MORPHOLOGICAL AND PHYSICOCHEMICAL CHARACTERISTICS OF BAOBAB (A*dansonia digitata* L.) FROM KILIFI AND KITUI COUNTIES IN KENYA

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Morphological and Physicochemical Characteristics of Baobab (A*dansonia digitata* L.) from Kilifi and Kitui Counties in Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

This work is dedicated to my parents, my late beloved father, Mr. John Omondi Ogola; my beloved mother, Patricia Magoha Omondi; my brothers, sisters, friends, relatives and the Franciscan Sisters of St. Joseph, Asumbi who made the foundation of my education. I greatly acknowledge your moral support and prayers that made me prosper in my studies.

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LIST OF ABBREVIATIONS AND ACRONYMS

AFLP	Amplified Fragment Length Polymorphism
APG	Angiosperm Phylogeny Group System
CEC	Commission of the European Communities
EU	European Union
FDA	Food and Drug Administration
FGD	Focus Group Discussion
IFAD	International Fund for Agricultural Development
MDT	Multidisciplinary Team
MVSP	Multivariate Statistical Package
NTF	Non-Timber Forests Products
SAJOREC	Sino-Africa Joint Research Centre
SPSS	Statistical Package for Social Science
TSS	Total Soluble Solids
TTA	Total Titratable Acidity

ABSTRACT

Baobab (*Adansonia digitata* L.) is an indigenous deciduous fruit tree species belonging to the Malvaceae family. It is of great importance in African drylands due to its nutritional and health benefits, as well as its contribution to the income of local communities. In Kenya there is natural regeneration of baobab trees but no domestication implying that the wild trees could diminish through natural death and extinction. Thus, there is need for domestication to conserve the existing trees. The study aimed at contributing to domestication of baobab through evaluation of tree productivity, morphological characterization and physicochemical properties of the pulp of fruits from Kilifi and Kitui Counties in Kenya. Fruit sampling was done between the months of September 2017 and May 2018 since these were the harvesting seasons of fruits in Kilifi and Kitui respectively. Data were collected from a total of 71 fruiting baobab trees; 33 from Kilifi County along Mavueni – Mariakani road and 38 from Kitui along Kitui – Kibwezi road. Baobab fruit yield per tree was evaluated using a handheld counter to find the number of fruits per tree from all the 71 trees. All the fruits in a single tree were counted twice with the help of 'Descriptors for Baobab' and other tools such as Vernier caliper, weighing balance and colour chart. Both quantitative and qualitative data was collected from the 710 fruits that were sampled from the two counties. The physicochemical properties of the baobab pulp from both counties was also assessed using the Association of Official Analytical Chemist method where hand held refractometer was used to determine the total soluble solids (TSS) and total titratable acidity (TTA) was determined through titration using 0.1NaOH. Elite trees were identified and selected in three ways: statistically by using scatter plot with the fruit weight, pulp proportion and pulp sweetness as the main target, Focus Group Discussion and Multidisciplinary Team (MDT) considering fruit weight, pulp weight, seed weight, TSS: TTA ratio (pulp quality) and fruit number per tree (yield). The data were analyzed using SPSS by performing, Chi-square tests, Mann-Whitney U-tests and correlations to detect the differences between the fruits from the two study regions. Mean separation was done using LSD at $P < 0.05$. There was high variation among the 71 baobab trees across the two regions regarding fruit shapes, quantitative variables and fruit tree productivity. The mean productivity in weight of fruits per tree was significantly higher in trees from Kilifi County (91.1 kg/tree) than from Kitui County (35.2 kg/tree; $p<0.001$). In addition to that, mean fruit length and weight were significantly higher among fruits from Kilifi than those from Kitui (24.7 versus 14.7 cm and 402 versus 159 g, respectively; $p<0.001$ for both). Similarly, mean pulp weight was significantly higher in samples from Kilifi County than from Kitui County (67.5 versus 27.2 g; $p<0.001$), while pulp proportion was similar among fruits from two counties (mean 17% of the whole fruit weight), ranging from 13 to 23%. Fruit weight correlated significantly with pulp weight ($r = 0.948$; $p<0.001$), but not with pulp proportion. TSS mean was 11.3° Brix, while the TTA was 7.3%. The large variation in fruit traits might be due to environmental and genetic factors and their interactions. The most frequent fruit shape was ellipsoid (about 60% of all trees), followed by obovate (32%) in Kilifi County and oblong (21%) in Kitui County. Two elite trees with high fruit weight, high pulp proportion, and intermediate or sweet tasting fruit pulp were selected in each of the two research regions. In the light of the results from focus group discussions and the scatter plot demonstration, 15 were also selected as per the (MDT) agreement. The high variability detected between two counties and among trees provided opportunities for the selection of elite trees for domestication. Therefore, 17 elite trees with potential for domestication were selected from each of the two Counties, Kilifi and Kitui. This research will contribute to increased utilization and domestication of this important indigenous fruit tree of Kenya.

CHAPTER ONE

INTRODUCTION

1.1 Back Ground of the Study

The African baobab, *Adansonia digitata* L. is a native deciduous tree of the African savanna which is also known as the “upside down tree”. It belongs to the Malvaceae family and can live for several hundreds of years (Gebauer *et al.* 2002). It is a massive tree that grows to a height of 25 m and a girth of 28 m, its trunk is cylindrical rising to thick tapering branches which resembles the root- system (upside-down tree). Baobab is a multipurpose fruit tree whose pulp is incorporated daily in the diet of rural communities in West Africa to nutritionally enrich their food (Assogbadjo *et al.* 2005). It contributes to rural income through the sale of its products for instance pulp, leaves and bark can be utilized as food, medicine and fibre (Assogbadjo et al. 2005; Assogbadjo *et al.* 2010). Baobab is a source of income to the locals. Its pulp sold in Kenya as ‘mabuyu’ sweets. Over the years, there has been an increase on the sale of baobab pulp which is used in processing mabuyu from 0.07 USD per kg to 1.50 USD per kg. This serves as a source of income to the local communities especially during dry season when no farming takes place (Jäckering *et al.* 2019).

In a recent study, Gebauer and Luedeling, (2013) reported that there are more than 300 products with baobab as part of the ingredients that are already available in Europe. These range from foodstuffs, such as soft drinks, sandwich spreads, cereal bars, sweets and chocolates to pharmaceutical products like after-shave, shampoo and foot spray. The fruit pulp is high in micronutrients such as calcium, vitamin C and iron, while the seeds contain edible oil and the leaves have high protein, provitamin A and iron contents (Chadare *et al.* 2008; Stadlmayr *et al.* 2013).

Recently, baobab fruit pulp was approved as a novel food by the EU (200/575/EC) and GRAS (Notice No. GRN 000273) and is regarded as a ‘superfood’ in Europe and the USA (EC 2008). Therefore, high demand for pulp is expected from the growing international markets, offering further income generation opportunities for African farmers, but at the same time putting the resource base at risk of over-exploitation because baobab fruits and leaves are only harvested from wild trees (Gebauer *et al.* 2016; Schreckenberg *et al.* 2008). Venter and Witkowski, (2011) identified constraints to full use of baobab's economic potential such as limited availability of planting material, lack of knowledge on sustainable resource management techniques, poor fruit processing technologies and the lack of well-organized market chains.

Research in several African countries has shown that there is high variation among individual baobab trees regarding tree shape, bark, leaf, fruit, and seed characteristics (Parkouda *et al.* 2012; Smedt *et al.* 2012). In addition, variation has been reported regarding the taste of leaves and fruit pulp as well as the productivity of baobab (Assogbadjo et al. 2008; Sidibe and Williams, 2002). Variation of productivity and fruit traits is attributed to various factors, both genetic and environmental (Assogbadjo *et al.* 2005; Venter and Witkowski, 2011). Variation in tree growth, yield and other physiological and ecological traits is as a result of multiple gene interactions, often affected by the environment. Thus accuracy to select individual trees with rapid growth or high yield for cultivar development is a challenge in the first phase of domestication.

1.2 Problem Statement

The existence of non-domesticated trees in the wild are always threatened by genetic erosion despite the fact that they may possess drought, pest and disease tolerance traits. Baobab is a multipurpose fruit tree with very high nutritional and economical value. It is a plant that has been neglected by majority of people in Kenya due to ignorance on the nutritional and economic values of the tree and its products. It is one of the trees that has been left in the wild undomesticated. This points to the fact that we could soon lose the naturally regenerated trees through natural death and extinction thus there is need for its domestication. Baobab has high potential for home consumption and income generation for the local communities. In Kenya there are some existing baobab products such as mabuyu sweets being sold countrywide and surprisingly all these fruits are harvested from the wild as there is no cultivation of baobab fruit tree.

Knowledge on the utilization of baobab products is advancing and also demand for baobab fruit pulp is featuring in Europe and America. This will eventually lead to over-utilization.This resource may decrease over time due to lack of regeneration in some locations, cut-down of old trees due to population increase, road expansion, installation of communication lines, human settlements and for cultivation of other crops. The existing young baobab trees are also not nurtured for the future but are removed from the fields. The other risk is also high mortality of the wild trees. Despite all these factors that endanger the already existing trees, demand for pulp may increase at the same time. This may result in over-utilisation of the remaining resources, decreased or unreliable production, and finally loss of genetic resources of this species.

1.3 Justification

Morphological characterization and productivity estimation of baobab trees from Kitui and Kilifi counties is a way forward to utilization and domestication. The study may eventually lead to cultivation of baobab fruit tree ensuring long-term reliable provision of high quantity and quality of fruit pulp. It may also lead to proper utilization of baobab hence improving local diets and livelihoods in marginalized areas in Kenya.
Protection of the wild baobab tree can be achieved through domestication and cultivation of the species which is a source of income to the local community. In West Africa, several studies have been done on baobab tree ecology, morphological, chemical and genetic characterization, utilization and indigenous knowledge, mainly to regenerate the species (Stege *et al.* 2010). Characterization is also an important factor for selecting baobabs with good fruit quality.

Therefore, tree productivity, fruit morphology and physicochemical properties of baobab pulp studied in Kenya will eventually promote the preservation and utilization of baobab fruit tree products. Characterization of the fruits, pulp and yield evaluation that was documented from this research will be a source of reference for the elite trees to be domesticated especially by the local communities where the research took place. With the available data on the fruit yield, an estimation on the pulp harvest can be done to ensure that fruit is available throughout the year.

1.4 Objectives

1.4.1 General Objective

To evaluate the diversity in productivity and quality of baobab fruits in Kilifi and Kitui Counties as a strategy for domestication of baobab in Kenya.

1.4.2 Specific Objectives

1. To evaluate baobab tree productivity and the morphological variation of fruits within the county and between the two counties.
2. To determine the physicochemical variation among baobab fruit pulp within the county and between the two counties.
3. To identify and select elite baobab trees for domestication in Kitui and Kilifi.

1.4.3 Hypotheses

1. There are no significance differences in baobab tree productivity and morphological characteristics of baobab fruits from Kitui and Kilifi Counties.
2. There are no significance differences in the physicochemical characteristics of baobab fruit pulp from Kitui and Kilifi Counties.
3. There are no elite trees selected for domestication in Kitui and Kilifi County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Taxonomy and Distribution of the Baobab Tree in Africa

Sidibeand Williams (2002) states that baobab (*Adansonia digitata* L.) belongs to the family of Malvaceae which has about 250 species distributed in 30 genera, including the genus *Adansonia*, species for the baobabs and a member of the tribe *Adansonieae*, or Bombaceae. Baobab fruit tree is also known as monkey-bread tree (the dry fruit is a source of food for monkeys), cream of tartar tree (due to the acidic taste of the fruits), dead-rat tree (from the appearance of the fruits) and upside-down tree (as the bare branches resemble roots) (Sidibe and Williams, 2002).

Table 2.1: Common names for African baobab fruit tree

Language	Country	Name
English	United States of America and United Kingdom	Baobab, Monkey bread tree, Ethiopian sour gourd, Cream of tartar tree, Senegal calabash (fruit) and Upside-down tree
French	France	Baobab, pain de singe (fruit), arbre aux calebasses, arbre de mille ans and calebassier du Senégal
Portuguese	Portugal	Cabaçevre
Arabic	United Arab Republic	Buhibab, hamao-hamaraya, gangoleis (fruit)
More	Burkina Faso	Trega, twega, toayga
Dogon	Mali	Oro
Dierma	Niger	Konian
Bambara	Mali	Sira
Peulh	Mali	Babbe, boki and olohi
Hausa	Nigeria, Niger	Kouka, kuka
Wolof	Senegal	Goui, gouis, goui, lalo and boui
Amhara	Ethiopia	Bamba
Yao	Malawi	Mlonje
Kamba	Kenya	Mwambo
Swahili	Somalia to Mozambique	Mbuyu, majoni ya mbuyu (Tanzania)
Zulu	South Africa	Isimuhu and umshimulu
Hindi	India	Gorakh-imli and hathi-khatiy

Source:(Sidibe andWilliams, 2002)

Baobab tree is distributed in Africa between 16.5N and 15.0S (Sidibe´ and Williams 2002). This fruit tree is mostly found in drier parts of the African savanna and in West African parklands. It can also be found in the agroforestry systems of dryland Africa. (Boffa, 1999). There has been an introduction of the baobab tree in Oman, India, Madagascar, Yemen and Sri Lanka among other areas (Sidibe´ and Williams 2002). In Kenya baobab is distributed in the eastern part of the country in two belts; one in the inland from the Tanzanian border east of Mt. Kilimanjaro towards the north-east around Kitui town and a second one along the whole coastal region (NRC, 2008).

Baobabs from the eastern slopes of Mt. Kilimanjaro (Tsavo West National Park) to the south Kenyan coast were recently surveyed (Pettigrew *et al.* 2012). As per the surveyed areas, the baobabs of Kenya are geographically distinct from the baobab stands in Sudan, and it is possible that the alluvial clays with rather undrained soil conditions of the White Nile and Bahr el Arab flood plains effectively isolated the baobab populations in Sudan and Kenya (Gebauer *et al.* 2016).

2.2 Morphological Description

Adansonia digitata L. is a massive deciduous tree, up to 20-30 m tall with a diameter up to 2-10m at adult age (Sidibe and Williams, 2002). It has large palmate leaves and showy whitish flowers that open at night and are pollinated by fruit bats and nocturnal moths (Zagga *et al.* 2018). Young trees of baobab have conical trunk while in mature individuals, it may be cylindrical, bottle-shaped, or tapering with branching near the base (Yusha *et al.* 2010). It has an uneven distribution of branches with large, primary branches which are sometimes well distributed along the trunk or limited to the apex. The young branches are tomentose but in rare cases glabrous. The bark is smooth, reddish brown to grey, soft and fibrous. The bark of leaf-bearing branches is normally ashy on the last node.

The tree has a smooth, reddish brown to grey, soft bark and possessing longitudinal fibers (Sidibe and Williams, 2002). It is highly branched with stout branches which are near the trunk and the young branches are often tomentose (Gebauer *et al.*, 2016; Sidibe and Williams, 2002). Due to the sulfur fragrance which is emitted by the flowers, bats are attracted to the tree thus they play the role of pollinators (Fleming *et al.*, 2009; Martin *et al.* 2014). Fruits have length measuring between 10 and 45 cm with different forms (ovoid, spherical, fusiform, and elongated) and a weight varying significantly among individuals and provenances. Fruit weight from Mali and Benin ranged from 165 to 305 g and 204 to 276 g respectively (De Smedt *et al.* 2011; Assogbadjo *et al.* 2005). Completely dry mature endocarp consists of white mealy pulp. The seeds are embedded in the pulp and are dark brown to reddish black with a smooth tegument. *Adansonia digitata* L. produces an extensive lateral root system upto

50 meters from the trunk. Its root tips are often in the form of tubers though the primary roots of old trees are relatively shallow and rarely extend beyond 2 m depth thus, very sensitive to strong winds and can be uprooted by a storm (Sidibe Williams, 2002). It is a long- live species and can survive for 1,200 years and more (Patrut et al. 2007).

Figure 2.1: The photo of a typical African baobab tree (Adansonia digitata L.)

Source: (Chadare**,** 2010)

Variation in fruit characteristics has been noted by the majority of farmers where some distinguish the fruits by their shapes among other variables. In Benin, fruit shapes are used to distinguish the baobab trees, while in Mali, pulp taste is taken into consideration by farmers among other characteristics (Sidibe and Williams, 2002; De Smedt *et al.* 2011). Environment plays a key role in the variation of fruit morphology. There is a significant variation in fruit morphology and productivity from one climatic zone to another (Assogbadjo *et al.* 2005). They also reported that seed and pulp yield was associated with zones having high values of potential evaporation, rainfall, relative humidity, temperature, pH of water, and percentage of fine silt.

