Fruits for the Future 4

Baobab

Adansonia digitata L.

M. Sidibe and J.T. Williams

FRP ICRAF IPGRI DFID

BAOBAB

Adansonia digitata L.

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The International Centre for Research in Agroforestry (ICRAF), established in Nairobi in 1977, is an autonomous, non-profit research body supported by the Consultative Group on International Agricultural Research. ICRAF aims to improve human welfare by alleviating poverty, improving food and nutritional security, and enhancing environmental resistance in the tropics.

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ABBREVIATIONS

FAO -	Food and Agriculture Organisation of the United Naitons
ICRAF -	International Centre for Research in Agroforestry
ICUC -	International Centre for Underutilised Crops
KOH -	Potassium Hydroxide
MSW -	Malawi Society for Wildlife
NGO -	Non-Governmental Organisation
NORAD -	Norwegian Agency for Development Cooperation
RE -	Retinol Equivalent
RI -	Refractive Index
SAFIRE -	Southern Alliance for Indigenous Resources
DG -	Specific Gravity
SIDA -	Swedish International Development Cooperation Agency
WHO -	World Health Organisation

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PREFACE

Tropical fruit trees are important crops which supplement and improve the quality of diets. Many of the species have multi-purpose uses, as they produce non-food products such as fuel, timber, fodder, medicines and industrial products for small-holders. Harvesting from these trees enables rural people to provide nutrition for a balanced diet and generate income thus helping to alleviate poverty. The potential of indigenous tropical fruits has not been fully realised.

Fruit trees play a vital role in crop diversification programmes and agroforestry systems. Their inclusion in production systems reduces the risks which are inherent in the monoculture of staple food crops. In many countries farmer income from indigenous fruits is much higher than that from traditional agriculture.

The purpose of this book is to assemble information on production, processing, marketing and utilisation of baobab (*Adansonia*), in order to identify research constraints and highlight the importance of the species for nutrition and poverty alleviation. This information will be disseminated to a wide audience in both developed and developing countries. An extension manual is in preparation for dissemination to farmers, field workers and policy makers.

The preparation and publication of this book has been funded by the Department for International Development (DFID), UK, as part of a project called "Fruits for the Future". Other partner organisations involved in the project are the International Centre for Research in Agroforestry (ICRAF) and the International Plant Genetic Resources Institute (IPGRI). Baobab is the fourth in a series of 5 monographs and extension manuals.

We hope the information presented in this monograph will be a useful tool for teachers, students, extensionists, policy makers, fruit tree growers and more importantly traders. We also hope that this work may encourage further production, processing and marketing of baobab particularly at the village level, and researchers and scientists to further explore the benefits of indigenous tropical fruit trees such as *ber*. For further information on the series, please visit the project website at: *http://www.soton.ac.uk/~icuc/frufut1*

We would like to express our sincere thanks to Dr. M. Sidibe ??? who has diligently produced the manuscript for this publication, also to Mr. David Jackson for reviewing the manuscript, Ms. Rosemary Wise for the illustrations, the Editorial Committee who has helped our editing and to all the collaborators who provided information and current research papers for analysis and citation.

Editors, August 2002

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Dr. M. Sidibe
2002

CHAPTER 1. INTRODUCTION AND TAXONOMY

1.1 Introduction

The African baobab and its related species belong to the family Bombacaceae and the genus *Adansonia*. *Adansonia* is a member of the tribe Adansonieae, or Bombaceae, depending on the taxonomic treatment, and however natural or not these groupings are, almost certainly the genus is monophyletic. The tribe, which is pantropical, includes *Bombax* and *Ceiba* with species producing fruit fibres used as kapok. *Ceiba pentandra* (L.) Gaetrn. is cultivated in West Africa and Asia. The family includes about 30 genera, six tribes and about 250 species. A number of these species are used locally for wood, fruits, seeds or gum but few are economically important. The family does include economically-important species, such as the durian fruit, *Durio zibethinus* Murr. of tropical Asia; and balsa wood, species of *Ochroma*, of South and Central America; as well as the African baobab.

The distribution of the individual genera of Adansonieae includes those mainly found in tropical America, one Asian e.g. *Bombax*, and some like *Adansonia* that are essentially African but with representation in Australia.

The species of the tribe are usually trees, often having swollen trunks, and producing a staminal tube or androphore in the flower as well as having stipulate, usually palmately compound leaves. The genera of the family show a truncate calyx – except for *Adansonia*, which is typified by the calyx totally enclosing the buds. *Adansonia* also possesses a unique fruit type with a woody pericarp surrounding a spongy pulp with reniform seeds.

1.2 Nomenclature of baobab

The history of known references to African baobab is well documented in Baum (1995). The binomial *Adansonia digitata* was given by Linnaeus, the generic name honouring Michel Adanson who had been to Senegal in the eighteenth century and described *Baobab* (Adanson, 1771).

African baobab is a very long-lived tree with multipurpose uses. It is thought that some trees are over 1000 years old. Since it is not grown agronomically nor properly domesticated, there are no known varieties; earlier attempts to describe some on the basis of fruit differences are not now accepted (Chevalier, 1906; Baum, 1995). It has been introduced to areas outside Africa and grown successfully.

Adansonia digitata L. is related to 7 other species that have not been well known except for descriptions in floras. Most scientific references to these species date from the 1960s (Keraudren, 1963; Miège, *et al.*, 1968, 1973; Miège, 1974, 1975; Armstrong, 1977, 1977a,1983; and the recent work of David A. Baum in the 1990s). They are listed here (table 1.1) to provide a comprehensive picture, although there appears little potential to utilise these other species more widely and certainly research emphasis will be on selection and suitable agronomy of *A. digitata* for the foreseeable future.

