40 ^d	108.33 ± 22.39 ^e	1.30 ± 0.05 ^a	0.69 ± 0.03 ^a
Globose	BN	Taloba	119.52 ± 39.37 ^a	297.33 ± 104 ^a	1.16 ± 0.13 ^a	0.71 ± 0.07 ^a
		AbuGudaf	60.3 ± 30.6 ^d	155.83 ± 15.97 ^c	1.07 ± 0.16 ^{bc}	0.60 ± 0.07 ^c
	NK	Elkhuwei	138.33 ± 31.39 ^a	251.33 ± 104 ^{ab}	1.26 ± 0.04 ^a	0.75 ± 0.04 ^a
		KorTaggat	24.27 ± 6.62 ^g	81.5 ± 19.89 ^f	1.25 ± 0.04 ^a	0.74 ± 0.05 ^a
Spheroid Emarginate	BN	Taloba	187.7 ± 23.95 ^a	382 ± 60.44 ^a	1.16 ± 0.02 ^a	0.75 ± 0.03 ^a
	NK	Elkhuwei	82.96 ± 19.17 ^c	161.02 ± 80.64 ^c	0.95 ± 0.78 ^g	0.64 ± 0.07 ^a
Clavate	NK	Elkhuwei	81.16 ± 17.23 ^c	213.6 ± 82.29 ^{ab}	1.03 ± 0.05 ^d	0.63 ± 0.03 ^a
Rhomboid	BN	Shenisha	88.0 ± 18.16 ^b	148.6 ± 23.22 ^c	1.24 ± 0.08 ^a	0.67 ± 0.04 ^a
Ellipsoid pointed	BN	Taloba	125.04 ± 41.41 ^{ab}	147.57 ± 27.08 ^c	1.25 ± 0.06 ^a	0.63 ± 0.02 ^a
	NK	Derrira	75.35 ± 9.77 ^{cd}	295.33 ± 94.29 ^a	1.10 ± 0.06 ^a	0.67 ± 0.05 ^a
Crescent Shape		Derrira	47.33 ± 11.56 ^d	33.5 ± 9.09 ^g	1.24 ± 0.08 ^a	0.67 ± 0.19 ^a
	NK	Saata	16.92 ± 4.86 ^h	130.27 ± 32.8 ^d	1.02 ± 0.03 ^e	0.66 ± 0.03 ^a

Means followed by the same letter within a column are not significantly different at $P \leq 0.05$

Correlations between pulp weight and other fruit characteristics

There were significant correlations between fruits pulp and the fruit characteristics (Tab. 5a and Tab. 5b). For both states, associations between pulp weight and the indicated fruit characteristics with exception of fruit ratio (length over width), were detected to be insignificant. The same tables indicated that pulp weight was significantly associated with the mean fruit weight, fruit dimensions (length and width) and number of seeds. The study results also revealed that fruit characteristics were found to be negatively correlated with pulp weight of spheroid emarginated, clavate, rhomboid, ellipsoid pointed and crescent fruit shapes. Generally speaking, the

study findings explained that fruits pulp was significantly correlated with fruit studied characteristics (Tab. 5a; 5b).

4. Conclusion

A high phenotypic variability in fruit characteristics was found in the two studied locations of baobabs, namely Blue Nile and North Kordofan States, Sudan, indicating valuable considerable opportunities for selection of trees with improved productivity and great potential for domestication, which needs to be more considered. However the results from this study offers data on the morphological variation of baobab fruits across Blue Nile and North Kordofan State, more research is needed in order to paint a complete representation of the baobab populations in South of Blue Nile and Kordofan, Sudan.

The choice of trees with better fruit characteristics this information could increase the productivity and provide an incentive for farmers, to plant baobab trees in their individual farming systems, leading to socio-economic and environmental benefits, therefore enhancement of Sudan rural livelihoods.

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Table 5a. Coefficients of correlation between pulp weight and fruit characteristics (weight, length, width, fruit ratio, seed number, epicarp thickness and seeds weight)

Fruit Pulp										
Fruit shapes Characters	Ellipsoid		High Spheroid		Ovate		Obovate		Oblong	
	BN	NK	BN	NK	BN	NK	BN	NK	BN	NK
Fruits weight	0.76**	0.64**	0.59**	0.27	0.24	0.85**	0.88**	0.89**	0.33*	0.83*
Fruit length	0.53**	0.34**	0.40**	0.71**	0.21	0.68**	0.86**	0.58**	0.48**	0.43
Fruit width	0.53**	0.45**	0.59**	0.31	0.36	0.87**	0.55	0.89**	0.45	0.03
Fruit ratio	0.14	0.00	0.26-	0.48*	-0.08-	0.41-**	0.23	0.68**	0.12	0.43
NO. of Seeds	0.68**	0.54**	0.78**	0.47*	0.01	0.94**	0.71*	0.89**	0.08	-0.03-
Epicarp thickness	0.49-**	0.03	0.34	0.40	0.04	0.59**	0.13	0.17	0.23	0.49
Seeds weight	0.71**	0.51**	0.49**	0.36	0.04	0.86**	0.76**	0.89**	-0.01-	-0.03-

** indicate correlations is significant at the $p < 0.01$ (Spearman's rank order correlation coefficients).

* indicate correlations is significant at the $p < 0.05$ (Spearman's rank order correlation coefficients)

Table 5b. Coefficients of correlation between pulp weight and fruit characteristics (weight, length, width, fruit ratio, number of seeds, epicarp thickness and seeds weight)

Fruit Pulp											
Fruits Type Characters	Fusiform		Globose		Spheroid Emarginate		Clavate	Rhomboid	Ellipsoid Pointed		Crescent shaped
	BN	NK	BN	NK	BN	NK	NK	BN	BN	NK	NK
Fruits weight	0.77**	0.83*	0.91**	0.98**	0.35	1.0**	0.61	0.54	0.09	0.66	0.65*
Fruit length	0.27	0.37	0.79**	0.86**	-0.03-	0.27	0.06	0.06	0.55	-0.14-	0.24
Fruit width	0.55**	0.81*	0.78**	0.94**	0.14	0.71	0.28	0.83*	0.09	0.60	0.53
Fruit ratio	-0.36-	-0.14-	-0.04-	-0.33-	-0.54-	-0.37-	-0.15-	-0.60-	0.20	-0.14-	0.10
NO. of Seeds	0.28	0.49	0.76**	0.96**	0.6	1.0**	0.20	0.66	0.20	0.54	0.53
Epicarp thickness	0.02	0.77	0.65**	0.69*	0.55	-0.26-	0.28-	0.44	0.49	0.26-	-0.02-
Seeds weight	0.43	0.77	0.84**	0.95**	0.37	1.0**	0.20	-0.49-	0.60	0.09	-0.59-

** indicate correlations is significant at the $p < 0.01$ (Spearman's rank order correlation coefficients).

* indicate correlations is significant at the $p < 0.05$ (Spearman's rank order correlation coefficients).

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