Figure 2.2: Diversity in baobab fruit shape from North Kordofan and Blue Nile States in Sudan

2.3 Baobab Tree Ecology and Domestication

Adansonia digitata prefers sandy topsoil overlying a loamy subsoil. It tolerates poorly drained soils with heavy texture, but is absent on deep sand. Seedlings and small trees are vulnerable to fire, but mature trees are fire resistant (Sidibe and Williams, 2002). It is very necessary to cultivate and domesticate baobab trees in order to protect natural stand and also to provide sustainable source of food, income and medicine to the local community. Domestication refers to multiplication of trees with desirable characteristics and also taking advantage of the variations that are found in the wild fruits (Pye-Smith, 2010). Domestication and cultivation will increase the harvest and also ensure reliability and quality supply which are marked as the key factors that will determine long-term viability of a given product targeted for international trade (Chikamai and Tchatat, 2009)

2.4 Effects of agro-ecological conditions on the morphological traits of baobab fruits and physicochemical properties of the pulp.

Baobab phenotypic traits and fruit characteristics seems to be significantly affected by environmental factors since general morphological diversity are completely not correlated to each other (Assogbadjo et al. 2008). Majority of local baobab forms differ in habit, vigor, size, quality of the fruits and foliar vitamin content, depending on the locality of the tree and local people recognizes these differences (Assogbadjo et al. 2006, 2008; Gebauer et al. 2002; Sidibe´ and Williams 2002). Assogbadjo *et al*.(2011), reported on the significant differences that was found in some of the fruit characteristics within –trees, between individuals and also between different climatic zones in Benin.

More variability was detected between baobab trees than within the same trees in the length, width, thickness, length/ width ratio and weight of the capsules, as well as the weight of the pulp and the length of the peduncle, while other traits shown variability within trees than between trees. Ethnobotanical survey of the perceptions and human/cultural meaning of morphological variation, preferences and used forms of the pulp indicated that the local community apply a morphological classification system for baobab trees thus guiding them in the selection and collection of germplasm from trees with combination of traits that are preferred (Assogbadjo *et al*. 2008).

2.5 Socio-Economic Importance of Baobab (*Adansonia Digitata* L.)

Baobab contributes to food security as well as to cash income generation, particularly for the marginalized since many parts can be used as food thus has an important role in contributing to the rural communities' livelihood. Conservation measures and domestication strategies have to be considered for better use of the species which contributes to a better income and livelihood of African farmers who are nurturing the tree in their farmlands (Jama *et al.* 2007). Baobab is considered as very important for its non-timber forest products. The baobab tubers, twigs, fruits, seeds, leaves, and flowers are all used as common ingredients in traditional dishes of rural and urban areas (Sanchez and Assogbadjo, 2010; Sidibe and Williams, 2002). Due to the high demand for leaves as vegetables in various sauces in some areas, the trees are severely pruned and no longer set fruits, thus endangering the regeneration capacity of the stands.

Akinnifesi *et al.* (2008) and Jama *et al.* (2007) reported that baobab tree has been identified as one of the essential edible savannah trees to be conserved, domesticated and valorized in Africa due to its economic relevance at local to international scales.

The baobab fruit pulp obtained novel foods approval in 2008 by the European Union, giving African farmers an opening for a billion-dollar industry (de Boer and Bast, 2018). The tree contributes to food security, nutrition and cash income for the local population, particularly for women and their children in many areas (Schreckenberg *et al.* 2006). A. digitata prevents fevers, dysentery, and bleeding wounds beyond the food (Rahul *et al.* 2015; Kamatou *et al.* 2011).

2.6 Nutritional Composition of Baobab

The fruit pulp is high in micronutrients such as calcium, Vitamin C and iron (table 2 and 3) while the seeds contain edible oil and the leaves have high protein, provitamin A and iron contents (Chadare, 2010; Stadlmayr *et al.* 2013).

Table 2.2: Proximate and Vitamin C composition of baobab fruit pulp per 100 g

Nutrients	Mean ± SD	(min–max)	n
Energy((kcal) kJ)	(327) 1380		
Water (g)	11.0 ± 5.0	(4.7-27.6)	42
Protein (g)	2.5 ± 0.5	(1.1–3.2)	19
Fat (g)	0.5 ± 0.3	(0.2–1.2/[3.7])	19
Carbohydrate (g)	74.9		
Fibre (g)	6.2 ± 1.7	(4.4–8.7/[43.0*])	5
Ash (g)	4.9 ± 0.7	(3.7–6.3)	29
Vitamin C(mg)	273 ± 100	(126–509)	31

Source: (Stadlmayr *et al.* 2013)

Table 2.3: Mineral composition of Baobab (Adansonia digitata L.) fruit pulp per 100g

Nutrients	Mean ± SD	(min–max)	n
Calcium(mg)	275 ± 141	(60–611)	14
Iron(mg)	6.2 ± 3.8	(1.5–13.4	9
Magnesium(mg)	232 ± 133	(90–420)	10
Phosphorus(mg)	51 ± 21	(35–98)	8
Potassium(mg)	1730 ± 510	(1140–2500)	8
Sodium(mg)	14.3 ± 10.2	(5.1–27.9)	4
Zinc(mg)	1.36 ± 0.79	(0.42–2.40)	5
Copper(mg)	0.82 ± 0.47	(0.49–1.6)	5

Source: (Stadlmayr *et al.* 2013)

Baobab is an important source of human nutrition in Africa today (Wickens, 2008). The leaves, seeds and pulp results from chemical analysis showed the availability of proteins, amino acids, iron, vitamins C, A and E in abundant for daily up take (Codjia *et al.* 2001; Sidibe and Williams, 2002). High antioxidant activity is found in baobab pulp and leaves as compared to other fruits (Vertuani *et al.* 2002; Besco *et al.* 2007) and therefore they are termed as functional foods with positive impact on health.

Table 2.4: Antioxidant capacity of baobab pulp compared to other fruits

Integral antioxidant capacity (IAC) corresponding to the sum of the corresponding water and lipid soluble antioxidants capacity	
Products	IAC (mmol Trolox equivalent/g fresh weight, uncooked portion
Baobab fruit pulp	11.1
Baobab dry leaves	8.7
Baobab fruit glycolic extract	1.02
Baobab leaves glycolic extract	4.41
Kiwi fruit pulp	0.34
Orange fresh pulp	0.10
Strawberry fresh pulp	0.91
Apple fresh pulp	0.16

Source: (Vertuani *et al.* 2002)

Oxidation of human cell can be prevented by consuming antioxidant –rich foods. Baobab pulp and leaves in table 2-4 above indicates high antioxidant capacity in baobab as compared to other fruits (Vertuani *et al.* 2002). Baobab pulp can be used to enrich other foods such as yoghurt. This enhances the nutritional content of yoghurt with vitamins such as vitamin C, minerals, riboflavin, niacin, pectin (Besco *et al.* 2007).

2.7 Baobab fruit yield and utilization

In Kibwezi, Kenya 25 selected trees were used for fruit counts and the yields ranged from 12 to 2675 fruits per tree with an average of 360 fruits per tree (Muchiri and Chikamai, 2003). Yield assessment of the 96 trees that was done along a road transect from Kibwezi to Mombasa also included some interviews to the farmers. About 64 farm owners that were interviewed and they reported that the average number of fruits per tree was 707 with ranges of 140 to1800 fruits (Gebauer *et al.*, 2016). There are numerous challenges that may lead to inaccurate data on production of baobab such as baboons and early harvesting of mature fruits before the yield assessment takes place (Gebauer *et al.* 2016). In Sudan, six mature trees with fruits were counted resulting to an average of 381 fruits per tree with fruits per tree ranging from 145 to 595 fruits per tree (Gebauer *et al.* 2016).

Baobab fruit pulp can be consumed raw, dissolved in water or milk or added to porridge Maundu *et al.* 1999). Ruffo *et al.* (2002) explained that in Kenya especially in Nairobi and Taita-Taveta, the pulp is diluted in water sweetened and then is frozen in small polythene packets. The Kambas of eastern Kenya use the pulp in production of local beer (Orwa *et al.* 2009), while in Coastal region dried baobab pulp with seeds embedded are made to ‘mabuyu’ sweets by coating them with food colour and sugar. These are in turn sold in supermarkets and Kiosks (Bosch *et al.* 2004). Ndabikunze *et al.* (2011) reported that baobab seeds can be roasted dried or eaten fresh and the oil found inside the seeds can be used as cosmetic or for cooking.

The fruit shells which are woody can be used in various ways as vessels, dishes and also in the production of curio items and souvenirs such as jewel cases, mouse traps, lamp shades and drums (Gebauer *et al.* 2016). In Western Sudan, the young tender leaves are mixed with peanuts to be eaten as salads (Bella *et al.* 2002). Leaves are utilized as vegetables in certain parts of Kenya (Muthoni and Nyamongo, 2010). Baobab leaves are prepared like spinach or mixed with cassava leaves and then boiled (Maundu *et al.* 1999). Lack of baobab domestication in Kenya might lead to loss of potential revenue and also loss of genetic resources of this resourceful tree to the local communities.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was performed in the counties of Kilifi which is located in coastal Kenya (between latitudes S2˚18' and S3˚59', and longitudes, E39˚6' and E40˚14') and Kitui found in the lower eastern part of Kenya, between latitude 0˚3'S and 3˚3'S and longitudes 37˚33'E and E38˚58' E. (Figure 3.1). Temperatures in Kilifi range from 21°C to 32°C during the hottest and coldest months respectively with rains between 900 mm and 1000 mm annually. The county has two rainy seasons; April to June (long rains) and October to December (short rains). In Kitui County, the rains are between 500 mm and 1050 mm annually with an average rainfall of 900 mm per year.

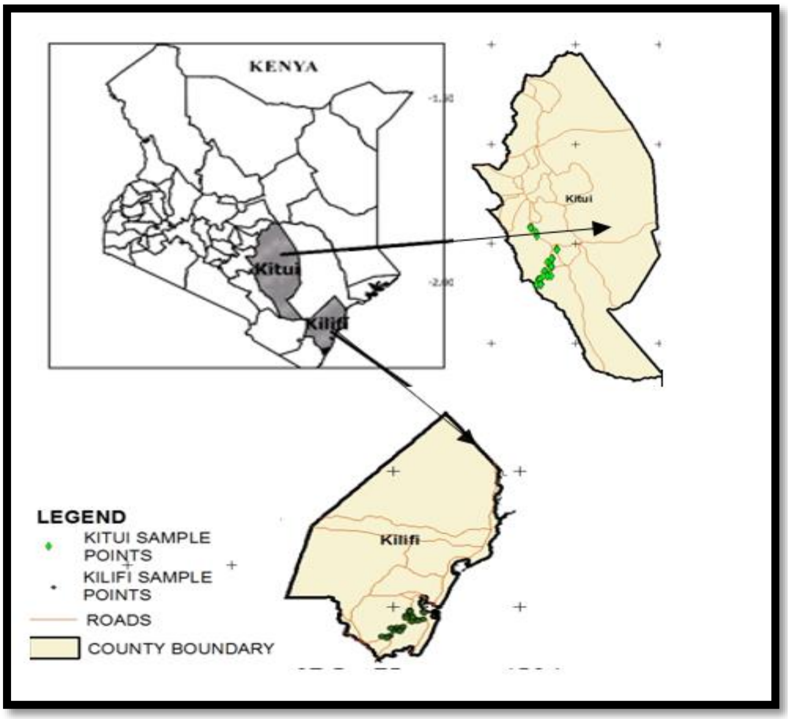


Figure 3.1: Geographical locations of the study counties Kitui and Kilifi

with the 71 baobab trees sampled

(Source of map: Eddah Mumo, JKUAT, Kenya).

3.1.1 Field Sampling Design

These counties were selected due to the known occurrence of baobab and its use by local communities (Gebauer *et al.* 2016). Two transects were chosen along C-level roads for better accessibility, one from Mavueni to Mariakani in Kilifi county and the other one from Kitui to Kibwezi in Kitui county. Eleven quadrats of 0.5 x 3 km each were randomly selected within transect in Kilifi County and 13 in Kitui County. All baobab trees within the quadrat were documented and three trees with mature fruits were randomly selected per quadrat if available.

In three quadrats, less than three trees with fruits were found, and in three other quadrants, no tree with fruits was found. In such cases, an equivalent number of trees with fruits close to the respective quadrat were sampled. However, for the two quadrats with too few fruiting trees in Kitui area, no equivalent trees were found nearby. Therefore, four trees instead of three were sampled in two of the other quadrants. In total, 71 baobab trees were sampled, 33 in Kilifi County and 38 in Kitui County. The coordinates of all the selected baobab trees were taken using a hand held GPS (Garmin, model GPSMAP64s) (Table 3.1).

Table 3.1: Sample ID's and the GPs co-ordinates baobab fruit trees from Kilifi

	Tree ID	Lat.	Long.	Altitude(m)
1	KFQ10T1	3.6782	39.6968	278
2	KFQ10T2	3.8210	39.6041	195
3	KFQ10T3	3.7628	39.6230	246
4	KFQ11T1	3.6810	39.7256	200
5	KFQ11T2	3.7763	39.6671	212
6	KFQ11T3	3.6524	39.7822	47
7	KFQ1T1	3.7084	39.7544	64
8	KFQ1T2	3.7019	39.7784	44
9	KFQ1T3	3.6476	39.7830	37
10	KFQ2T1	3.6873	39.7296	181
11	KFQ2T2	3.7660	39.6203	241
12	KFQ2T3	3.6605	39.7823	62
13	KFQ3T1	3.7075	39.7354	128
14	KFQ3T2	3.7789	39.6657	217
15	KFQ3T3	3.7192	39.7261	161
16	KFQ4T1	3.6464	39.7133	114
17	KFQ4T2	3.6491	39.7135	120
18	KFQ4T3	3.8306	39.6009	204
19	KFQ5T1	3.7159	39.7534	51
20	KFQ5T2	3.7607	39.6495	238
21	KFQ5T3	3.7772	39.6346	280
22	KFQ6T1	3.7023	39.7382	125
23	KFQ6T2	3.7163	39.7556	51
24	KFQ6T3	3.7744	39.6687	221
25	KFQ7T1	3.7632	39.6206	244
26	KFQ7T2	3.6956	39.6961	278
27	KFQ7T3	3.8285	39.6004	214
28	KFQ8T1	3.8074	39.5281	217
29	KFQ8T2	3.6808	39.6951	149
30	KFQ8T3	3.7849	39.6666	208
31	KFQ9T1	3.8120	39.6173	183
32	KFQ9T2	3.6537	39.7120	127
33	KFQ9T3	3.8207	39.5747	221

Table 3.2: Sample ID's and the GPs co-ordinates trees from Kitui County

	Tree ID	Lat.	Long.	Altitude(m)
1	KTQ10T1	2.1374	38.0976	768
2	KTQ10T2	2.1377	38.0957	771
3	KTQ10T3	2.1300	38.1083	763
4	KTQ11T1	2.1803	38.1120	786
5	KTQ11T2	2.1802	38.1148	784
6	KTQ11T3	2.1775	38.1173	766
7	KTQ12T1	2.2221	38.0404	774
8	KTQ12T2	2.2201	38.0258	781
9	KTQ12T3	2.2219	38.0437	766
10	KTQ13T1	2.2602	38.0514	755
11	KTQ13T2	2.2602	38.0508	754
12	KTQ13T3	2.2614	38.0634	760
13	KTQ14T1	2.0597	38.1362	717
14	KTQ14T2	2.0586	38.1373	714
15	KTQ14T3	2.0605	38.1386	707
16	KTQ14T4	2.0621	38.1544	673
17	KTQ15T1	1.7000	38.0817	858
18	KTQ16T1	1.6613	38.0433	911
19	KTQ16T2	1.6611	38.0410	904
20	KTQ16T3	1.6590	38.0377	892
21	KTQ2T1	1.8591	38.2318	898
22	KTQ2T2	1.8590	38.2407	890
23	KTQ2T3	1.8596	38.2365	895
24	KTQ4T1	1.9409	38.1979	842
25	KTQ4T2	1.9408	38.1996	837
26	KTQ4T3	1.9396	38.2061	819
27	KTQ5T1	1.9775	38.1907	773
28	KTQ5T2	1.9793	38.1673	749
29	KTQ5T3	1.9785	38.1656	741
30	KTQ7T1	1.7381	38.0847	856
31	KTQ7T2	1.7377	38.0849	860
32	KTQ8T1	2.0165	38.2006	750
33	KTQ8T2	2.0146	38.1898	764
34	KTQ8T3	2.0181	38.1941	774
35	KTQ9T1	2.1001	38.1678	690
36	KTQ9T2	2.0996	38.1640	685
37	KTQ9T3	2.1014	38.1650	680
38	KTQ9T4	2.0985	38.1924	691

Note: Accession numbers are coded according to the County (KT- Kitui, KF- Kilifi) of collection

3.2 Data Collection

3.2.1 Tree productivity assessment and fruit sampling and characterization

Tree productivity was determined by manual counting of all the fruits hanging on the tree using a manual counter. The fruits were counted twice where both the first and second counts were clearly put in records for further analysis to find the fruit yield per tree. Fruit yield per tree was calculated by multiplying the total mean weight of the ten fruits which were harvested on the same tree by the mean of the two counts that was done per tree. This procedure was carried out in all the 71 fruit trees that were sampled in the study regions. Thereafter, fifteen mature and undamaged fruits were randomly picked per tree covering the 4 sectors of whole crown and focusing only on typical, representative fruits of the tree. The collected fruits were labelled, stored in manila bags and transported to the laboratory in Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya, for assessment of morphological characteristics. Morphological characterization of baobab fruits was carried out using the descriptors for Baobab (Kehlenbeck K. 2015). Out of the fifteen harvested fruits ten fruits per tree

were selected for the morphological characterization.