Table 1.1. Nomenclature of *Adansonia* species (after Baum, 1995)

Genus Section	Species	Synonyms	Reference	Area
Adansonia	*A. digitata* L.	*A. baobab* L. (1763), *A. baobab* Gaertn. (1791), *A. sphaerocarpa* A.Chev. (1901), *A. sulcata* A. Chev. (1906), *A. digitata* var. *congolensis* A. Chev. (1906)	Syst. Nat. ed. 10, 2:1144 (1759)	Widespread in Africa
Brevitubae Hochreutiner	*A. grandidieri* Baill.		Hist. Nat. Pl. (1893)	Restricted to Madagascar
	A. suarezansis H. Perrier		Notul. Syst. 14 (1952)	Restricted ro Madagascar
Longitubae Hochreutiner	*A. gibbosa* (A. Cunn.) Guymer ex D. Baum	*A. gregori* Mueller (1857), *A. rupestris* W. Saville-Kent (1897), *A. stanburyana* Hochreutiner (1908)		Restricted to NW Australia
	A. rubrostipa Jum. & H. Perrier	*A. fony* Baill. ex H. Perrier (1952)	Mat. Grass (1909)	Restricted to Madagascar
	A. madagascarensis Baill.	*A. bernieri* Baill. ex Poisson (1912)	Adansonia (1876)	Restricted to Madagascar
	A. za Baill.	*A. bozy* Jum. & H. Perrier, *A. alba* Jum & H. Perrier	Mem. Soc. Linn. Paris (1890)	Restricted to Madagascar
	A. perrieri Capuron		Notul. Syst. Paris (1960)	Restricted to Madagascar

1.3 Vernacular names of Baobab

The African baobab is known by a very large number of local names. A selection of important ones is shown in table 1.2.

Table 1.2. Common names for African baobab.

Language	Country	Name
English		Baobab, Monkey bread tree, Ethiopian sour gourd, Cream of tartar tree, Senegal calabash (fruit), Upside-down tree.
French		Baobab, pain de singe (fruit), arbre aux calebasses, arbre de mille ans, calebassier du Senégal.
Portuguese		Cabaçevre
Arabic		Buhibab, hamao-hamaraya, gangoleis (fruit)
	Egypt	Habhab
	Chad	Hamar, hamaraya
	Mauratania	Teidoûm
	Sudan	Tebeldi, humr, homeira
Dinka	Sudan	Dungwol
More	B. Faso	Trega, twega, toayga
Senufo	B. Faso, Mali, Cote d'Ivoire	Ngigne
Dogon	Mali	Oro
Sonrai	Mali	Konian, ko
Dierma		Konian
Bambara	Mali	Sira
Peulh	Mali	Babbe, boki, olohi
Mandinke	Mali	Sira, sito
Baule	Cote d'Ivoire	Fromdo
Hausa	Nigeria, Niger	Kouka, kuka
Wolof	Senegal	Goui, gouis, goui, lalo, boui
Serer	Senegal	Bak
Dirla fogny	Senegal	Boubakakou
Fulani	Nigeria	Boki, bokki
Amhara	Ethiopia	Bamba
Tigre	Ethiopia	Hemmer, dumma
Yao	Malawi	Mlonje
Chichewa	Malawi	Mnambe, Mlambe
Nkonde	Malawi	Mbuye

Language	Country	Name
Yao	Malawi	Mlonje
Somali Kamba	Somalia Kenya	Yag Mwambo
Swahili	Somalia to Mozambique	Mbuyu, majoni ya mbuyu (Tanzania)
Masai	Kenya, Tanzania	Olimisera, ol-unisera
Meru	Kenya	Muramba
Ndebele	Zimbabwe	Umkhomo
Afrikaans and others	S. Africa	Kremetart, kremetartboom; mubuyu, muyu, mbuyu, mkulukumba, mlambe
Zulu	S. Africa	Isimuhu, umshimulu
Creole	W. Indies	Mapou zombi
Hindi	India	Gorakh-imli, hathi-khatiyan
Tamil	India	Papparappuli, anaipuliya-marum
Gujarati	India	Sumpura
Telegu	India	Brahma-mlinka, seemasinta

Other local names can be found in Burkill, 1985 and von Maydell, 1986.

1.4 The importance of baobab

Although *A. digitata* is mostly regarded as a fruit-bearing forest tree, it is a multipurpose, widely-used species with medicinal properties, numerous food uses of various plant parts, and bark fibres that used for a variety of purposes. Centuries ago the products were traded: it was well known in Cairo markets in the sixteenth century.

More recently the Forestry Department of the Food and Agriculture Organisation of the UN (FAO) has issued information on the species (e.g. FAO, 1988), and the International Centre for Research in Agroforestry (ICRAF) continues to promote its use as a multipurpose species. A number of bilateral agencies promoted the species in the past e.g. Norway (NORAD) in Kenya, and Sweden (SIDA) in Tanzania. Regional consultations organised by the International Centre for Underutilised Crops (ICUC) have accorded high priority to enhanced research and development of baobab.

Additionally national research efforts, especially in Nigeria and Mali, have provided relatively recent data on food values and agronomy. Other research, especially in India, has accelerated knowledge of compounds valuable in medicine, and work in Saudi Arabia has also tested certain folk-medicine concepts.

Trials in the dry tropical regions of Africa for plantation development have included the baobab (Delwaulle, 1977; von Maydell, 1981). This publication summarises the most up-to-date knowledge on African baobab. Whatever its future exploitation, it is likely to remain one of the wonders of nature with its huge, swollen trunk (oddly distorted, and thus incongruous) shape, and its close linkages to numerous human cultures with a concomitant wealth of ethnobotanical knowledge. It is to be hoped that exploitation will indeed benefit local people in terms of food and well-being. Interestingly, baobab has affected modern human culture. In Barbados two trees introduced from Guinea are considered one of the seven wonders of Barbados; in South Africa, bonsai baobabs are much sought after; in India, baobab long ago entered the Pharmacopoeia.

CHAPTER 2. DESCRIPTION OF SPECIES

2.1 Botanical and morphological description

2.1.1 The genus Adansonia *(Baum, 1995)*

The genus comprises deciduous trees, some massive and up to 30m tall, others such as *A. gibbosa* less than 10m, and two species, *A. rubrostipa* and *A. madagascarensis* 5-20m. Crowns are usually compact and trunks taper from top to bottom or are large and cylindrical or bottle-shaped. Diameter of trunk can vary 2-10m. Bark is coloured red to grey and the inner bark possesses longitudinal fibres. Wood is soft and arranged in sheets with mucilaginous gum produced when damaged.

Leaves are compound, palmate in shape, spiral and deciduous. Stipules are up to 2mm and caducous (up to 15mm and persistent in *A. perrieri*), Leaflets 5-11, lateral smaller than medial, margins entire or toothed, sessile or petiolate. Apex acute to apiculate, rarely obtuse. Lamina glabrous to tomentose; hairs simple or clumped (figure 2.1).