Figure 3.2: The selected ten fruits of a tree from Kitui (KTQ9T3) used in

the laboratory for qualitative and quantitative characterization

3.2.2 Qualitative data

Data for qualitative traits was sourced as per baobab descriptor (Kehlenbeck K. *et al.* 2015), for all 71 trees that were sampled for analysis. This amounted to 29 qualitative traits (e.g. fruit shape, apex shape, stalk insertion, neck prominence, beak type, the colour of fruit pulp) (Table 3.2).

Table 3.3: Qualitative characteristics as described in baobab descriptor

Trait		Description		
Fruit Shape	1Oblong	2 Oblong compressed	3 Ellipsoid	4 Globose
			8 Ovate	9 Obovate
Fruit Apex Shape	1Acute	2 Obtuse	3 Round	4 Depressed
Fruit pedicel insertion	1 Vertical	2 Slightly oblique	3 Oblique	
Fruit neck prominence	0Absent	1 Slightly prominent	2 Prominent	3 Very prominent
Fruit beak type	0Absent	1 Perceptible	2 Pointed	3 Prominent
Fruit shell hairiness	0 Not hairy	1 Partly hairy	2 Evenly hairy	
Colour of hairs on the fruit skin	1 Green	2 Grey	3 Yellowish	
Fruit ground colour	1 Black	2 Brown	3 Green	4 Gray
Fruit cross section outline	1 Not contoured	2 Shallowly contoured	3 Deeply contoured	
Fruit shell surface texture	1 Smooth	2 Wrinkled		
Fruit shell hardness to crack	1 Easily cracked	2 Slightly hard	3 Hard	4 Very hard
Fibre colour	1 White	2 Cream	3 Orange	4 Brown
Adherence of fibre to fruit shell	3 Weak	5 Intermediate	7 Strong	
Texture of fibres in fruit	1 Soft	2 Intermediate	3 Coarse	
Adherence of pulpy seed to fibre	3 Weak	5 Intermediate	7 Strong	
Pulp colour of fresh fruit	1 White	2 Cream	3 Light orange	4 Dark orange
Adherence of fruit pulp to seed	0 Absent	3 Weak	5 Intermediate	7 Firm / Strong
Pulp texture of ripe fruit	3 Soft	5 Intermediate	Firm	
Pulp sweetness	0 Absent	3 Slightly sweet	5 Sweet	7 Very sweet
Pulp sourness	0 Absent	3 Slightly sour	5 Sour	7 Very sour
Pulp bitterness	0 Absent	3 Slightly bitter	5 Bitter	7 Very bitter
Pulp aroma / scent	0 Absent	1 Mild	2 Perceptible	3 Strong
Seed coat colour	1 Dark brown	2 Reddish black		
Seed shape	1 Oblong	2 Reniform (kidney-shaped)	3 Very reniform	
Seed testa hardness	3 Soft	5 Intermediate	7 Hard	9 Very hard
Colour of endosperm	1 White	2 Grey		

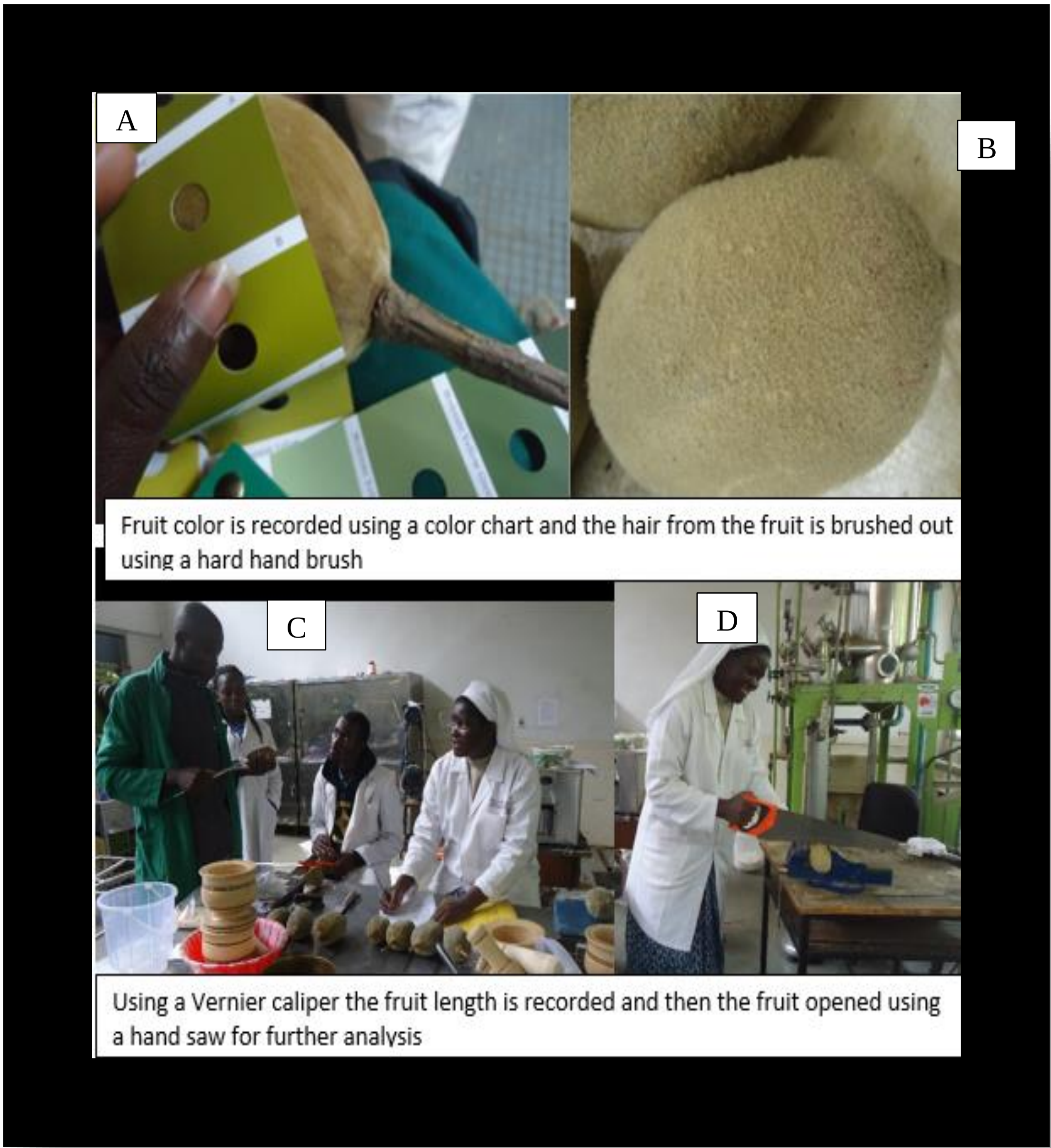
proportion of endosperm to whole seed [%]	1 < 25%	2 26 – 50%	3 51 – 75%	4 >75%

Characterization of the fruits was done for all the traits as described in the baobab descriptor beginning with the outer fruit traits before cracking the fruit; shape, length, and weight. Using the Royal Horticultural Society Colour Chart (RHS, 2015), colour of the fruit hairs, fruit ground colour, pulp colour and fibre colour, was recorded this assessment was done per tree but not per fruit. Therefore one representative fruit per tree was used in determining the colour (Figure 3.3 A)**.**

3.2.3 Quantitative data

Morphological characterization was done using the 18 traits as described in the baobab descriptor which was generally used to collect the morphological data (fruit length, stalk length, fruit diameter, fruit weight, pulp weight, seed weight). These were documented for each fruit (Appendix I). Fruit length (cm), fruit diameter, petiole length, shell thickness, seed length, were measured using a Vernier caliper. Fruit weight, shell weight, pulp weight, seed weight, seed pulp weight and fibre weight were measured using weighing balance (Dahongying, SKU model).

This data was taken for all the 710 fruits that were analyzed for morphological traits. Fruits were opened using a hand saw in order to extract out the fibre, pulp and seeds from the fruit. Weight for all the extracts were then recorded. Seeds and pulp were then separated using a wooden mortar and pestle without crashing the seeds. The content from the mortar was sieved after pounding to separate the seeds and the pulp powder. The weights of both pulp powder and seeds separately taken thereafter. Afterwards, the seeds were washed to remove remaining pulp, dried and their weight taken (Figure 3.3 A, B, C, D, E and F). The data sheet is shown in appendix I



Fruit color is recorded using a color chart and the hair from the fruit is brushed out using a hard hand brush

Using a Vernier caliper the fruit length is recorded and then the fruit opened using a hand saw for further analysis

Figure 3.3: Illustrations on the procedures of fruit characterization and pulp extraction in the laboratory (A, B, C, D, E and F)

3.2.4 Formulas used in the evaluation of quantitative variables

There are some values that were not attained directly through the measurements taken and therefore these are the stipulated formulas that were used to generate the values.

Pulp proportion% = Pulp weight /Fruit weight

Fibre proportion% = Fibre weight/ Fruit weight

Shell proportion% = Shell weight / Fruit weight

Fruit number =1st count + 2nd count/2

Yield (kg) tree^{-1} =Fruit number * mean fruit weight (kg) (for the 10 fruits per tree)/1000.

3.4 Analysis on the physicochemical properties of baobab fruit pulp

The pulp from the 10 fruits per tree was pooled together and used to determine the pulp colour, texture, taste, total soluble solids and titratable acidity. 'Descriptors for Baobab' (Kehlenbeck *et al.* 2015) was used in determining the qualitative variables such as pulp texture, taste and the colour chart for pulp colour, fruit colour, fibre colour and seed colour. TSS (°Brix) data was obtained in triplicate and there after mean value per tree was calculated. The TTA (% Acidity) was calculated using the following formula (% Acidity = (Vol.0.1NNaoH) × Conversion factor (0.064) ÷ Vol. of sample ×100) ÷Dilution factor. TSS: TTA ratio was calculated by dividing the TSS and TTA values for each tree.

3.4.1 Determination of Total Soluble Solids

The total soluble solids was determined using a calibrated digital hand-held refractometer as described by the Association of Official Analytical Chemists (AOAC) method 932.12 (AOAC, 2002). Five (05) g of baobab fine pulp was diluted into 145 ml of distilled water to make a concentration of 150 ml. The diluted sample was left to settle for 30 min to allow the separation of clear juice. The clear filtered juice from the concentration was then used to determine the TSS of the pulp.

3.4.2 Determination of Total Titratable Acidity

Association of Official Analytical Chemists (AOAC) method was used in determining the % Acidity (TTA) where 5ml of juice was titrated against 0.1 M NaOH standard solution using phenolphthalein indicator (AOAC, 2000). The volume of NaOH solution required for titration was recorded.

3.5 Identification and Selection of Elite Baobab Trees for Domestication in Kenya

Two processes were involved namely; Focus group discussions (FGDs) and multidisciplinary team (MDT) participatory approach.

3.5.1 Focus group discussions in Kitui and Kilifi counties

FGDs were performed in four different locations in Kitui (Kyamatu, Mutomo, Ikutha, and Darajani) and Kilifi Counties (Mavueni, Mbuzi and Kaloleni). These locations were selected as baobab fruit sampling had been performed in the same area and the local communities were familiar with the use of baobab fruits and therefore they fully participated in the discussions (Appendix II). A total of 41 men and 44 women participated in the FGDs from the two Counties, including farmers, traders, and processors of baobab fruits in both Counties. In terms of gender, 21 men and 24 women participated in Kitui County, while 20 men and 20 women participated in Kilifi County.

3.5.2 Multidisciplinary team (MDT)

The MDT was carried out in JKUAT's Sino-Africa Joint Research Centre (SAJOREC). The participants comprised lecturers, technicians and Masters Students from different disciplines. The aim of the multidisciplinary team meeting was to unite the professionals from different disciplines to decide upon the best possible domestication plans based on scientific evidence.

The group comprised of ladies and gentlemen who were 11 people in total. The team was made up of agriculturalist, horticulturalist, plant breeders, landscape specialists, food scientist and social scientist. Qualitative and quantitative data which had been collected from 71 trees in the two Counties were used in the discussion during the process of selecting elite trees for domestication. The study was carried out on participation approach by sharing skills and knowledge from different disciplines. Data from 15 trees with 5 different variables (fruit weight, pulp weight, seed weight, TSS: TTA ratio (pulp quality) and fruit number per tree (yield) was critically analyzed.

The method used was the selection index method where the following traits were considered in the selection; yield, fruit weight, pulp weight and the TSS: TTA ratio (pulp quality) such as pulp weight for fruits from Kilifi County. All the data of the different variables were arranged from the largest to the smallest and a rank column created beside every variable. Sum/averages of the variables was done and the arrangement done from the smallest to the largest value. Selection was then done from the least sum/average values to the largest.

3.6 Statistical Data Analysis

3.6.1 Fruit yield per tree, qualitative and quantitative traits of fruits

After standardizing the data, both quantitative and qualitative data were subjected to statistical analysis using SPSS version 23. To detect differences in the median quantitative fruit variables between the two research areas, Mann-Whitney U-tests was performed. ANOVA was conducted using a split plot design with regions or counties as the main plots and trees as the subplots. Mean separation was done using LSD at $P < 0.05$. Correlation analyses were performed between continuous variables such as fruit weight and fruit length, pulp weight and pulp proportion from the whole fruit. For qualitative data, frequencies were calculated, and Chi-square tests were done to detect differences among the fruits from the two study regions. Finally, scatter plots were generated to show the relationship between variables for the selection of the elite trees for domestication in each of the two research regions.

3.6.2 Physicochemical of pulp analysis

The TSS, TTA and the TSS: TTA data were all subjected to SPSS for descriptive statistics and Mann-Whitney U-test to assess the significant differences in the pulp quality from the two Counties (Kitui and Kilifi).

CHAPTER FOUR

RESULTS

4.1 Diversity in Tree Productivity, Fruit Morphology and Physicochemical Characteristics of Baobab Fruit Pulp from Kilifi and Kitui Counties

In the two study regions, variation within and between the counties was found in almost all the traits that were evaluated. Tree to tree variation in tree yield per tree was there in fruit number but there was no significant differences between the two regions. Evaluation of the fruit weight and length within the two counties depicted high variation within the county and between the county in every tree (Appendix VII). However, there were no significant differences within the region and also between the quadrants from the same region (Appendix IV Appendix V and Appendix VI).

4.1.1 Fruit yield per tree and Fruit morphological traits

Fruit number per tree was highly variable though there were no significant differences between the two study regions. However, due to variation in fruit weights, the calculated productivity of trees in kg of fruit per tree was significantly higher in trees from Kilifi County than those from Kitui County (Table 4.1). In Kilifi county number of fruits tree-^{1} ranged from (KFQ7T2) 118 to (KFQ2T1) 308 mean number of fruits tree-^{1} whereas the mean fruit weight tree-^{1} was from (KFQ7T2) 220.3g to (KFQ3T1) 696.1g and the mean fruit yield tree-1 was between (KFQ7T2) 25.9 Kg tree-^{1} to (KFQ6T3) 160.3 Kg tree-^{1}. The variation went across the quadrants and the trees in the same county (Table 4.1).

Table 4.1: Least to highest mean values of number of fruits, fruit weight and fruit yield in Kilifi County.