Flowers single, axillary, up to 5 per branch apex. Peduncle and pedical distinct, pedical with 3 caducous bracteoles. Buds are subglobose or ovoid or cylindrical. Calyx of 5 lobes joined and enclosing the flower at least 6 h before anthesis. Petal 5, free, inserted on the staminal tube, white, yellow or red. Ovary superior with hairs. Fruit a dry many-seeded berry, hard and woody, usually indehiscent. Seeds in a white or creamy, dry or spongy pulp.

A simple key to the species is as follows (modified from Baum, 1995):

Flower buds twice as long as broad, ovoid to oblong. Trees with flat crowns.
- Leaflets usually 9-11, blue green, tomentose. Outer surface of calyx red brown…………………………………...………………..*A. grandidieri*
- Leaflets 6-9, yellow green, subglabrous to scabrous. Outer surface of calyx green………………………………………………*A. suarezensis*

Flower buds elongated (at least 5 times as long as broad or globose). Tree with rounded crown.
- Flowers and fruit on long pendulous stalks, petals as broad as long……………………………….…………………..……..*A. digitata*
- Flowers and fruit on short erect or horizontal stalk, petals 5 times as long as broad.
  - Flower buds 10-15cm, petals white or cream……..……....*A. gibbosa*
  - Flower buds 15-28cm, petals yellow or red.
    - Leaflets with serrate margins, medial less than 2 cm wide, stamen filaments fused into a bundle above top of staminal tube…………………………………………….*A. rubrostipa*

Leaflets with entire margins, medial more than 2 cm wide, stamen filaments free above top of staminal tube.

Leaflets obovate to obovate-elliptic, stipules persistent, fruit peduncle not swollen..…………..…………………..*A. perrieri*

Leaflets lanceolate or elliptic, stipules caducous, fruit peduncle swollen.

Style persistent, fruit usually longer than wide.………*A. za*

Style caducous, fruit usually wider that long …*A. madagascarensis*

*2.1.2 Adansonia digitata (*Wild *1961;* Robyns*, 1963;* Villiers*, 1975,* Palgrave*, 1977;* Wickens*, 1982;* Baum*, 1995)*

The African baobab **tree** is characterised by its massive size, reaching to a height of 18-25m and producing a rounded crown and showing a stiff branching habit. The trunk is swollen and stout, up to 10m in diameter, usually tapering or cylindrical and abruptly bottle-shaped; often buttressed. Giant individuals can reach a girth of up to 28m. Branches are distributed irregularly and large; primary branches may be well distributed along the trunk or limited to the apex; young branches are somewhat tomentose but rarely 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. There is a green layer below the outer layer of the bark presumed to photosynthesise when the tree has shed its leaves.

The tree produces an extensive lateral **root** system and the roots end in tubers. Seedlings produce a strong prominent taproot but this is soon replaced by laterals. Roots of mature trees rarely extend beyond 2m and are relatively shallow: one reason explaining why trees are often toppled in old age.

Leaves are 2-3-foliate at the start of the season and they are early deciduous, more mature ones are 5-7(-9)-foliate. Leaves are alternate at the ends of branches or occur on short spurs on the trunk. Leaves of young trees are often simple. Leaflets are sessile to shortly petiolulate, with great variation in size. Overall mature leaf size may reach a diameter of 20cm and the medial leaflet can be 5-15 x 2-7cm, leaflet elliptic to obovate-elliptic with acuminate apex and decurrent base. Margins are entire and leaves are stellate-pubescent beneath when young becoming glabrescent or glabrous. Stipules are early caducous, subulate or narrowly triangular, 2-5mm long, glabrous except for ciliate margins.

Flowers are pendulous, solitary or paired in leaf axils, large and showy and produced during both wet and dry seasons (plate 1). Pedicels usually vary greatly in length, 15-90cm, with 2 small, caducous bracteoles near the apex of the pedical. Flower bud is globose, sometimes somewhat ovoid with an apex conical to apiculate. **Calyx** (3-)5 lobed, 5-9 x 3-5(-7)cm fused into a disc below but divided to half or more above, lobes triangular or oblong-triangular with apex acute or subacute; green and tomentose outside and cream and villous within; lobes reflexed. **Corolla** 5 partite, white; petals overlapping, obovate about as long as wide (4-)5-9(-10) x (3-)4-8(-12)cm, apex rounded, base shortly clawed, sparsely hairy or glabrous (except for the inside of the claw which is densely hairy).

The **androecium** is made up of a very large number of stamens, 720-1600 forming a lower staminal tube (1.5-)3-5(-6)cm long, tube cylindrical or tapering; upper filaments of stamens free for about the same length as the tube and reflexed to form a ring. Anthers are reniform and *ca* 2mm in length.

The **ovary** is usually 5-10 locular, with deeply intruded placentae; conical to globose, silky tomentose with upward-pointing hairs. Style is exserted about 15mm beyond the anthers, reflexed or erect, villous below and glabrous above and persists after floral abscission. Stigma white with 5-10 irregular fimbriate-papillose lobes.

Fruits are very variable, usually globose to ovoid but sometimes oblong-cylindrical, often irregular in shape, 7.5-54cm long x 7.5-20cm wide, apex pointed or obtuse, covered by velvety yellowish hairs (sometimes greenish) (plate 3). Pericarp 8-10mm thick, woody, enclosing a dry mealy pulp. Seeds are reniform and embedded in the pulp, dark brown to reddish black with smooth testa and 10-13 x 8-10 x 4-5mm due to lateral flattening (plate 2). Seed weight: 2000-3000/kg (von Maydell, 1986). Germination is phanerocotylar and seedlings have flattened hypocotyl *ca* 5 x 4cm and shorter epicotyl. Variation in seedling types has been reported (Srivastava, 1959).

As the key in 2.1.1 shows, *A. digitata* has a number of clear diagnostic characters separating it from the other species of the genus. These include the pendulous flower, the globose buds and broad petals. Additionally the rounded crown and irregularly distributed branching are useful diagnostic characters.

2.2 Reproductive biology

2.2.1 Phenology of Adansonia digitata

The flowering time varies greatly; in general flowering can occur anytime except during the height of the dry season and whether leaves are present or not. Timing of flowering appears to differ between geographically isolated populations but this could be due to regional climatic differences.

Flowers open in the late afternoon and this continues through the night and the number per tree varies from 1 or 2 to 10-50 (Baum, 1995 a) per day and

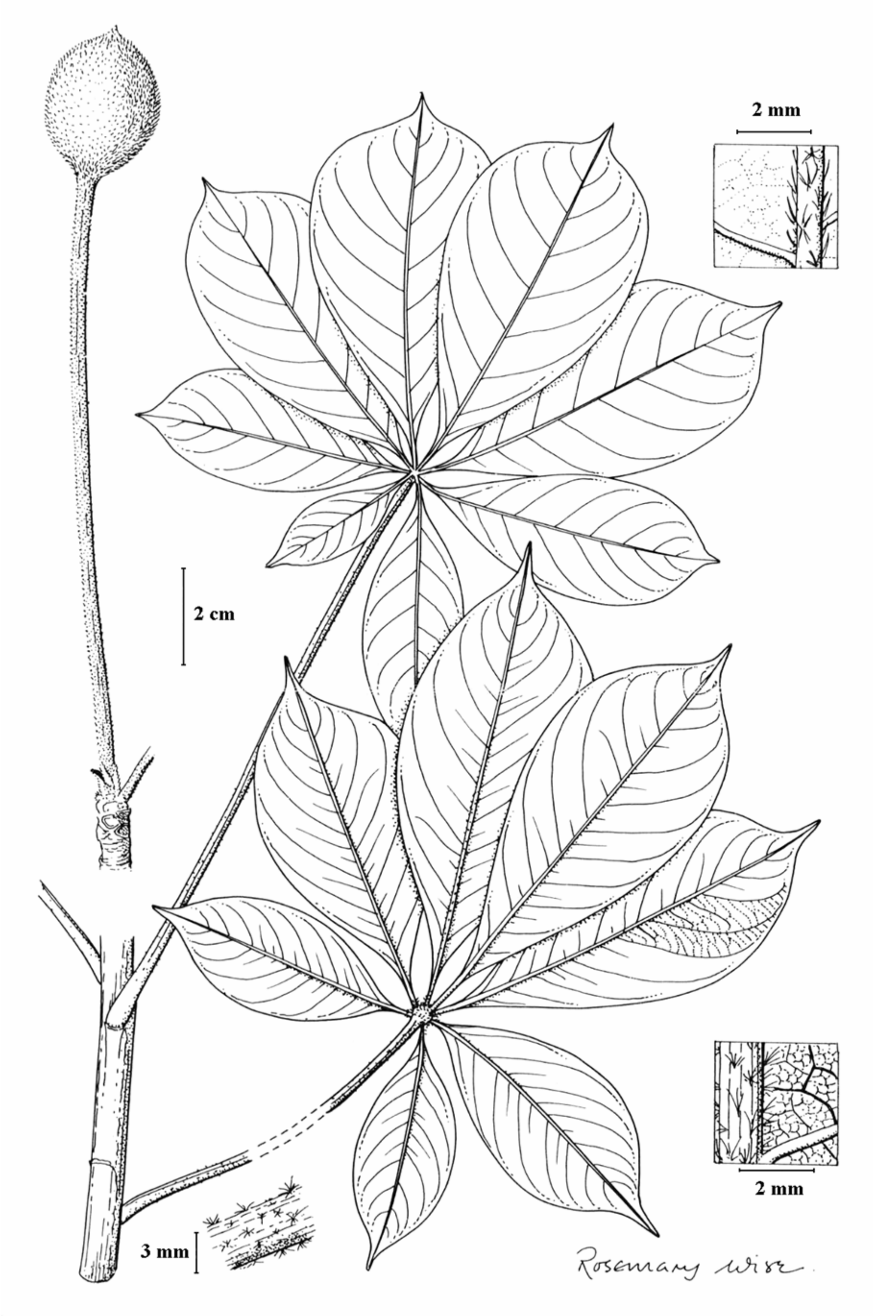


Figure 2.1. Palmate leaf and stem detail of baobab showing clumped hairs.

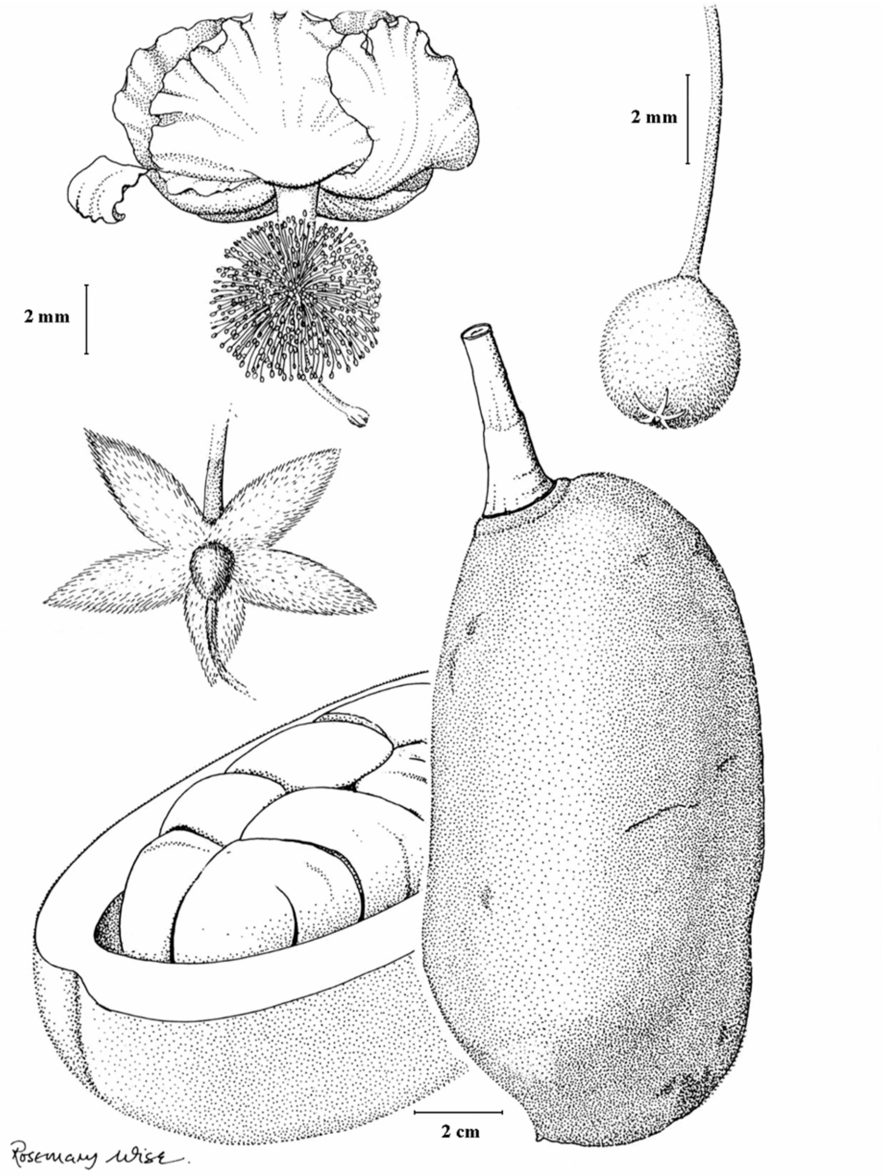


Figure 2.2. Flower of baobab showing the flower bud and calyx, and the fruit showing the mealy pulp inside the hard outer shell