Tree ID	No. of fruits $tree^{-1}$	Tree ID	Fruit weight(g)	Tree ID	Fruit yield (kg)$tree^{-1}$
KFQ7T2	118	KFQ7T2	220.3	KFQ7T2	25.9
KFQ8T2	120	KFQ4T2	257.0	KFQ8T2	37.1
KFQ7T3	120	KFQ2T3	258.2	KFQ10T1	47.5
KFQ10T1	138	KFQ11T1	278.0	KFQ10T3	50.6
KFQ9T2	138	KFQ10T3	297.5	KFQ9T2	52.5
KFQ2T2	151	KFQ8T2	308.9	KFQ7T1	52.6
KFQ7T1	154	KFQ8T3	315.0	KFQ2T2	58.9
KFQ10T3	170	KFQ4T1	326.5	KFQ10T2	65.6
KFQ10T2	174	KFQ5T3	329.1	KFQ5T3	66.6
KFQ4T3	200	KFQ11T3	333.0	KFQ2T3	74.9
KFQ9T3	200	KFQ7T1	342.9	KFQ4T3	75.2
KFQ5T3	203	KFQ10T1	345.7	KFQ4T2	77.7
KFQ9T1	208	KFQ2T1	351.5	KFQ7T3	79.0
KFQ5T2	218	KFQ6T1	355.9	KFQ6T1	79.2
KFQ3T3	222	KFQ11T2	366.2	KFQ3T3	81.6
KFQ3T1	222	KFQ3T3	368.3	KFQ11T1	83.8
KFQ6T1	223	KFQ4T3	376.1	KFQ5T2	87.7
KFQ1T2	229	KFQ10T2	378.1	KFQ8T3	92.6
KFQ6T2	248	KFQ9T2	381.7	KFQ6T2	97.9
KFQ1T1	250	KFQ2T2	391.5	KFQ4T1	98.0
KFQ5T1	261	KFQ6T2	395.5	KFQ11T3	98.2
KFQ2T3	290	KFQ5T2	403.0	KFQ1T2	104.2
KFQ1T3	291	KFQ3T2	403.0	KFQ2T1	108.4
KFQ8T3	294	KFQ1T3	422.5	KFQ11T2	108.6
KFQ11T3	295	KFQ8T1	422.5	KFQ1T1	115.1
KFQ3T2	296	KFQ1T2	455.0	KFQ3T2	119.3
KFQ11T2	297	KFQ1T1	461.5	KFQ9T3	119.4
KFQ6T3	298	KFQ6T3	538.0	KFQ1T3	122.7
KFQ8T1	299	KFQ5T1	582.3	KFQ8T1	126.1
KFQ4T1	300	KFQ9T3	596.8	KFQ9T1	126.7
KFQ11T1	302	KFQ9T1	610.7	KFQ5T1	151.7
KFQ4T2	303	KFQ7T3	661.3	KFQ3T1	154.2
KFQ2T1	309	KFQ3T1	696.1	KFQ6T3	160.3

Note: Accession numbers are coded according to the County (KF- Kilifi) of collection

Table 4.2: Mean values of the number of fruits, fruit weight and fruit yield arranged from the least to the highest in Kitui County

Tree ID	No. of fruits tree-1	Tree ID	Fruit weight(g)	Tree ID	Fruit yield (kg)tree-1
KTQ13T3	101	KTQ15T1	72.8	KTQ15T1	7.3
KTQ15T1	101	KTQ11T2	95.6	KTQ13T3	12.2
KTQ10T1	105	KTQ16T1	99.8	KTQ9T2	12.5
KTQ12T1	106	KTQ9T2	103.5	KTQ10T3	13.3
KTQ12T3	108	KTQ10T3	120.1	KTQ11T2	14.4
KTQ10T3	111	KTQ13T3	121.8	KTQ16T1	15.1
KTQ14T1	111	KTQ8T3	123.1	KTQ10T1	16.2
KTQ9T2	121	KTQ13T1	126.3	KTQ12T3	17.4
KTQ4T1	129	KTQ4T2	127.8	KTQ13T1	19.3
KTQ9T3	131	KTQ5T1	129.2	KTQ14T1	20.2
KTQ10T2	133	KTQ2T3	136.2	KTQ10T2	20.9
KTQ5T3	149	KTQ12T2	144.5	KTQ4T3	21.9
KTQ11T2	151	KTQ4T3	145.2	KTQ9T3	22.0
KTQ16T1	151	KTQ9T4	146.0	KTQ4T1	22.6
KTQ4T3	151	KTQ7T2	147.5	KTQ12T1	24.1
KTQ13T1	153	KTQ16T2	147.5	KTQ5T3	26.7
KTQ16T3	181	KTQ2T2	148.2	KTQ2T3	27.6
KTQ11T3	184	KTQ11T1	154.3	KTQ9T4	29.1
KTQ9T4	200	KTQ10T1	154.5	KTQ16T3	29.4
KTQ16T2	201	KTQ9T1	155.1	KTQ16T2	29.7
KTQ5T2	201	KTQ10T2	157.8	KTQ11T1	31.1
KTQ11T1	202	KTQ14T2	161.3	KTQ4T2	32.4
KTQ2T3	203	KTQ12T3	161.8	KTQ11T3	35.9
KTQ8T1	203	KTQ16T3	163.0	KTQ8T1	36.5
KTQ4T2	254	KTQ7T1	165.3	KTQ8T3	37.3
KTQ13T2	258	KTQ9T3	167.8	KTQ5T2	38.4
KTQ2T1	288	KTQ13T2	171.2	KTQ12T2	41.7
KTQ12T2	289	KTQ4T1	175.0	KTQ5T1	42.1
KTQ14T3	301	KTQ14T3	177.8	KTQ13T2	44.2
KTQ8T3	303	KTQ5T3	179.1	KTQ14T3	53.5
KTQ14T4	318	KTQ8T1	179.7	KTQ7T2	54.6
KTQ8T2	322	KTQ14T1	181.8	KTQ14T2	57.0
KTQ5T1	326	KTQ8T2	185.8	KTQ2T2	59.1
KTQ14T2	354	KTQ5T2	191.7	KTQ8T2	59.7
KTQ7T2	371	KTQ11T3	194.9	KTQ9T1	62.8
KTQ2T2	399	KTQ12T1	227.0	KTQ2T1	65.9
KTQ7T1	403	KTQ2T1	228.7	KTQ7T1	66.5

KTQ9T1	405	KTQ14T4	343.3	KTQ14T4	109.0

Note: Accession numbers are coded according to the County (KT- Kitui) of collection

In Kitui county mean number of fruits tree^{-1} ranged from (KTQ15T1) 101 to (KTQ9T1) 405 whereas the mean fruit weight tree^{-1} was from (KTQ15T1) 72.8g to (KTQ14T4) 343.3g and the mean fruit yield tree^{-1} was between (KTQ15T1) 7.3Kg tree^{-1}and (KTQ14T4) 109 Kg tree^{-1}.The variation went across the quadrants and the trees in the same county (Table 4.2).

Fruits of baobab trees from Kilifi County had significantly higher fruit length, diameter and weight as well as higher weights of shells, seeds and pulp than those from Kitui County, while fruit pulp proportions did not differ between the two regions (Table 4-3).

Table 4.3: Mean comparison for some of the selected variables showing significant differences between Kilifi and Kitui counties.

Variables	Kilifi County (n=33)	Kitui County (n=38)	P-value (U-Test)
Fruit length (cm)	24.7[a] (18.3-49.0)	14.7[b] (8.9-21.4)	<0.001
Fruit diameter (cm)	10.5[a] (8.6-13.3)	8.0[b] (5.8-11.1)	<0.001
Fruit weight (g)	402.2[a] (256.7-696.1)	159.0[b] (72.8-343.3)	<0.001
Petiole length (cm)	9.1[a] (5.5-13.2)	8.7[a] (2.2-13.5)	0.526
Shell weight (g)	183.1[a](102.5-378.5)	59.2[b] (27.0-126.3)	<0.001
Shell Thickness (cm)	0.6[a] (0.2-1.0)	0.3[b] (0.1-0.5)	<0.001
Seed pulp weight (g)	211.5[a] (142.2-348.9)	96.6[b] (21.8-206.0)	<0.001
Fibre weight (g)	3.3[a] (1.1-11.1)	3.2[a] (1.1-11.1)	0.742
Seed weight (g) after washing	141.6[a] (76.7-224.5)	69.1[b] (11.2-153.5)	<0.001
Total pulp weight (g)	67.5[a] (41.0-136.1)	27.2[b] (10.9-51.7)	<0.001
Shell proportion (%)	45.6[a] (36.6-60.8)	38.3[b] (20.9-68.6)	<0.001
Pulp proportion(%) from whole fruit	16.6[a] (12.6-22.9)	17.3[a] (12.9-21.8)	0.226
Weighed seed proportion (%)	35.2[a] (20.3-44.8)	42.3[a] (14.8-59.4)	<0.001
Fibre proportion (%)	1.8[b] (0.4-4.7)	3.4[a] (1.1-7.4)	<0.001
Mean Fruit no. (productivity)	228.2[a] (117.5-308.5)	215.0[a] (100.5-405.0)	0.273
Total yield (kg)	91.1[a] (30.4-160.3)	35.2[b] (7.3-109.0)	<0.001

Significant at $p \leq 0.05$ ([a] =shows there is significant difference [b]=No significant difference)

Fruit number per tree was highly variable though there were no significant differences between the two study regions. Kilifi County had long, huge and heavy fruits as compared to the fruits in Kitui County which were short, smaller and light.

Table 4.4: Means of some selected fruit traits of individual baobab fruit trees from Kilifi County

Tree ID	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Pulp weight (g)	Pulp proportion (%)
KFQ10T1	26.0	10.0	345.7	55.0	15.8
KFQ10T2	27.1	10.3	378.1	63.5	16.7
KFQ10T3	19.6	10.2	316.7	66.7	20.3
KFQ11T1	21.1	9.8	278.0	44.5	15.9
KFQ11T2	21.3	11.4	366.2	67.7	18.5
KFQ11T3	18.3	11.1	327.5	57.0	17.0
KFQ1T1	25.7	11.8	461.5	82.8	17.8
KFQ1T2	26.9	11.3	455.0	75.5	16.2
KFQ1T3	21.2	10.2	436.1	57.8	13.2
KFQ2T1	26.3	9.3	351.5	52.3	14.9
KFQ2T2	21.5	11.8	391.5	66.0	16.9
KFQ2T3	20.3	9.5	258.2	47.5	18.4
KFQ3T1	34.2	13.3	696.1	89.5	12.8
KFQ3T2	22.0	10.8	403.0	67.0	16.6
KFQ3T3	22.8	9.6	373.0	62.2	16.5
KFQ4T1	27.5	8.6	315.6	43.0	13.3
KFQ4T2	19.8	10.4	256.7	53.6	20.8
KFQ4T3	27.7	9.9	376.1	53.1	14.0
KFQ5T1	27.6	11.5	582.0	132.8	22.9
KFQ5T2	22.1	10.3	403.0	66.3	16.5
KFQ5T3	21.6	10.7	329.1	41.0	12.6
KFQ6T1	22.9	9.8	355.9	59.0	16.6
KFQ6T2	21.7	11.4	395.5	57.2	14.5
KFQ6T3	49.0	8.8	537.8	104.4	19.3
KFQ7T1	21.9	10.5	334.0	58.8	16.9
KFQ7T2	20.8	8.6	258.5	44.8	17.3
KFQ7T3	38.1	11.0	654.8	136.1	20.7
KFQ8T1	21.9	11.4	422.5	65.8	15.6
KFQ8T2	22.1	10.6	308.9	52.5	17.0
KFQ8T3	23.2	9.5	315.0	61.3	19.4
KFQ9T1	31.7	11.3	610.7	96.8	16.1
KFQ9T2	20.7	9.7	381.7	54.5	13.3
KFQ9T3	21.6	12.1	596.8	91.4	15.4

Note: Accession numbers are coded according to the County (KF- Kilifi) of collection

There were variations between the trees from the same County was observed in almost in all the traits that were analyzed (length, diameter, weight, and pulp weight and pulp proportion) (Table 4.4). Despite the fact that fruits were sampled in the same quadrant still the differences could be deduced from the results. Tree ID'S KFQ7TI, KFQ7T2 and KFQ7T3, had very slight differences in the means of fruit length 21.9, 20.8, 38.1cm, fruit diameter 10.5cm,8.6cm , 11.0cm,fruit weight 334g, 258.5g, 654.8g, pulp weight 58.8g, 44.8g, 136.1g and pulp proportion 16.9%, 17.3%, 20.7% respectively among the three trees that were sampled in quadrant 7 (Table 4.4). Fruit weight differed from tree to tree from the fruits that were analyzed despite being sampled from the same environment. In Kilifi County, tree to tree variation and quadrant variation was shown from the minimum mean fruit length, diameter, weight, pulp weight and pulp proportion, KFQ11T3-18.3cm, KFQ7T2-8.6cm, KFQ4T2-256.7g, KFQ5T3-41g and KFQ5T3-12.6% while the fruits with maximum mean fruit length, diameter, weight, pulp weight and pulp proportion ,KFQ6T3-49cm, KFQ3T1-13.3cm, KFQ3T1-696.1g, KFQ7T3-136.1g and KFQ5T1-22.9% were from different quadrants and trees.

Variability in fruit traits in Kitui County between the trees and quadrants was also shown to be different. Trees varied in means of their fruit lengths, diameter, weight and proportion from one tree to another and from one quadrant to another (Table 4-5). This was also observed given the range in mean fruit length, KTQ15T1-8.9cm to KTQ11T3-21.4cm, fruit diameter KTQ16T1-5.8cm to KTQ5T2-11.1cm, fruit weight KTQ15T1-72.8g to KTQ14T4-343.3g, pulp weight KTQ15T1-10.9g to KTQ14T4-51.7g and pulp proportion KTQ16T2-12.9% to KTQ11T1-21.8%. These variations that covers across 5 quadrants with different trees show that even fruits from the same environment differs in size and weight.

Table 4.5: Means of some selected fruit traits of individual baobab fruit trees from Kitui County

Tree ID	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Pulp weight (g)	Pulp proportion (%)
KTQ16T2	12.5	7.1	147.5	18.0	12.9
KTQ4T1	16.0	7.7	175.0	23.7	13.6
KTQ12T1	18.2	8.2	227.0	31.0	13.6
KTQ9T4	13.2	8.0	146.0	20.0	13.8
KTQ10T3	12.1	7.6	120.1	16.5	14.0
KTQ15T1	8.9	6.3	72.8	10.9	15.1
KTQ9T3	19.4	6.9	167.8	25.5	15.2
KTQ14T4	20.9	10.9	343.3	51.7	15.2
KTQ13T1	10.3	8.7	126.3	19.0	15.2
KTQ10T2	13.1	8.3	157.8	24.5	15.4
KTQ7T1	12.4	8.6	171.7	26.7	15.4
KTQ16T1	17.8	5.8	99.8	16.0	15.6
KTQ2T1	15.1	8.7	228.7	35.5	15.7
KTQ9T1	13.1	8.4	155.1	25.5	16.3
KTQ8T3	15.3	7.3	123.1	20.0	16.6
KTQ13T3	14.5	6.7	121.8	20.0	16.7
KTQ9T2	13.9	7.1	108.8	18.9	17.2
KTQ5T3	19.6	7.9	174.6	30.6	17.3
KTQ2T2	16.9	6.7	148.2	25.0	17.3
KTQ16T3	14.0	7.8	163.0	28.5	17.8
KTQ11T3	21.4	8.8	194.9	34.5	17.8
KTQ13T2	13.2	9.3	173.7	31.1	17.9
KTQ5T1	11.7	7.6	129.2	23.0	18.0
KTQ14T3	18.1	7.7	177.8	32.0	18.2
KTQ10T1	14.3	9.0	154.5	28.0	18.2
KTQ2T3	10.4	8.2	136.2	23.5	18.3
KTQ12T3	11.9	8.9	161.8	28.5	18.5
KTQ14T1	14.5	8.4	181.8	34.5	19.0
KTQ4T2	13.1	7.1	127.8	24.0	19.0
KTQ7T2	16.0	6.4	147.5	28.0	19.2
KTQ4T3	14.1	8.5	145.2	27.7	19.2
KTQ14T2	16.7	7.6	161.3	31.0	19.4
KTQ12T2	12.2	8.2	144.5	28.5	19.6
KTQ5T2	11.4	11.1	191.4	38.3	20.2
KTQ8T1	18.6	8.7	191.7	38.3	20.4
KTQ8T2	18.0	8.6	185.8	39.0	20.9
KTQ11T2	10.7	7.1	102.8	21.7	21.5

KTQ11T1	14.3	8.3	154.3	33.5	21.8

Note: Accession numbers are coded according to the County (KT- Kitui) of collection

Pulp weight correlated positively with the fruit weight, fruit length, fruit diameter, seed weight and shell weight but there was no correlation detected with the fruit shape, shell weight and number of segments in both counties. Pulp proportion was observed to have no significant correlation with all the traits that were analyzed (Table 4.6).

Table 4.6: Coefficients of correlation between pulp weight and pulp proportion with some selected quantitative traits to show the differences between the two counties.