extends for up to 6 weeks. However, there are no data sets confirming this sequence for the wide range of baobab.

Essentially, flowering fits the particular climatic season; ranging from October-December in Southern Africa; November-December in Madagascar; sporadically through the year except January-March (dry season) in Sudan; to May-June in Western Africa.

Once flowers have opened the calyx and corolla lobes curl back to expose the stamens. The morning after flower opening, the calyx and corolla straighten and re-cover the stamens. Flowers progressively wilt until the late afternoon when the corolla is withered and falls off but the calyx persists. It is thought that pollination occurs over a 16-20 h period (Wickens, 1982); however anthesis may only last for less than 1 h (Baum, 1995 a).

Fruits develop 5-6 months after flowering. There are few data on age of trees when first flowering begins. Wickens (1982) notes 16-17 years in South Africa and 22-23 years in Zimbabwe. In part, lack of data is understandable for long-lived perennial trees and noting the difficulties in estimating ages of baobabs using simple girth measurements. Fruits tend to fall during the late rainy season onwards.

2.2.1.1 Phenology of related species

The other species, compared to *A. digitata*, were examined by Baum in Madagascar where they are endemic and to *A. gibbosa* in northern Western Australia where it is endemic. Phenological comparisons are shown in table 2.1. Broad similarities can be noted.

Table 2.1. Phenology of *Adansonia* species (Baum, 1995 a)

	Species	Location	Flowering season	Flowering when in leaf	Peak no. of flowers/night	Timing of Anthesis (h)	Flower duration (days)
Sect. *Adansonia*	*A. digitata*	Madagascar	Nov-Dec	Usually	10-50	19.30-20.00	1
Sect. *Longitubae*	*A. gibbosa*	Australia	Nov-Jan	Usually	10-40	19.30-21.30	2-4
	A. rubrostipa	Madagascar	Feb-Mar	Yes	10-20	19.15-21.15	1.5-3
	A. madagascarensis	Madagascar	Mar-Apr	Yes	20-30	17.30-19.00	3-4
	A. za	Madagascar	Nov-Jan	Yes	20-30	18.30-19.45	1
	A. perriera	Madagascar	Nov-Dec	Young leaves	10-20	17.30-19.00	2-3
Sect. *Brevitubae*	*A. grandieri*	Madagascar	Jun-Aug	No	40-80	17.50-18.20	2.5-4
	A. suarezensis	Madagascar	May-Jun	No	30-50	16.30-17.45	0.5-3

2.2.2 Pollination

Pollination of African baobab by bats was proposed by Porsch (1935) working in Bogor, Indonesia; this was confirmed by Pijl (1936) at the same location. In 1945 a fruit bat (*Eidolon helvum*) was recorded pollinating baobab in West Africa (Jaeger, 1945, 1954; see also Harris and Baker, 1959). Other evidence for bat pollination came from East Africa (Start, 1972). The species were all fruit bats: *E. helvum*, *Epomorphorus gambiensis* and *Rousettus aegyptiacus*.

The flowers emit a scent that attracts the bats. The scent is described as resembling carrion (i.e. a sour smell). Bats swoop down on the flowers to seek the nectar secreted on the inner basal part of the sepals from secretory hairs. Visits are for seconds only and bat claws cling to and damage both corolla and staminal tube of the flowers. Bats have also been thought to eat some pollen (Wickens, 1982).

Suggestions that wind pollination could occur (Jaeger, 1945; Wickens, 1982) or that ant pollination is possible (Humphries, 1982) are discounted by Baum (1995 a), although the suggestion that bush babies (*Otolemur crussicaudatus* and *Galago senegalensis*), known to feed on the flowers, play a pollinating role (Coe and Isaac, 1965) is not discounted; nevertheless they probably only play a minor role.

The sour scent of the flowers also attracts certain flies and nocturnal moths as well as several species of bollworms that might effect some pollination. However, the pendulatory nature of the flowers and phenology favours the action of fruit bats.

The pollination mechanisms of other *Adansonia* species has recently been elucidated by Baum (1995 a). Two systems are apparent: 1. Pollination by fruit bats and lemurs in the two species of Section *Brevitubae* both endemic to Madagascar; 2. Pollination by long-tongued hawkmoths in the species of section *Longitubae*. These include species in Australia (*A. gibbosa*) and 3 in Madagascar (observations not yet being confirmed for the fourth species, *A. madagascarensis*). The two diverse systems correlate with the diversity in floral morphology, phenology and nectar scent of the species. All species pollinated by bats or mammals have a sour scent; all pollinated by insects have a sweet scent.

In all species of *Adansonia*, a number of animals, other than the major pollinators, visit the flowers to exploit nectar and/or pollen.

2.2.3 Seed dispersal and tree regeneration

When fruits fall in the field, the woody outside fractures and termites enter to eat the sweet pulp, thus freeing the seeds. A range of animals carry seeds away from the trees: Wickens (1982) records monkeys, squirrels and rats; and fruits are widely eaten by humans and a number of large animals such as elephants and elands as well as birds.

Fruits can also be dispersed by water systems and this is important when considering the disjunct distribution of the genus and the distribution patterns of *A. digitata* (see Chapter 3).

African baobab is characteristic of thorn woodlands of the savannahs and fears have been expressed that severe droughts of recent years have affected regeneration. Equally significant was a tendency to eliminate baobab when near cotton and cocoa production areas in West Africa because baobab is known to be an alternative host for pests affecting these crops and there was also a fear of certain cocoa viruses in the 1950s. In Eastern Africa, reduction in populations of baobab have been considered a result of increased elephant browsing in national parks.

Surprisingly little is known about natural regeneration rates, but to a large degree this could be because seedlings are not readily recognised since they lack the obvious palmately digitate leaves and swollen trunks. Additionally the association of baobab with the farmed parklands or savannah (plate 30) is a deliberate association with the agricultural environment because of the tree uses, and regeneration may well depend on trees being deliberately planted near settlements. A study in Burkina Faso clearly points in this direction (Gijsbers *et al.*, 1994). This probably marks a change from the past, when rural settlements could well have been made in areas where baobabs were naturally frequent, as postulated by Wickens. Artificial planting is also noted by Giffard (1974) in Senegal and by Sidibé *et al.* (1996) in Mali (plate 32).

For the above reasons, many populations are near to villages or exist as relicts from old human habitation patterns. Young trees respond well to transplanting. In the past some ethnic groups in Mali such as the Dogon, Kagolo and Bambara used to take cuttings from the wild and transplant them around their villages. The Dogon people used to transplant them next to their toilets where they could use wastewater to enable better growth of baobab. This practice originated from the shortage of water at certain times of the year and also a scarcity of wild seedlings: the germination rate of the hard seeds is usually less than 20% (Danthu *et al.,* 1995). In addition, the regenerated plants must be protected from wandering animals during the dry season. Using rigid stakes or fences ensures this protection. Efforts are underway to improve establishment rates from seed and as a result of research in Mali orchards of baobab are possible.

2.3 Cultural associations of baobab

The food, medicinal and other uses of baobab are described in Chapter 5. Here the importance of the tree to other cultural aspects of African life will be summarised.

The species has been accepted as the representative tree for the Republic of the Congo and has been used on stamps of several African countries. Maybe its oldest link to people and their culture is that nomads in dry areas used the hollowed trunks to make into water reservoirs. These have been recorded as holding at least 200 gallons of fresh water and up to 4000 gallons and the water remains sweet for years if kept well closed. Reservoirs can be hollowed out in a few days.

In East Africa, the trunks are hollowed out to provide a variety of shelters and storage spaces (plates 9 and 10). In West Africa, especially in Senegal, and in Zimbabwe, such spaces have been used as tombs – in fact the baobab is one of the only trees in Africa preserved as repositories for the ancestors and hence has spiritual power over the community's welfare. For instance, in Nigeria certain baobabs are centres of worship involving fertility spirits. The Yoruba of South Nigeria often include the name for baobab (Ose) in their village name. In some regions more than one tribal group may venerate a particular tree – especially in Matabeleland, Zimbabwe and the mythical origins of some tribes can be related to ancestor–baobabs. A book on the spiritual significance of baobab is in preparation by David Scannell (see www.mg.co.za/mg/africa) and references to the folklore associated with baobab can be found in Owen (1970) and Armstrong (1983).

CHAPTER 3. DISTRIBUTION

3.1 Baobab in Africa

African baobab occurs naturally in most countries south of the Sahara with notable absence in Liberia, Uganda, Djibouti and Burundi. In some of these countries its distribution is limited, e.g. in Chad, where it is not found in the east, and South Africa where it is mostly limited to the Transvaal.

Essentially, baobab is associated with the savannah, especially the drier parts. However, there are extensions of the distribution into forest areas, probably associated with human habitation. It appears to be introduced into more equatorial areas, such as Gabon, Democratic Congo and Zaire, and to countries with a marked dry season such as São Tomé, Madagascar and Comoros.

Central African Republic represents a natural gap in the distribution, although some introduction has occurred. It has been introduced into Egypt (and Yemen).

Distribution was inadequately known until the Royal Botanic Gardens, Kew, UK initiated a mapping project (Lucas, 1971). This permitted Wickens (1982) to publish a map (reproduced as figure 3.1). To save the need for numerous boundaries on figure 3.1 a list of countries is shown in table 3.1. It should be noted that there are still gaps in the knowledge about distribution.

Table 3.1. Countries of Africa with distribution of *A. digitata*.

Type	Countries
1. Considered indigenous	Angola, Benin, Botswana, Burkina Faso, Cameroon Cape Verde, Chad, Congo, Côte d'Ivoire, Ethiopia, Eritrea, Gambia, Ghana, Guinea, Kenya, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Zambia, Zimbabwe.
2. Considered introduced	Central African Republic, Comoros, Democratic Congo, Egypt, Gabon, Madagascar, São Tomé, Zaire

Figure 3.1. Distribution of *Adansonia digitata* in Africa and neighbouring areas

Source: Wickens, 1982

3.2 Regional diversity and distribution

As would be expected with such a wide distribution, botanists have recorded certain plant characteristics that appear to represent morphological types. For instance, Oliver (1868) noted that Mozambiquan trees had narrower leaves than other types and Worsfold (1899) and Chevalier (1906) noted diverse fruit types in West Africa and North Mozambique, respectively. Much more scientifically-based work is needed to consider patterns of genetic diversity in relation to distribution.

It appears that the extant distribution is probably determined by minimum requirement for a certain annual precipitation - hence its occurrence, at times, in upland areas coupled with the need for a dry season. Its relatively wide ecological tolerance (see Chapter 7), and its amenity to artificial propagation (see Chapter 8) suggests that some wider provenance testing should repay dividends. Trials initiated in the 1970s used exceedingly narrow variation.

3.2.1 West and Central Africa

Baobab is typically a scattered tree in the savannah, and also along tracks and associated with habitation. Its frequent association with similar habitats of *Tamarindus indica* (tamarind) (plates 28 and 29), *Butyrospermum paradoxum* (shea), *Parkia* spp. (locust bean), *Balanites aegyptiaca* (desert date) or *Acacia albida* (Wickens, 1982) places it into a category of incipient domesticate and a likely tolerance beyond its natural home into ecotones.

It is also found on coastal areas e.g. estuarine areas of Senegal, coastal plains of Ghana, Benin and Togo, also coastal regions of Zaire, suggesting secondary colonisation after introduction.

3.2.2 Northeastern Africa

A northern limit is in semi-desert scrub and it becomes more common as annual rainfall increases. In Eritrea and Somalia it is typically lowland, but in Sudan it thrives in the Nuba mountains.