	Pulp weight		Pulp proportion	
Fruit traits	**Kilifi(n=33)**	**Kitui(n=38)**	**Kilifi(n=33)**	**Kitui(n=38)**
Fruit weight	0.863**	0.878**	0.025	-0.069
Fruit length	0.645**	0.550**	0.138	-0.016
Fruit diameter	0.449**	0.736**	0.027	0.173
Fruit shape	-0.197	-0.116	-0.236	0.012
Seed weight	0.756**	0.772**	0.022	-0.122
Shell thickness	0.102	-0.04	0.039	-0.315
Shell weight	0.698**	0.726**	-0.164	-0.176
Fibre weight	0.08	0.654**	0.116	-0.112
Number of segments	0.033	0.047	0.037	-0.023

** Correlation is significant at the 0.01 level (2-tailed).

Significant correlations were found between pulp weight and fruit weight, fruit length, fruit diameter seed weight in both Kilifi and Kitui Counties while there was no correlation between pulp proportion and all other fruit traits (Table 4.6). In addition to this, there was significant correlation between pulp weight and fiber weight in Kitui County but not in Kilifi County. Strong correlation between fruit weight and pulp weight was found in both counties, though in Kitui it was high than in Kilifi (r=0.878 and 0.863 in Kitui and Kilifi respectively, $p<0.01$).

General assessment of correlation among all the 71 trees, significant levels were observed in the relationships between different fruit traits. For example, fruit weight correlated significantly with shell weight, seed weight and pulp weight while total yield was significantly correlated with fruit length and weight (Table 4.7). However, none of the fruit traits correlated with pulp proportion.

Table 4.7: Pearson correlation coefficients and significance levels between selected quantitative variables of 71 baobab trees sampled in Kilifi (n=33) and Kitui (n=38) Counties

Traits	Fruit diameter (cm)	Fruit weight (g)	Shell weight (g)	Seed weight (g)	Pulp weight (g)	Pulp proportion (%) from whole fruit	Total yield (kg per tree)
Fruit length (cm)	0.556***	0.847***	0.815***	0.789***	0.834 ***	-0.044	0.739 ***
Fruitdiameter(cm)		0.836***	0.812***	0.804***	0.781 ***	-0.051	0.720 ***
Fruit weight (g)			0.973***	0.947***	0.948 ***	-0.112	0.851 ***
Shell weight (g)				0.858***	0.888 ***	-0.194	0.810 ***
Seed weight (g)					0.894 ***	-0.121	0.833 ***
Pulp weight (g)						0.165	0.803 ***

*** Correlation is significant at the 0.001 level (2-tailed)

There was no significant differences in the ration of pulp proportion with all the traits that were correlated to it. However, there was a strong positive correlation as expected of the fruit weight with the fruit length and width (r=0.847 and 0.836, respectively, $p<0.001$). Additionally, there was a stronger correlation between the fruit weight and the pulp weight (r=0.948, $p<0.001$).

4.1.2 Qualitative Fruit Traits

There was high variation among the 71 baobab trees regarding fruit shapes (Fig. 4.1). The most frequent fruit shape was ellipsoid (about 60% of all trees) in both study regions, followed by obovate (33%) in Kilifi County and oblong (21%) in Kitui County (Table 4.8 and Figure 4.3). Fruits within the same county had diversity in shape as shown (Figure 4.3). Based on Figure 4.3 A, there are different shapes in Kilifi fruits though they were all sampled from different trees and quadrants. Figure 4.3 B indicates that the same applies to those in Kitui County.

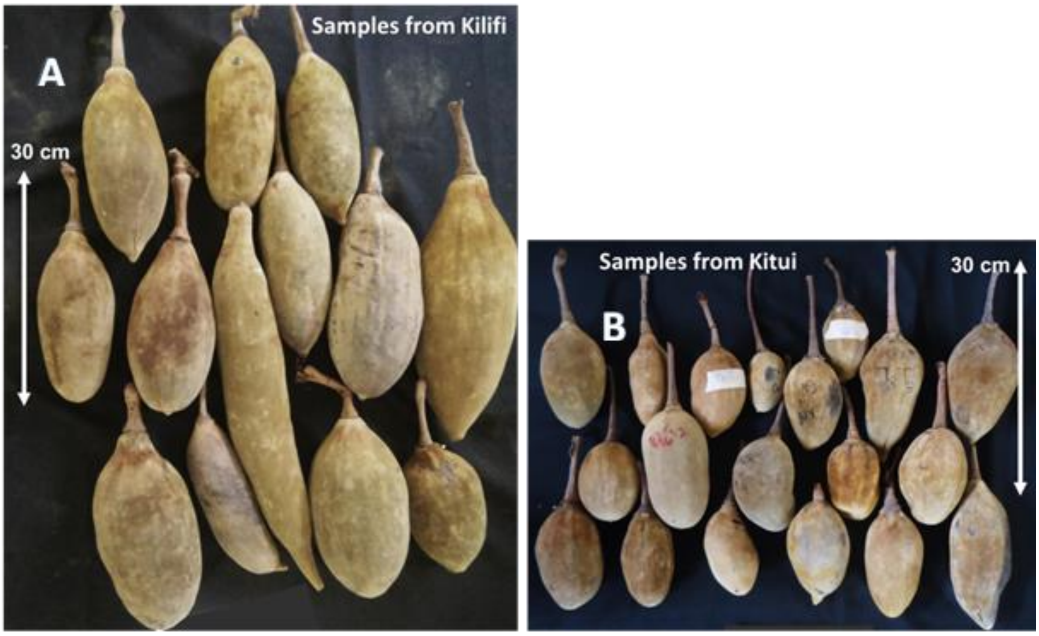


Figure 4.1: Differences in shape among baobab fruits from 71 trees sampled in Kilifi (A), Kitui (B) Counties, Kenya

From the pictorial point view of the fruits clear variation was also noted in the fruits sampled in the same county but a higher variation between the two counties. These results were not far from the statistical results which clearly detected the significant differences in fruit shape between the two regions (table 4.8).

Table 4.8: Selected qualitative characteristics of fruits from 71 baobab trees sampled in Kilifi, Kitui County, Kenya

Trait	Frequency Kilifi County (%)	Frequency Kitui County (%)	X^2 P-value	X^2 value	Df
Fruit shape is ellipsoid	60.6	63.2			
Fruit shape is obovate	33.3	5.3			
Fruit shape is oblong	3.0	21.1	0.004	13.554	3
Fruit pedicel insertion is slightly oblique	84.8	21.1	<0.001	32.378	2
Fruit neck is prominent or very prominent	45.5	7.9	0.001	13.306	2
Fruit beak is pointed	48.5	13.2	0.012	10.896	3
Fruit shell is very hard to crack	81.8	7.9	<0.001	42.319	3
The fruit pulp is sweet	0.0	26.3	<0.001	18.276	2
Pulp weakly adhered to the seed	3.0	50.0	<0.001	20.728	2
Seed testa is hard	78.8	42.1	0.013	10.843	3

Significant at P≤0.05

In addition to fruit shape, several other measured fruit traits differed significantly between trees from the two study regions. Fruits from Kilifi County mostly had a slightly oblique fruit pedicel, a prominent neck and a pointed beak and their shell was rather hard to crack. On the other hand, fruits from Kitui and Makueni County often had a sweet taste.

4.2 Physicochemical properties of Baobab Fruit Pulp in Kilifi and Kitui Counties

4.2.1 TTA (% Acidity) and TSS (°Brix) of Baobab Fruit Pulp

Variation between the trees from the same county was shown from the results. The TSS content ranged from 6.1°Brix to 12.5°Brix, TTA from 4.3% to 8.8% and the TSS: TTA ratio from 1.0 to 2.2 in Kilifi County. A relationship was detected between the ˚Brix and the % Acidity tree KFQ16T3 that had the lowest ˚Brix and at the same time lowest % Acidity. Variation in TSS, TTA and TSS: TTA ratio was from one tree to another, KFQ10T1 (6.2°Brix, 12.3% and 2.0), KFQ10T2 (6.3°Brix, 12.5% and 2.0) and KFQ10T3 (5.4°Brix, 11.5% and 2.1), even if the trees were from the same quadrant.

Different trees from different quadrant also gave a variation much more than the variation that was detected within the same quadrant, KFQ6T2 (5.5°Brix, 9.3% and 1.7), KFQ5T2 (6.9°Brix, 11.1% and 1.6) and KFQ10T3 (5.4°Brix, 11.5% and 2.1). TSS value was also similar in other trees which were harvested from different quadrants and very distant from one another, KFQ1T3 (6.6°Brix, 10.8% and 1.6), KFQ5T3 (6.6°Brix, 10.0% and 1.5), KFQ7T2 (6.6°Brix, 9.2% and 1.4) and KFQ9T2 (6.6°Brix, 11.0% and 1.7).

Table 4.9: Means of the TSS, TTA and TSS: TTA ratio, per tree in Kilifi County

Tree ID	Total Titratable Acidity	Total Soluble Solids	TSS:TTA ratio
KFQ10T1	6.2	12.3	2.0
KFQ10T2	6.3	12.5	2.0
KFQ10T3	5.4	11.5	2.1
KFQ11T1	5.9	9.1	1.6
KFQ11T2	6.8	9.5	1.4
KFQ11T3	8.8	9.1	1.0
KFQ1T3	6.6	10.8	1.6
KFQ2T2	5.1	11.1	2.2
KFQ2T3	5.5	10.3	1.9
KFQ3T1	5.5	9.5	1.7
KFQ3T2	5.6	10.2	1.8
KFQ3T3	6.8	9.5	1.4
KFQ4T1	7.1	10.2	1.4
KFQ4T2	5.7	9.6	1.7
KFQ4T3	5.0	10.5	2.1
KFQ5T1	5.7	10.5	1.8
KFQ5T2	6.9	11.1	1.6
KFQ5T3	6.6	10.0	1.5
KFQ6T1	6.1	9.6	1.6
KFQ6T2	5.5	9.3	1.7
KFQ6T3	5.4	9.4	1.7
KFQ7T1	6.8	8.3	1.2
KFQ7T2	6.6	9.2	1.4
KFQ8T3	4.3	6.1	1.4
KFQ9T1	6.1	9.7	1.6
KFQ9T2	6.6	11.0	1.7
KFQ9T3	5.6	9.8	1.7

Note: (KF- Kilifi, Q-Quadrant and T- Tree)

In Kitui County the range was 8.6°Brix to 17.6°Brix TSS content 5.7 %to12.3% TTA content and 1.1 to 2.0 TSS: TTA ratio (Table 4.10). Variation within the trees as shown in the table below indicates the TSS differs from tree to tree. Trees from the same quadrant also differed in both TSS, TTA and TSS: TTA ratio.

Table 4.10: Mean values for the TSS, TTA and TSS: TTA ratio of the baobab fruit pulp in Kitui County.

Tree ID	Total Soluble Solids	Total Titratable Acidity	TSS:TTA ratio
KTQ14T1	8.6	5.7	1.5
KTQ4T2	9.7	5.9	1.7
KTQ7T2	12.0	6.2	1.9
KTQ5T1	12.9	6.3	2.0
KTQ12T3	10.0	6.5	1.5
KTQ8T1	11.7	6.5	1.8
KTQ16T2	11.7	6.7	1.7
KTQ13T3	9.7	6.9	1.4
KTQ13T2	12.0	6.9	1.7
KTQ9T4	10.0	7.1	1.4
KTQ2T2	10.0	7.3	1.4
KTQ11T1	10.6	7.3	1.4
KTQ11T3	11.5	7.3	1.6
KTQ15T1	10.7	7.6	1.4
KTQ4T1	12.9	7.6	1.7
KTQ12T1	12.0	7.8	1.5
KTQ11T2	13.2	7.8	1.7
KTQ14T2	13.4	7.8	1.7
KTQ5T2	11.4	8.1	1.4
KTQ7T1	13.0	8.1	1.6
KTQ14T4	13.6	8.1	1.7
KTQ4T3	12.9	8.4	1.5
KTQ14T3	11.5	8.7	1.3
KTQ13T1	11.8	8.7	1.4
KTQ8T3	13.4	8.7	1.5
KTQ10T1	14.1	8.7	1.6
KTQ9T2	11.7	9.0	1.3
KTQ10T3	12.5	9.0	1.4
KTQ16T3	13.0	9.0	1.4
KTQ8T2	13.2	9.0	1.5
KTQ5T3	14.1	9.0	1.6
KTQ9T1	11.5	9.4	1.2
KTQ2T1	12.5	9.8	1.3
KTQ2T3	12.3	10.2	1.2
KTQ10T2	13.2	10.2	1.3
KTQ9T3	17.6	10.7	1.7
KTQ12T2	14.3	11.7	1.2

KTQ16T1	14.1	12.3	1.1

Note: (KT- Kitui, Q-Quadrant and T- Tree)

These are three different trees that were sampled from the same quadrant but there is slight difference between the values of the TSS, TTA and TSS: TTA ratio, KTQ11T1 (10.6°Brix, 7.3% and 1.4), KTQ11T2 (13.2°Brix, 7.8% and 1.6), and KTQ11T3 (11.5°Brix, 7.3% and 1.7). These variations and similarities within the trees were observed across the quadrants too, KTQ2T2 (10.0°Brix, 7.3% and 1.4), KTQ8T2 (13.2°Brix, 9.0% and 1.5) and KTQ16T2 (11.7°Brix, 6.7% and 1.7). The TSS in KTQ11T2 and KTQ8T2 are both similar and so are T2, Q11 and Q8 but the TTA differs.

There were significant differences regarding the total titratable acidity (% acidity), total soluble solids (°Brix) and TSS: TTA ratio of the fruit pulp of samples from Kilifi and Kitui Counties. Regarding TTA, the fruit pulp of samples from Kilifi had a significantly lower value than those from Kitui (Figure 4.2). The pulp of samples from Kitui had significantly higher TSS than those from Kilifi. The Total Soluble Solids (Brix) of the pulp from Kitui was significantly different as compared to the Brix of the pulp from Kilifi. Besides, total Titratable Acids (% Acidity) was highly significant in Kitui than in Kilifi (Figure 4.2). However, no significant differences was found in the TSS: TTA ratio of pulp from both counties had no significant differences.

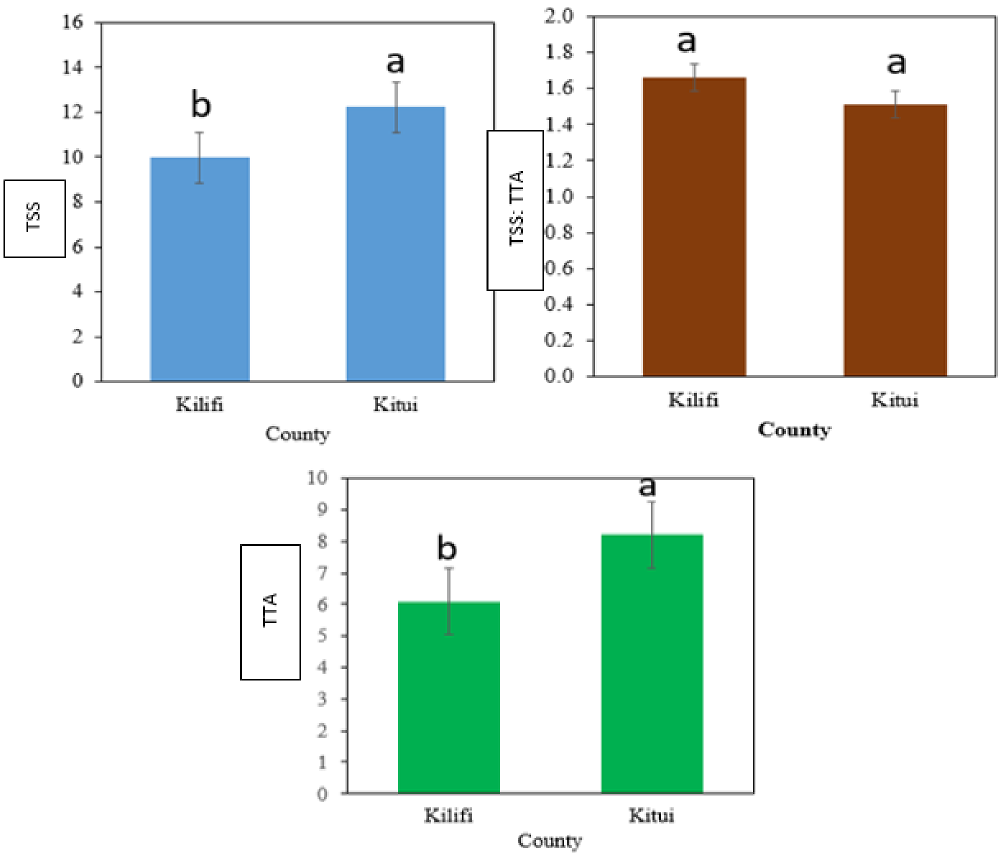


Figure 4.2: The three graphs above shows the significant differences between the TSS, TTA, and TSS: TTA ratio in the baobab fruit pulp from Kitui and Kilifi Counties.