3.2.3 Eastern Africa

In Kenya, southwards to Mozambique, populations are coastal as well as scattered in lowland bush and scrub, although in Tanzania it is a relict on upland plateaux cleared for cultivation.

3.2.4 Southern Africa

In Angola and Namibia it occurs in mature woodland and throughout Angola, Zimbabwe and northern South Africa as a savannah component. In Angola there are also coastal lowland populations.

3.3 Introductions outside Africa

Part of the distribution in Africa can be understood when it is postulated that Arab traders moved baobab. This would explain its occurrence in Yemen and Oman, also on the island of Zanzibar and the introduction to Madagascar (Burton-Page, 1969).

Baobab was widely introduced into India and Sri Lanka and probably resulted from Moslem traders, and Moslem control of large areas, centuries ago. Wickens (1982) records that baobab cannot be identified in any ancient Sanskrit writings.

In a number of areas of introduction, baobab can naturalise e.g. in Mauritius in the past. This is also true of some of the African coastal areas of introduction.

The Portuguese and French traders, as well as Moslem traders, also introduced baobab to other areas. Hence it is found also in Réunion, Malaysia, Indonesia (Java), China-Taiwan, Philippines, Guyana, New Caledonia, Cuba, Haiti, Dominican Republic, Martinique, USA (Hawaii, Puerto Rico, Virgin Islands and Florida), Jamaica, Montserrat, Netherlands Antilles, Dominica, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Trinidad and Tobago, and Barbados.

The basis for many of these introductions was the oddity of the plant shape and its use as an ornamental.

3.4 Distribution of related species

Six of the *Adansonia* species, enumerated in table 1.1 are endemic to Madagascar. They are distributed particularly on the western slopes from the north to the south of the island but they are more numerous in the west and south-west (Baum, 1996). They can be the dominant species in so-called baobab forests. They are, in general, lowland species of dry, deciduous (or semi-deciduous) forest. Baum (1995) considers *A. perrieri* to be a threatened species and *A. suarezensis and A. grandidieri* are facing threats. One species, *A. gibbosa* is distributed in the Kimberley region of Western

Plate 1. Large, showy, white flower of the baobab tree

Plate 2. Open fruit with immature seeds

Plate 3. Pendulous baobab fruits with a velvet-like coating

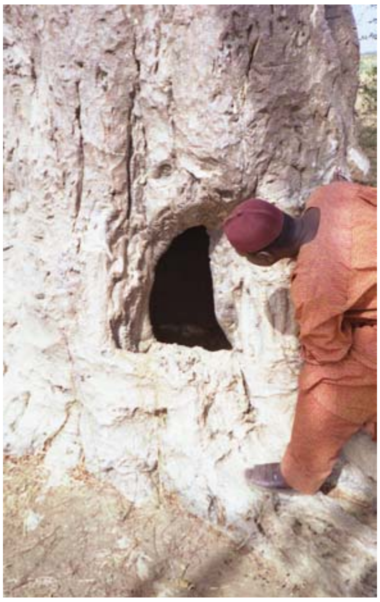
Plate 4. Fruits at different stages of maturity (Cinzana area, Mali)

Plate 5. A tree retaining its leaves during fruiting (Cinzana area, Mali)

Plate 6. A tree without its leaves during fruiting

Plate 7. Two baobab tree varieties planted side by side, one fruiting with leaves and one fruiting without leaves

Plate 8. Fruits stored on the roof of the shelter after harvesting for future use



Plates 9 and 10. Holes in trees vary in size and are used by small animals
and humans for shelter and storage (Cinzana area, Mali)

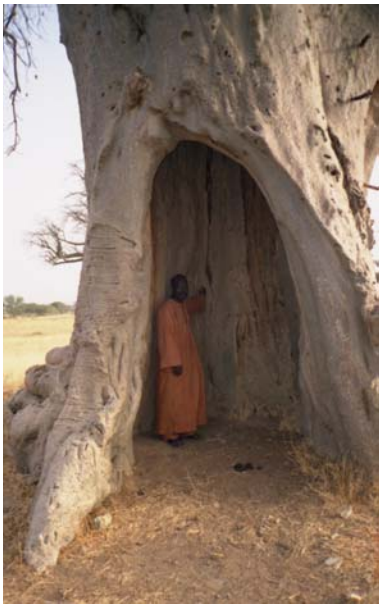


Plate 11. Evidence can be seen of fiber extraction

Plate 12. Bark used for fibre

Plate 13. Cosmetics containing baobab (courtesy of the Baobab Fruit Copamy)

Plate 14. Craft products made from the fruit shell (Courtesy of the Baobab Fruit Company)

Plate 15. Baobab drink products

Plate 16. A women climbing the tree to pick leaves (top left) (Niono area, Mali)

Plate 17. Fresh leaves for sale in a rural market

Australia and the Victoria River area of Northern Territory. It occurs near habitation, along seasonal creeks and river plains and persists in open areas subject to burning.

Every species shows use of the trunks for emergency water supplies and fruits being eaten by humans.

Until Wickens (1982) discussed the disjunct distribution it had been explained as a very ancient relic of the flora of Gondwanaland, the Mesozoic southern continent which later split to form Africa, Australia, Antarctica and South America (Armstrong, 1977). Wickens, however, stressed the possibility of water dispersal of fruits and transoceanic dispersal became a possibility. In a study of the phylogeny of the genus using morphology, molecular analyses of *Adansonia* species and comparisons between *Adansonia* and closely related genera, the evidence produced ruled out Gondwanan disjunction but points to transoceanic dispersal (Baum *et al.*, 1998).

CHAPTER 4. PROPERTIES

Throughout its range, baobab is used for food. The pulp of the fruit, the seeds and leaves are all used and are essentially wild-gathered foods. Such foods play a significant role in preparation of traditional dishes and as sources of food during times of scarcity and famine (Sai, 1969).

Understanding the dietary contribution of such food resources requires data on nutrient composition of both raw and prepared food (Nordeide *et al.*, 1994; Nordeide, 1995). For baobab, the data are widely scattered and relevant research is somewhat fragmentary.

4.1 Leaves

Young leaves are widely used, cooked as spinach, and frequently dried, often powdered and used for sauces over porridges, thick gruels of grains, or boiled rice. Available data (Becker, 1983; Yazzie *et al.*, 1994 and Nordeide *et al.*, 1996) show that leaves contain (dry weight): 13-15% protein, 60-70% carbohydrate, 4-10% fat and around 11% fibre and 16% ash. Energy value varies from 1180-1900kJ/100g of which 80% is metabolisable energy.