4.3 Selection of Superior Elite Trees

4.3.1 Outcome from the Multidisciplinary Team

This was approached through different methods; MDT, FGD and Scatter plot procedures. It was done based on the MDT selection that considered the quantitative data focusing on the specific traits that favored both the consumers and traders. In Kilifi County, the tree with highest fruit weight and pulp weight were among the 15 fruit trees that were selected as elite trees for domestication.

Table 4.11: Criteria used in the identification and selection of elite tree: fruit weight, pulp weight, pure seed weight, fruit number and the TSS: TTA ratio being the preferred traits in Kilifi County.

	Tree ID	Fruit weight(g)	Pulp weight(g)	Pure seed weight(g)	Fruit number	TSS:TTA ratio
1	KFQ5T1	582.3	146.5	205.5	260.5	1.8
2	KFQ11T4	538.0	82.8	188.0	298.0	1.7
3	KFQ9T3	596.8	91.4	210.8	200.0	1.7
4	KFQ9T1	610.7	96.8	231.7	207.5	1.6
5	KFQ3T2	403.0	59.0	142.5	296.0	1.8
6	KFQ3T1	696.1	41.0	216.0	221.5	1.7
7	KFQ15T3	395.5	66.0	160.0	247.5	1.7
8	KFQ2T2	391.5	141.7	122.5	150.5	2.2
9	KFQ5T2	403.0	65.8	183.4	217.5	1.6
10	KFQ1T3	422.5	58.1	153.0	290.5	1.6
11	KFQ11T2	366.2	67.7	156.0	296.5	1.4
12	KFQ4T1	326.5	103.0	122.3	300.0	1.4
13	KFQ1T1	461.5	61.0	164.7	249.5	
14	KFQ16T1	422.5	47.5	165.3	298.5	
15	KFQ4T3	376.1	39.7	163.2	200.0	2.1

Note: (KF- Kilifi, Q-Quadrant and T- Tree)

In both Kitui and Kilifi county 15 trees were identified as elite trees for domestication, considering that the tree that bears more fruits, has a heavy weight, more pulp, more seeds and high TSS: TTA ratio value hence could be preferable for domestication (Table 4.11 and 4.12). The first tree that was indexed one had the highest pulp weight of 146g. Pulp is more considered even by the farmers themselves since it’s a source of income and nutrient provision too (KFQ5T1). Fruit tree KFQ4T3 with pulp weight 39g was indexed number 15 in the selection of the elite tree. Pulp is very important product in baobab fruit tree. Fruit with the highest fruit weight was indexed number 6 KFQ3T1-696.1g and the least fruit weight among the 15 elite trees that were selected was KFQ4T1-326.5g indexed as tree number 12.

Table 4.12: Criteria used in the identification and selection of elite tree: fruit weight, pulp weight, pure seed weight, fruit number and the TSS: TTA ratio being the preferred traits in Kitui County.

Tree Rank	Tree ID	Fruit weight(g)	Pulp weight(g)	seed weight(g)	Fruit number	TSS:TTA ratio
1	KTQ14T4	343.3	44.6	154.3	318.0	1.7
2	KTQ8T1	179.7	29.5	68.0	203.0	1.8
3	KTQ14T2	161.3	21.0	80.0	354.0	1.7
4	KTQ11T3	194.9	26.5	73.0	184.0	1.6
5	KTQ8T2	185.8	28.0	67.5	322.0	1.5
6	KTQ2T1	228.7	23.5	110.0	288.0	1.3
7	KTQ5T2	191.7	26.5	82.5	201.0	1.4
8	KTQ13T2	171.2	20.0	66.0	258.0	1.7
9	KTQ12T1	227.0	24.5	103.0	106.0	1.5
10	KTQ7T1	165.3	16.0	69.0	403.0	1.6
11	KTQ5T3	179.1	19.0	90.5	149.0	1.6
12	KTQ14T1	181.8	18.5	83.5	129.0	1.5
13	KTQ4T1	175.0	13.1	82.8	129.0	1.7
14	KTQ5T1	129.2	9.0	77.0	326.0	2.0
15	KTQ14T3	177.8	22.0	79.0	151.0	1.3

Note: (KT- Kitui, Q-Quadrant and T- Tree)

In Kitui the same indexing was done and the fruit tree with the highest pulp weight and fruit weight was index 1(KTQ14T4-44.6g and 343.3g) and the least pulp weight was index 14(KTQ5T1-9g and 219.2g), though this was not systematically followed throughout the indexing procedure with other trees.

4.4 Preferences of the local communities in Kitui and Kilifi counties

Feedback results from the focus group discussions (FGDs) from Kitui county clearly indicated that 40 % of the participants rated the baobab trees which bear fruits with sweet tasting fruit pulp as superior while 13% preferred trees with small fruits (a characteristic traditionally related to a sweet tasting fruit pulp) and 47% those with high harvest amounts (Figure 4.3). While in Kilifi County 50% of the participants considered the sweet tasting baobab tree as a superior, 32 % related the pulp sweetness to the fruit shape where elongated fruit shape was identified to be having sweet pulp and finally 18% of the participants considered the high and heavy bearing fruit trees (Figure 4.4).

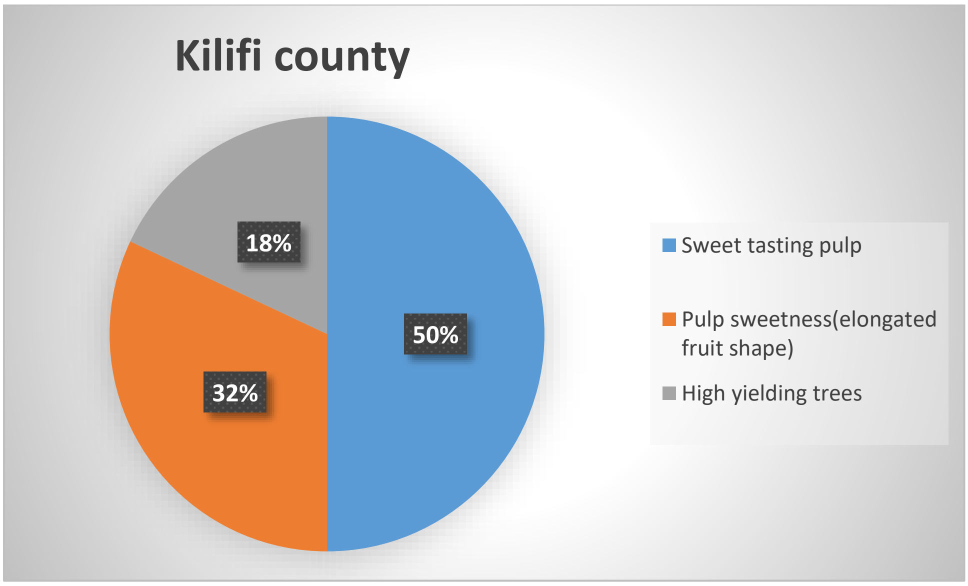


Figure 4.3 Preferences for tree selection for domestication an elite tree in Kilifi

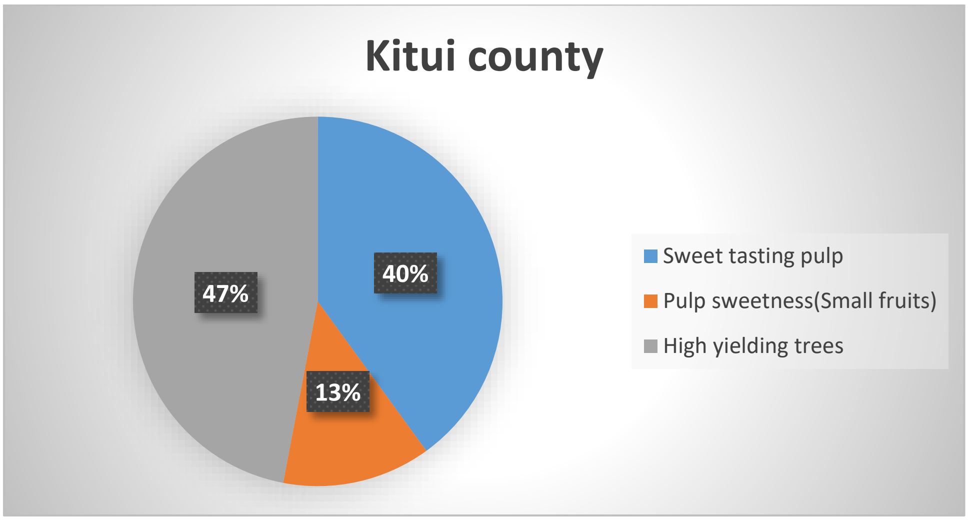


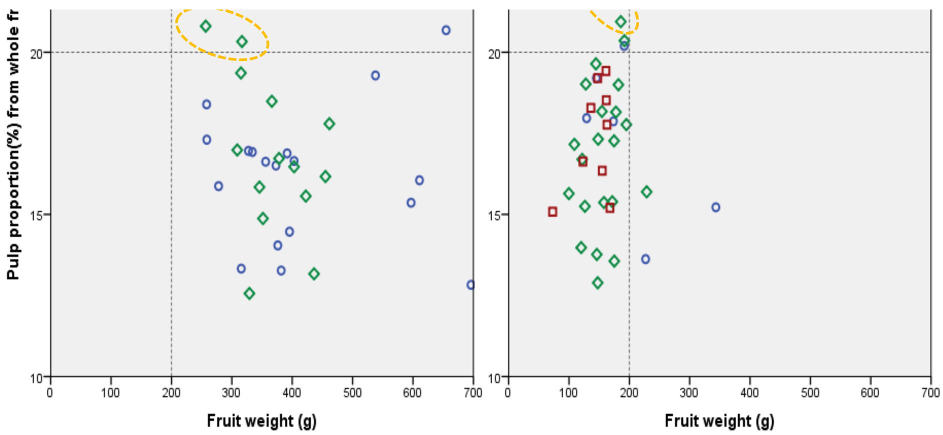
Figure 4.4: Preferences for tree selection for domestication an elite tree in Kitui

The sweetness of the pulp was not only associated with small fruit size but also with smooth shell surface and seeds that are only loosely attached to the pulp, according to the FGD participants. In locations where the majority of the FGD participants were baobab traders and pulp processors, the superiority of baobab trees was only based on high fruit yields but not on the taste of the fruit pulp that was instead preferred in locations where the majority of participants were farmers, who used the pulp for home consumption, not for sale.

4.4.1 Scatter Plot Approach in Elite Tree Selection

The scatter plot approach which was considered in the selection of elite trees for future domestication was mainly based on the fruit weight (as it was highly correlated to fruit yield in our study), the pulp proportion and the sweet taste of the fruit pulp. In this study, 200g was set as minimum fruit weight and 20 % as minimum pulp proportion for selection, while rating of pulp sweetness was to be ‘sweet’. However, in the Kitui County, fruit pulp was generally sweeter than in Kilifi County, which limited the selection of superior mother trees in Kilifi County. Fruits from Kitui County were sweet but small in size as compared to the fruits from Kilifi County, which also resulted in difficulties when selecting elite trees. According to the above mentioned constraints, two elite trees were selected in Kilifi County with intermediate sweet fruit pulp, pulp proportions between 20.3 and 20.8% and mean fruit weights between 257 and 317 g (Figure 4.5), referring to tree numbers KFQ10T3 and KFQ4T2. In Kitui County, no accession with more than 200 g fruit weight and more than 20% pulp proportion was found (Figure 10) Therefore, two trees with values close to our defined limits were selected, one with sweet pulp taste, 21.8% pulp and 154 g fruit weight (tree no. KTQ11T1) and another with intermediate sweet pulp taste, 20.9% pulp and 186 g fruit weight (tree accession no. KTQ8T2.

Figure 4.5: Scatter plot of fruit weight and pulp proportion plus indication of the pulp sweetness level of 71 baobab accessions sampled in Kilifi (n=33) and Kitui (n=38) Counties



CHAPTER FIVE

DISCUSSION

5.1 Tree Productivity and Morphological variation of baobab fruits

5.1.1 Variation in quantitative variables

There was high variation in baobab tree productivity the between two counties studied. In Kilifi County, the number of fruits per tree ranged from 118 to 309, while in Kitui County the number of fruits per tree ranged from 101 to 405. However, fruit weight in Kg per tree was higher in Kilifi ranging from 30.4 to 160.3 compared to Kitui where it ranged from 7.3 to 109. Thus, baobab tree productivity was higher in Kilifi than Kitui. This variation can be attributed to genetic and environmental factors. On environmental contribution, Kilifi County receives more rainfall that Kitui County (Omoyo *et al.*, 2015; MTE *et al.* 2013; Jaetzold *et al*.1983). In Benin the mean number of fruits per tree varied from 57 to 157 in three surveyed regions with different climatic conditions, while the mean total fruit yield per tree ranged from 14 to 35 kg (Assogbadjo *et al.* 2005). They also reported lower fruit yield in areas that receive slightly higher rainfall (wet zone) compared to the areas which receive lower rainfall (intermediate dry zone).

Fruit yield estimations not only contribute to sound economic planning and sustainable natural resource management, but also to estimate the potential income for local communities, which can be generated by selling the fruit pulp (Dhillion and Gustad, 2004; Sanchez *et al.* 2011). Significant differences were found in fruit length, thickness, fruit weight and pulp weight between the two studied regions in Kenya. Baobab fruits from Kilifi County with its slightly more humid climate were longer, wider and heavier as compared to the fruits from Kitui County, which have a transitional to semi-arid climate (Jaetzold *et al.* 1983). Similar differences were also found in studies from other parts of Africa. In Mali, for example, where ten regions were surveyed, mean fruit weight and pulp weight were significantly higher in the wettest than the driest areas (De Smedt *et al.* 2011). Contrarily, fruit weight was either slightly negatively correlated with annual precipitation in Malawi (Sanchez *et al.* 2011), or did not show any clear trend (Munthali *et al.* 2012).

In general, fruit length and weight in this study (particularly regarding fruits from Kilifi County) were markedly higher than those reported from other regions of Africa. Sanchez *et al.* (2011) measured 400 fruits each in Malawi and Mali, resulting in lower fruit length and weight (15.6 cm and 201 g, and 18.8 cm and 232 g, respectively) as compared to the present findings in Kilifi County (medians 22 cm and 376 g). Assogbadjo *et al.* (2011) Measured 1200 fruits in Benin resulted in a mean fruit length of 20.7 cm and a weight of 275 g, which was still lower than the present results from Kilifi County, but higher than those from Kitui County (medians 14 cm and 155 g) or the above mentioned ones from Malawi and Mali. These findings are also comparable to the present results where the general mean fruit weight and length from the two counties were 272 g and 19.3 cm respectively though silently lower than the 1200 fruits that were measured in Benin.

With regard to pulp proportion from the whole fruit, results of the present study with a range from about 13 to 23% and a median of 17 % are comparable to those reported from Sudan (range of four sampled trees 14-21%; (Gebauer, J., and Luedeling, 2013), Benin (mean of 30 trees each in three surveyed zones around 18%; Assogbadjo et al. 2005), Malawi (range of 400 trees 14-28%, mean 19%; Sanchez *et al.* 2011) and Mali (range of 400 trees 18-25%, mean 21%; Sanchez et al. 2011). A strong positive correlation was found between several quantitative fruit parameters such as fruit weight, shell weight, seed weight and pulp weight in this study (Table 4), which was similar to results from Burkina Faso, Mali and Niger (Parkouda *et al.* 2012) and from Mali and Malawi (Sanchez *et al.* 2011). Similar correlations were found for other wild fruit tree species such as tamarind (Van den Bilcke *et al.* 2014). Our finding that pulp proportion is not correlated with fruit length or weight was only partly confirmed by findings of Sanchez *et al.* (2011), who reported a similar lack of such correlations for baobab fruits from Mali, while those from Malawi showed a weak positive correlation between pulp proportion and fruit weight and length.

Most probably, both genetic factors and environmental variables such as precipitation and soil characteristics influence quantitative fruit traits (Sanchez *et al.,* 2011; Munthali *et al.*, 2012) together with genotype x environment interactions(Assogbadjo *et al.,* 2011). Due to the high variation that was found in the present study, further research needs to be done, focusing mainly on environmental and genetic factors as agents causing the diversity on different traits.

5.1.2 Diversity in Baobab Fruit Shapes from Kilifi and Kitui Counties

There was a high tree-to-tree variability regarding fruit shapes of baobab trees from Kilifi, Kitui County with 'ellipsoid' being the most frequent shape. Similarly, 'ellipsoid' was the most frequent fruit shape in samples from two regions of Sudan (Nasreldin A. Gurashi and Maha, 2014). In Mali, baobab fruits were mainly of elongated shape and in Malawi of spherical shape with a round apex (Sanchez *et al.,* 2011). In Benin, there was a relationship between the fruit shape and pulp sweetness (Assogbadjo *et al.,* 2008). Similarly, in Kenya, anecdotal knowledge related elongated fruits with sweeter taste (Simitu and Oginasako, 2005). However, the present study did not find any relationship between shape expressed as length-width ratio and level of pulp sweetness, but only a very weak negative correlation between the latter and fruit weight. Therefore, fruit shape should not be considered as an important trait for selecting elite baobab trees. Also, in much of the published literature on domestication of indigenous fruit trees such as *Sclerocarya birrea* (marula) or *Irvingia gabonensis* (bush mango), ideotype selection does not include the trait 'fruit shape' (Leakey and Page 2006; Leakey, 2017).

Fruit shapes assessment is an essential activity in the morphological characterization of intraspecific diversity in fruits. The fruit shape assessment is used for quality assessment, clone description, and selection as well as studying trait heritability (Costa *et al.,* 2011). Fruit shape variation in baobab may be a result of genetic, but also climatic and other environmental factors (De Smedt *et al.,* 2011; Sanchez *et al.,* 2011).

5.1.3 Physicochemical Characteristics of Baobab Fruit from Kitui and Kilifi

Both TSS and TTA of fruits pulp were significantly different among fruits from the two study regions, Kilifi and Kitui. The two quality characteristics were significantly lower in fruit pulp from Kilifi than those from Kitui. Additionally, fruit pulp from Kitui was sweeter than the pulp from Kilifi. Sweetness in the pulp was attributed to the fructose, saccharide, and glucose contents (Ekram *et al.,* 2014). Vertuani *et al.,* 2002) described the ripe baobab fruit as naturally dry and powdery, having s a slightly acidic taste which is as a result of organic acids (citric, tartaric, malic and succinic). Mean TSS (°Brix) in the fruit pulp in Kitui and Kilifi counties were 12.2°Brix and 10.0%, while the TTA was 8.2°Brix and 6.1 % acidity respectively. The results were slightly higher than those reported for western Sudan, at 7.0°Brix and 6.30% for TTA (Ekram et al., 2014). There were trees that also showed some similarities in their TSS though they were from very distant quadrants (KFQ1T3, KFQ5T3, KFQ7T2 and KFQ9T2) had TSS value of 6.6°Brix. This is interesting because these trees are from different trees and quadrants. Variation was in all the trees that were sampled from the same region. There was tree to tree variation and inter county variation as shown in the results. This implies that both genetically and environmental factors might have influenced the synthesis of these physicochemical traits.

5.1.4 Identification and selection of the Elite Trees for Domestication in Kenya

Through the MDT, FGD and Scatter plot approach that was considered, 17 trees were selected for domestication as elite trees with regard to fruit weight, fruit number per tree, pulp weight, seed weight, pulp proportion, TSS: TTA ratio and the sweet taste of the fruit pulp. Some of the traits were also mentioned as useful by Sanchez *et al.,* (2011) and De Smedt *et al.,* (2011) in their studies on baobab elite tree selection performed in Malawi and Mali.

Leakey *et al.,* (2012) suggest that not only the primary product of a tree species but also secondary ones should be put into consideration during the selection process of elite trees. In the case of baobab, the focus should therefore not only be on the fruit pulp but also seed oil content (for oil production) or leaf traits (for vegetable production). The traits that were put into consideration during the process of identification and selection of baobab fruit trees plays a major role of economic and nutrition benefits of baobab trees. There are 17 fruit trees from every county that were identified as elite trees. These trees may be used to source scions for grafting baobab fruit trees in order to shorten the maturity period of the tree. Once awareness is created on the importance of baobab fruits, there will be minimal wastage of the fruits, especially the seeds which can be used to extract oil. As other commercial fruits are domesticated, baobab fruit tree should be commercialized and so is its products. For instance, baobab flour, oil, ropes, and dried leaves can be produced for commercial purposes. Findings of the present study on the selection of elite trees will contribute to the domestication and increased utilization of this important wild fruit tree in Kenya.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Kilifi and Kitui Counties are located in different agro ecological zones of Kenya, coastal and lower eastern respectively. Results from the 2 Counties showed great variability in fruit yield, morphological traits and pulp quality between the trees in two regions and the trees within the region. Though the significant differences in baobab tree productivity, fruit morphology and pulp quality was only found between the two different regions. High yielding fruit trees were identified in Kilifi County with large and heavy fruits as compared to Kitui County where there was low fruit yield with small and light fruits but sweet tasting pulp. The TSS of the fruit pulp from Kitui County was higher than that of fruits from Kilifi County. Diversity on the different traits from the two regions could be as a result of the interaction between the genotype and the environment.

Different traits were put into consideration in the selection of the elite trees for domestication. There was a high preference given to the sweet tasting pulp than the sour taste pulp during the focus group discussion. In both the MDT and FGD, fruit weight and yield were also considered for the selection of the 15 elite trees for domestication from each County. These differences between regions and the documented high tree-to-tree variability offer interesting opportunities for the selection of elite trees for domestication in the two study areas. Two other trees were also selected in addition to the 15 trees that were selected earlier from the two regions. Traits considered for selection here, were the fruit weight, pulp proportion and pulp sweetness.

6.2 Recommendations

Achievements on the present study is away forward to do more research especially on the diversity of the fruits in order to find out the cause of variation within and between the trees in the two regions. Based on my present results, we therefore recommend baobab fruit tree to be domesticated in Kenya. Baobab trees can bloom in Kenya if domesticated since the yield and quality of the fruits were amazing and yet they are in the wild. The elite trees that resulted from our findings can be used in the domestication process. In order to have high yielding fruits. Investigation of the TSS TTA and TSS: TTA is very essential since mineral imbalance in the soil can lead to variation of the TTA, TTA and TSS: TTA ratio in the fruits. This study recommend some soil analysis to be carried out in order to find out the mineral composition that was in soils from the two counties. Baobab tree domestication especially the selected elite trees for the improvement of fruit yield and quality. These trials can be done within the same local communities to which the baobab samples were collected for easy comparison of the findings. There is need for more research on annual variability of yield regarding fruit numbers and weights or physicochemical properties of baobab fruit pulp.

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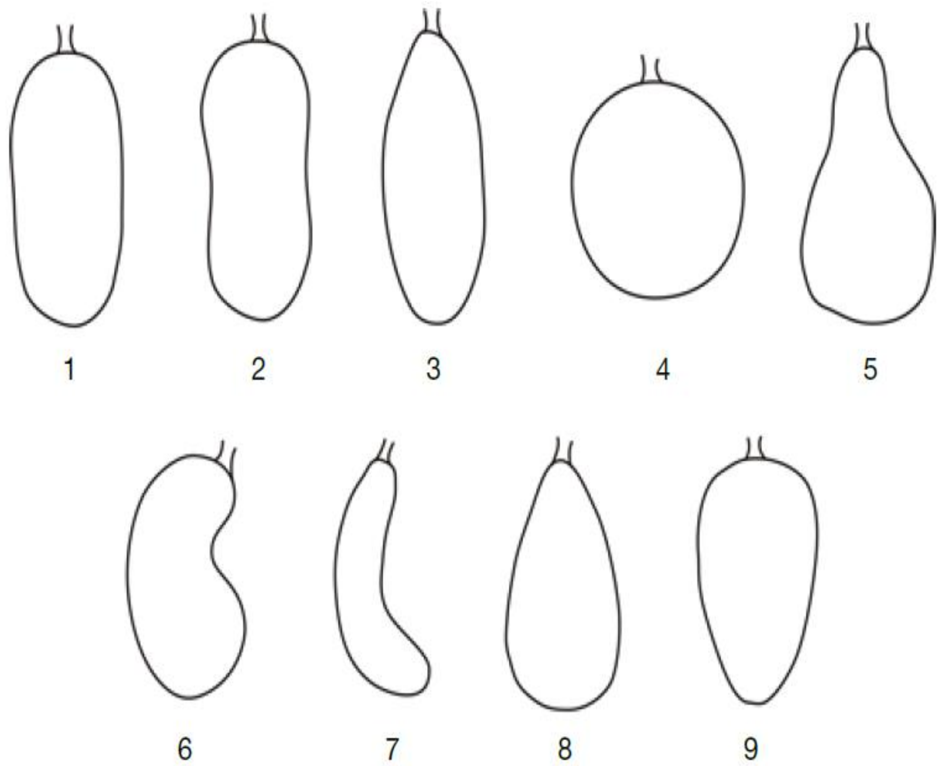
APPENDICES

Appendix I: Baobab fruit descriptors



7.3 Fruit

Randomly select 10 mature and healthy fruits at least with their pedicels per tree and record the average.

*7.3.1 Fruit shape

Record the predominant shape using 10 fruits per tree. (See Fig. 12).

1 Oblong

2 Oblong compressed

3 Ellipsoid

4 Globose

5 Obpyriform (pear-shaped)

6 Reniform (kidney-shaped)

7 Crescent-shaped

8 Ovate

9 Obovate

99 Other (i.e. ‘irregular’specify in descriptor **7.5 Notes**)

Fig. 12. Fruit shape

***7.3.2 Fruit apex shape**

(See Fig. 13).

1 Acute

2 Obtuse

3 Round

4 Depressed

99 Other (specify in descriptor **7.5 Notes**)

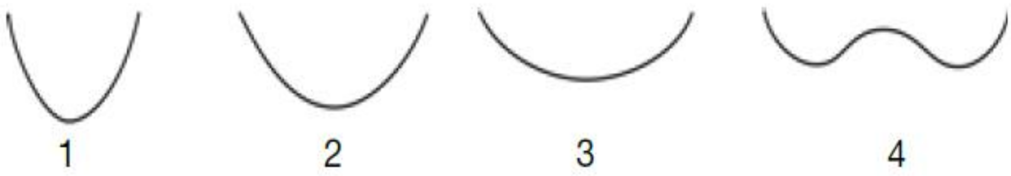


Fig. 13. Fruit apex shape

7.3.3 Fruit pedicel insertion

(See Fig. 14).

1 Vertical

2 Slightly oblique

3 Oblique

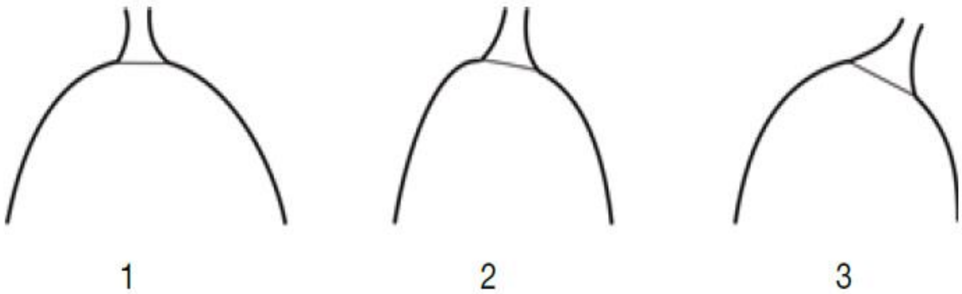


Fig. 14. Fruit stalk insertion

***7.3.4 Fruit neck prominence**

(See Fig. 15).

0 Absent

1 Slightly prominent

2 Prominent

3 Very prominent

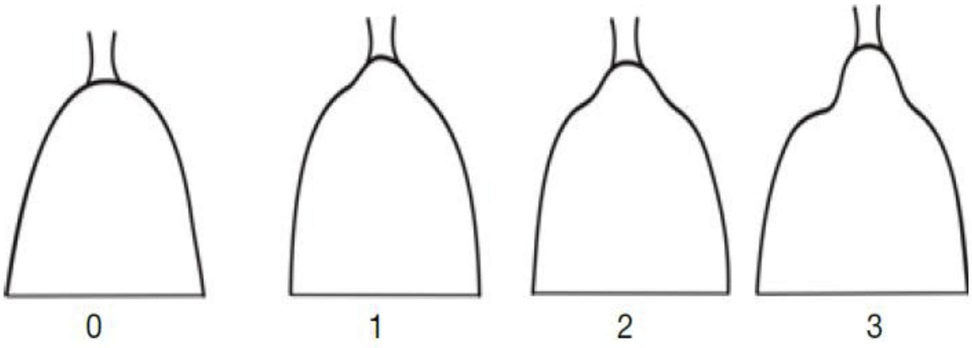


Fig. 15. Fruit neck prominence

***7.3.5 Fruit beak type**

(See Fig.16).

0 Absent

1 Perceptible

2 Pointed

3 Prominent

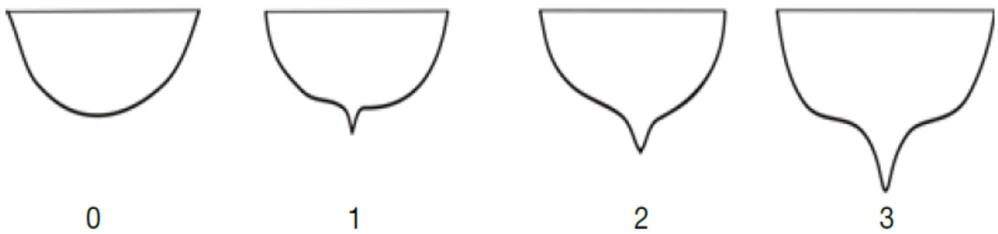


Fig. 16. Fruit beak type

***7.3.6 Fruit length [cm]**

Measured from the base to the tip of the fruit.

***7.3.7 Fruit diameter 1 [cm]**

Measured at the widest point.

7.3.8 Fruit diameter 2 [cm]

Measured at 90º from the first measurement at the widest point.

7.3.9 Fruit pedicel length [cm]

Measured at the longest length, but only if the complete pedicel is available.***7.3.10 Total weight of 10 fruits [g]**

***7.3.11 Pulp weight of 10 fruits [g]**

Remove the pulp-covered seeds and the fibre from the opened fruit shell, separate the pulp from the seeds by using a wooden mortar and pestle (or similar tools) without crushing the seeds, then sieve the pulp powder and determine its weight.

***7.3.12 Seed weight of 10 fruits [g]**

Remove the fibres from the sieved seeds (see above), wash the seeds to remove remaining pulp, dry the seeds and determine their weight.

7.3.13 Fruit shell weight of 10 fruits [g]

7.3.14 Fruit shell hairiness

0 Not hairy

1 Partly hairy

2 Evenly hairy

7.3.15 Colour of hairs on the fruit skin

If possible use colour codes from the Royal Horticultural Society. If these are not available, use the following colour codes:

1 Green

2 Grey

3 Yellowish

99 Other (specify in descriptor **7.5 Notes**)

7.3.16 Fruit ground colour

Remove all the hairs to observe colour of the skin. If possible use colour codes from the Royal Horticultural Society. If these are not available, use the following colour codes.

1 Black

2 Brown

3 Green

4 Gray

5 Yellowish

99 Other (specify in descriptor **7.5 Notes**)

***7.3.17 Fruit cross section outline**

(See Fig. 17).

1 Not contoured

2 Shallowly contoured

3 Deeply contoured

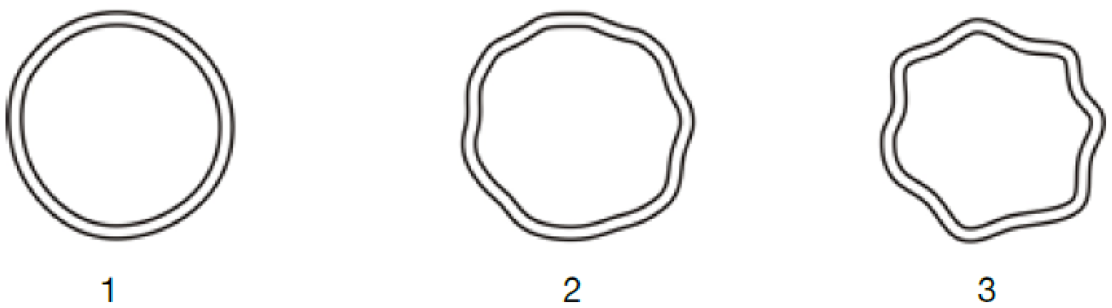


Fig. 17. Fruit outline

7.3.18 Number of segments per fruit

Record the average number of segments per fruit (fruit cross section).

7.3.19 Fruit shell surface texture

1 Smooth

2 Wrinkled

7.3.20 Fruit shell hardness to crack

Use fingers to determine shell hardness by breaking a piece of shell.

1 Easily cracked

2 Slightly hard

3 Hard

4 Very hard

***7.3.21 Fruit shell thickness [mm]**

Measured at the centre of fruit.

7.3.22 Fibre colour

Observe fibres in the central part inside the fruits. If possible use colour codes from the Royal Horticultural Society. If these are not available, use the following colour codes:

1 White

2 Cream

3 Orange

4 Brown

99 Other (specify in descriptor **7.5 Notes**)

7.3.23 Adherence of fibre to fruit shell

3 Weak

5 Intermediate

7 Strong

7.3.24 Texture of fibres in fruit

1 Soft

2 Intermediate

3 Coarse

***7.3.25 Adherence of pulpy seed to fibre**

3 Weak

5 Intermediate

7 Strong

***7.3.26 Pulp colour of fresh fruit**

If possible use colour codes from the Royal Horticultural Society. If these are not available, use the following colour codes.

1 White

2 Cream

3 Light orange

4 Dark orange

99 Other (specify in descriptor **7.5 Notes**)

***7.3.27 Adherence of fruit pulp to seed**

(Scratch with your finger nails).

0 Absent

3 Weak

5 Intermediate

7 Firm / Strong

7.3.28 Pulp texture of ripe fruit

3 Soft

5 Intermediate

7 Firm

***7.3.29 Pulp sweetness**

0 Absent

3 Slightly sweet

5 Sweet

7 Very sweet

***7.3.30 Pulp sourness**

0 Absent

3 Slightly sour

5 Sour

7 Very sour

***7.3.31 Pulp bitterness**

0 Absent

3 Slightly bitter

5 Bitter

7 Very bitter

7.3.32 Pulp aroma / scent

0 Absent

1 Mild

2 Perceptible

3 Strong

7.4 Seed traits

Randomly select 10 healthy seeds out of the total seeds from the 10 collected fruits from one tree.

7.4.1 Seed coat colour

If possible use colour codes from the Royal Horticultural Society. If these are not available, use the following colour codes:

1 Dark brown

2 Reddish black

99 Other (specify in descriptor **7.5 Notes**)

7.4.2 Seed shape

(See Fig. 18.).

1 Oblong

2 Reniform (kidney-shaped)

3 Very reniform

99 Other (specify in descriptor **7.5 Notes**)

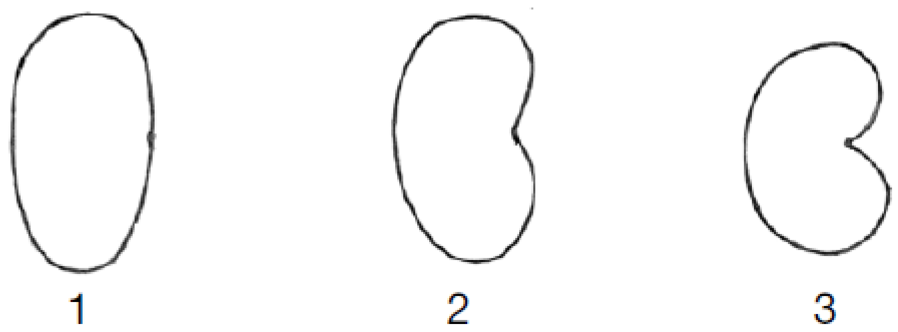


Fig. 18. Seed shape

***7.4.3 Number of seeds per fruit**

Average of 10 fruits.

***7.4.4 Seed length [mm]**

Average of 10 seeds.

7.4.5 Seed width [mm]

Measured at the widest point of the seed; average of 10 seeds.

7.4.6 Seed thickness [mm]

Measured at 90º from the measurement of seed width; average of 10 seeds.

7.4.7 Seed coat texture

(Thin coat of the seed).

1 Soft/smooth

2 Coarse/rough

7.4.8 Seed testa hardness

(Hard shell below the coat). Scarify several seeds with knife and finger, press with probe / penetrometer to quantify pressure needed to break testa.

3 Soft

5 Intermediate

7 Hard

9 Very hard

7.4.9 Colour of endosperm

Scarify seeds to reveal endosperm.

1 White

2 Grey

99 Other (specify in descriptor **7.5 Notes**)

7.4.10 Proportion of endosperm to whole seed [%]

Scarify seeds to reveal endosperm.

1 < 25%

2 26 – 50%

3 51 – 75% 4 >75%

QUANTITATIVE DATA FORM

	Fruit	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Fruit	Length										
	Width										
	Thickness										
	Weight										
Petiole	Length										
Seed+ Pulp	Weight										
Pulp powder	Weight										
Shell	Thickness										
	Weight										
Fibre	Weight										
Seed	Length										
	Width										
	Thickness										

Length, width, thickness [cm]

All weights are in grams

The focus group facilitator should introduce the team and clearly state the purpose and time need for the discussion. Confirm if it is okay to continue with meeting and seek consent on recording of the meeting.

Identification Data

Appendix II: Focus Group Discussion (FGD); selection of elite tree for domestication

Item	Response	Item	Response
Date of the focus grou discussion		County	
Discussions start)	(hh:mm	Sub county	
Discussions end time	(hh:mm)	Ward	
Name of the facilitato		Market/Town Name	
Number of tl members	Male ___ Female ___ Tot _____	GPS coordinates	
Name of the conta person		Telephone	

Local vernacular name for baobab

What is the local name for the baobab tree: ____

And what is the local name for the baobab fruit:

Access to baobab trees and person responsible for harvesting

Do you have access to baobab trees? ____

Do you harvest all baobab trees in your farm or public land? ____

In which months do you harvest baobab fruit? Explain?

____

____

____

____

Baobab use

Do you use baobab products in your households? Explain How? ____ ____ ____ ____ ____

Baobab taste

Can you differentiate between the sweet and sour taste of baobab fruit? Explain ____ ____ ____ ____ __________________________________
Is baobab pulp consumption at the household level influenced by the taste (sweet or sour)? Explain ____ ____ ____ ____ __________________________________
By looking at the tree, can you tell whether the fruits are sweet or sour? Explain how

What are the determinants of sweetness and sourness of a baobab fruit/ tree? Explain

Do think the taste of baobab changes over time during storage on the tree or house? Explain

Do you think the taste of baobab fruits changes over time as the tree ages? Explain

Are you aware of any nutritional benefits in baobab? Explain

In your opinion, do you think baobab taste is related to nutritional composition? Explain

When selling baobab to traders/processors, do you consider the taste (sweetness or sourness) of the fruits or pulp? Which one do you prefer dealing with? Explain

When the traders/processors are buying from you, do they consider the taste (sweetness or sourness) of the fruits or pulp? Which one do they prefer dealing with? Explain

Appendix III: ANOVA table indicating the significant differences in kitui and Kilifi counties in Kenya

		Sum of Squares	df	Mean Square	F	Sig.
Fruit length (cm)	Between Groups	1783.429	1	1783.429	78.502	.000
	Within Groups	1567.558	69	22.718		
	Total	3350.987	70			
Fruit diameter (cm)	Between Groups	109.766	1	109.766	94.257	.000
	Within Groups	80.353	69	1.165		
	Total	190.119	70			
Fruit weight (g)	Between Groups	1044948.702	1	1044948.702	143.808	.000
	Within Groups	501373.655	69	7266.285		
	Total	1546322.357	70			
Total yield (kg)	Between Groups	55205.245	1	55205.245	73.508	.000
	Within Groups	51819.390	69	751.006		
	Total	107024.634	70			
Mean Fruit no. (productivity)	Between Groups	3087.358	1	3087.358	.442	.508
	Within Groups	482073.100	69	6986.567		
	Total	485160.458	70			
Total pulp weight (g)	Between Groups	28718.469	1	28718.469	102.669	.000
	Within Groups	19300.574	69	279.718		
	Total	48019.043	70			
Pulp proportion(%) from whole fruit	Between Groups	7.205	1	7.205	1.261	.265
	Within Groups	394.138	69	5.712		
	Total	401.343	70			

Appendix IV: Table showing that there were no significant differences between the quadrants in Kitui County

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fruit length (cm)	Between Groups	111.147	12	9.262	.953	.514
	Within Groups	242.884	25	9.715		
	Total	354.031	37			
Fruit diameter (cm)	Between Groups	13.246	12	1.104	.892	.566
	Within Groups	30.936	25	1.237		
	Total	44.182	37			
Fruit weight (g)	Between Groups	26730.461	12	2227.538	1.161	.360
	Within Groups	47957.121	25	1918.285		
	Total	74687.582	37			
Total yield (kg)	Between Groups	7984.335	12	665.361	2.025	.066
	Within Groups	8212.903	25	328.516		
	Total	16197.238	37			
Mean Fruit no. (productivity)	Between Groups	169987.107	12	14165.592	1.978	.073
	Within Groups	179007.583	25	7160.303		
	Total	348994.691	37			
Total pulp weight (g)	Between Groups	1151.068	12	95.922	2.136	.053
	Within Groups	1122.460	25	44.898		
	Total	2273.528	37			
Pulp proportion(%) from whole fruit	Between Groups	81.014	12	6.751	1.414	.224

	Within Groups	119.401	25	4.776
	Total	200.415	37	

Appendix V: Kilifi County with selected variables showing no significant difference among the fruits sampled in the same location

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fruit length (cm)	Between Groups	58.529	9	6.503	.130	.998
	Within Groups	1154.998	23	50.217		
	Total	1213.527	32			
Fruit diameter (cm)	Between Groups	7.523	9	.836	.671	.726
	Within Groups	28.648	23	1.246		
	Total	36.171	32			
Fruit weight (g)	Between Groups	135634.376	9	15070.486	1.191	.347
	Within Groups	291051.697	23	12654.422		
	Total	426686.073	32			
Total yield (kg)	Between Groups	13070.805	9	1452.312	1.481	.213
	Within Groups	22551.346	23	980.493		
	Total	35622.151	32			
Mean Fruit no. (productivity)	Between Groups	57785.945	9	6420.661	1.961	.093
	Within Groups	75292.464	23	3273.585		
	Total	133078.409	32			
Total pulp weight (g)	Between Groups	2716.259	9	301.807	.485	.870
	Within Groups	14310.787	23	622.208		
	Total	17027.047	32			
Pulp proportion(%) from whole fruit	Between Groups	29.566	9	3.285	.460	.886

	Within Groups	164.158	23	7.137		
	Total	193.723	32			

Appendix VI: Shows that there were no significant differences between the trees sampled in the same locality.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Fruit length (cm) is the same across categories of Tree ID quantitative.	Independent-Samples Kruskal-Wallis Test	.469	Retain the null hypothesis.
2	The distribution of Fruit diameter (cm) is the same across categories of Tree ID quantitative.	Independent-Samples Kruskal-Wallis Test	.469	Retain the null hypothesis.
3	The distribution of Fruit weight (g) is the same across categories of Tree ID quantitative.	Independent-Samples Kruskal-Wallis Test	.469	Retain the null hypothesis.
4	The distribution of Total pulp weight (g) is the same across categories of Tree ID quantitative.	Independent-Samples Kruskal-Wallis Test	.469	Retain the null hypothesis.
5	The distribution of Pulp proportion (%) from whole fruit is the same across categories of Tree ID quantitative.	Independent-Samples Kruskal-Wallis Test	.469	Retain the null hypothesis.
6	The distribution of Mean Fruit no. (productivity) is the same across categories of Tree ID quantitative.	Independent-Samples Kruskal-Wallis Test	.469	Retain the null hypothesis.
7	The distribution of Total yield (kg) is the same across categories of Tree ID quantitative.	Independent-Samples Kruskal-Wallis Test	.469	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Appendix VII: Overall mean description of the selected quantitative variables of individual trees in Kilifi and Kitui County

Sample ID	Fruit length(cm)	width(cm)	Fruit diameter (cm)	Fruit weight(g)	pulp weight(g)	Seed weight(g)	Pulp proportion(%)TP whle fruit
KFQ10T1	26.0	9.7	9.8	352.0	60.0	140.0	17.0
KFQ10T1	25.5	10.3	10.3	353.0	60.0	140.0	17.0
KFQ10T1	27.1	10.0	10.0	357.0	55.0	135.0	15.4
KFQ10T1	23.0	9.9	10.0	338.0	50.0	145.0	14.8
KFQ10T1	27.1	9.8	9.8	356.0	60.0	135.0	16.9
KFQ10T1	28.1	9.5	9.5	383.0	65.0	135.0	17.0
KFQ10T1	25.1	10.6	10.7	358.0	65.0	155.0	18.2
KFQ10T1	27.7	10.5	10.3	307.0	35.0	105.0	11.4
KFQ10T1	26.7	9.1	9.0	281.0	45.0	100.0	16.0
KFQ10T1	24.1	10.6	10.7	372.0	55.0	130.0	14.8
KF10T2	25.6	11.0	11.0	340.0	55.0	82.0	16.2
KF10T2	26.5	10.0	9.9	311.0	50.0	78.0	16.1
KF10T2	27.0	10.0	10.0	359.0	60.0	87.0	16.7
KF10T2	26.6	10.0	10.1	352.0	57.0	84.0	16.2
KF10T2	24.3	9.8	10.1	360.0	61.0	82.0	16.9
KF10T2	32.6	11.7	11.6	583.0	103.0	154.0	17.7
KF10T2	30.7	9.6	10.1	430.0	73.0	107.0	17.0
KF10T2	24.8	9.8	10.1	368.0	62.0	80.0	16.8
KF10T2	28.3	9.3	10.1	327.0	56.0	71.0	17.1
KF10T2	24.2	10.5	10.6	351.0	58.0	95.0	16.5
KFQ10T3	14.0	9.7	9.7	200.0	36.0	56.0	18.0
KFQ10T3	22.3	12.7	12.7	495.0	109.0	203.0	22.0
KFQ10T3	26.7	12.2	12.2	540.0	117.0	187.0	21.7
KFQ10T3	18.9	9.3	9.4	245.0	37.0	45.0	15.1
KFQ10T3	20.4	10.0	10.0	290.0	67.0	97.0	23.1
KFQ10T3	24.4	12.3	12.3	510.0	121.0	196.0	23.7
KFQ10T3	13.4	8.2	8.2	155.0	30.0	47.0	19.4
KFQ10T3	17.6	8.7	8.7	195.0	39.0	46.0	20.0
KFQ10T3	18.4	8.8	8.8	220.0	44.0	61.0	20.0
KFQ11T1	18.1	8.3	8.3	160.0	25.0	55.0	15.6
KFQ11T1	21.5	10.2	10.2	270.0	50.0	110.0	18.5
KFQ11T1	23.1	11.5	11.5	430.0	80.0	185.0	18.6
KFQ11T1	20.2	10.5	10.5	280.0	45.0	115.0	16.1
KFQ11T1	21.5	9.8	9.8	285.0	45.0	120.0	15.8
KFQ11T1	21.7	9.0	9.0	230.0	35.0	130.0	15.2
KFQ11T1	22.7	9.0	9.0	260.0	40.0	80.0	15.4
KFQ11T1	21.9	8.0	8.1	215.0	35.0	115.0	16.3
KFQ11T1	19.1	10.4	10.4	305.0	30.0	145.0	9.8
KFQ11T1	21.2	11.5	11.5	345.0	60.0	150.0	17.4
KFQ11T2	20.3	10.9	10.7	356.0	64.0	141.0	18.0
KFQ11T2	18.4	11.3	11.3	352.0	58.0	177.0	16.5
KFQ11T2	20.5	11.0	11.0	294.0	59.0	108.0	20.1
KFQ11T2	20.3	11.4	12.0	383.0	74.0	171.0	19.3
KFQ11T2	20.4	9.9	10.1	262.0	48.0	113.0	18.3
KFQ11T2	20.3	11.3	11.6	382.0	69.0	155.0	18.1
KFQ11T2	22.3	11.5	11.7	389.0	73.0	164.0	18.8
KFQ11T2	23.2	11.1	11.3	360.0	65.0	142.0	18.1
KFQ11T2	22.4	10.8	11.0	402.0	77.0	172.0	19.2
KFQ11T2	24.9	13.0	13.2	482.0	90.0	217.0	18.7
KFQ11T3	15.9	9.7	10.2	235.0	37.0	62.0	15.7
KFQ11T3	19.7	12.0	12.0	460.0	87.0	121.0	18.9
KFQ11T3	19.8	10.6	11.1	380.0	71.0	116.0	18.7
KFQ11T3	20.5	13.5	13.3	425.0	69.0	133.0	16.2
KFQ11T3	20.0	10.3	10.8	385.0	77.0	107.0	20.0
KFQ11T3	17.8	10.4	11.0	265.0	47.0	78.0	17.7
KFQ11T3	16.3	11.2	10.6	260.0	44.0	45.0	16.9
KFQ11T3	16.7	10.0	10.0	210.0	24.0	45.0	11.4
KFQ6T3	51.0	9.4	9.0	550.0	110.0	195.0	20.0
KFQ6T3	60.0	9.6	9.3	750.0	165.0	225.0	22.0