In terms of protein content and WHO standards, leaves of baobab can be rated 'good' in that they score well for 5 of the 8 essential amino acids (table 4.1).

Table 4.1. Amino acid composition of baobab leaves (mg/g dry weight)

Amino acid	A	B	SD for A	% of total protein		
				WHO ideal	A	B
Aspartic acid	10.3	12.9	2.5			
Glutamic acid	13.4	11.4	3.8			
Serine	4.7	4.6	1.1			
Glycine	6.0	5.6	1.0			
Histidine	2.1	2.2	0.5			
Arginine	8.5	7.1	2.9			
Threonine	4.1	3.6	0.7	4.0	3.7	3.5
Proline	5.6	6.8	1.0			
Tyrosine	4.5	4.1	0.7			
Valine	6.3	6.5	0.8	5.0	6.2	6.4
Methionine	2.4	1.0	0.4			
Isoleucine	6.7	5.5	1.1	4.0	5.2	5.3

Amino acid	A	B	SD for A	% of total protein		
				WHO ideal	A	B
Leucine	8.7	8.7	1.4	7.0	9.5	8.5
Phenylalanine	5.7	6.0	1.0			
Cysteic acid	2.7	2.1	1.3			
Lysine	6.1	6.1	0.9	5.5	5.8	5.9
Tryptophan	1.6	2.0	0.5	4.0	3.1	2.0
Alanine		6.7				
Phenylalanine & tyrosine				6.0	9.7	9.9
Methionine & Cystine				3.5	4.9	3.0

Data from Glew *et al.*, (1997) and Yazzie *et al*., (1994)
A = material from Jos markets, Nigeria;
B = field collected material from South Burkina Faso.
SD = Standard deviation
WHO ideal (WHO, 1973)

It should be noted that the leaf amino acids, such as tryptophan are increased to acceptable levels when consumed with other staples such as coarse grains. Nordeide *et al.* (1996), who had analysed leaves from Southern Mali, showed lysine appeared to be a limiting amino acid relevant to the FAO reference protein for children 2-5 yrs old (FAO, 1985), but threonine and tryptophan exceeded the standard.

Leaves are also known to be significant sources of minerals, especially magnesium as manganese. Basic data are available in Smith *et al.*, (1996) in material from Burkina Faso and Niger and table 4.2 shows data from Burkina Faso according to Glew *et al.* (1997) and from Nigeria according to Yazzie *et al.* (1994).

Table 4.2 Mineral contents of baobab leaves (μg/100g dry weight)

Minerals	A	B	C	D
Aluminium	-	1230	228	2870
Barium	-	187	182	454
Calcium	20000	26400	3070	3150
Copper	11.6	1	-	-
Magnesium	5490	3120	4360	5350
Manganese	31	43.8	79.5	89.3
Molybdenum	-	9.1	19.8	17.6
Phosphorus	3020	1480	2880	1200
Potassium	-	10800	5400	3210
Sodium	1630	-	-	-

A = Data from Glew *et al.* (1997) B-D = Yazzie *et.al*. (1994)

Glew *et al*., (1997) point out that baobab leaves have a high content of iron compared to numerous other wild-gathered foods, and are a rich source of calcium. Comparisons between published data for the minerals iron, calcium, zinc and phosphorus show wide variations in content. Iron is of especial importance because of the prevalence of iron-deficiency anaemia in savannah areas.

Glew *et al*. (1997) recorded the total lipid content of baobab leaves at 55 mg/g of dry weight and that they were not a significant source of linoleic acid. Nordeide *et al.*, (1996) recorded that the level of vitamin A was about one-third the content in *Amaranthus* dried leaves. Becker (1983) noted the absence of vitamin C but a significant content of vitamin B2.

Scheuring (1999) published the analysis of dried leaf samples carried out by Hoffman-La Roche, Switzerland, for vitamin A (table 4.3).

Table 4.3 Vitamin A contents of baobab leaves

Leaves	Sun dried			Shade dried		
	1	2	3	1	2	3
Young trees, small leaves	5.7	74.5	12.9	12.9	156.5	27.2
Young trees, large leaves	6.7	54.0	9.3	5.1	130.0	22.0
Old trees, small leaves	9.9	87.0	15.3	19.4	147.5	26.2
Old trees, large leaves	4.1	69.0	11.5	7.1	107.0	18.5

1 = μ/g α carotene; 2 = μ/g β carotene; 3 = RE μ/g

4.2 Fruit pulp

The fruit pulp is probably the most important foodstuff. It is dry and mealy and it is used in cool and hot drinks. Pulp can be dissolved in water or milk and the liquid is used as a drink, as a sauce for food, as a fermenting agent in local brewing or as a substitute for cream of tartar in baking. The energy value of pulp is similar to that of baobab leaves (Becker, 1983).

Analysis of ripe fruit points to an average of 8.7% moisture with 2.7% protein, 0.2% fat, 73.7% carbohydrate, 8.9% fibres and 5.8% ash (Arnold *et al.*, 1985). A typical analysis of pulp is shown in table 4.4 and the amino acid composition in table 4.5.

Table 4.4 Chemical composition of baobab fruit pulp

Constituent	Mean %	SD
Total soluble solids	79.3	1.2
Alcohol soluble solids	57.3	2.4
Total sugars	23.2	0.2
Reducing sugars	18.9	0.5
Total pectin	56.2	0.9
Total starch	0	
Proteins (%Nx6.25)	2.6	0.3
Fat	0.2	0.01
Fibre	5.7	0.2
Ash	5.3	0.02

Material from Khartoum market, Sudan. Data from Nour *et al.* (1980)

Table 4.5. Amino acid composition of baobab fruit pulp (mg/g dry weight)

Amino acid	Composition (mg/g dry weight)
Aspartic acid	2.96
Glutamic acid	3.94
Serine	1.18
Glycine	1.21
Histidine	0.42
Arginine	2.28
Threonine	0.65
Proline	2.35
Tyrosine	1.06
Valine	1.62
Methionine	0.14
Isoleucine	1.37
Phenylalanine	2.06
Cysteic acid	1.09
Lysine	1.63
Tryptophan	0.18
Alanine	2.21

Material from Burkina Faso. Data from Glew *et al.* (1997)

The Baobab Fruit Company (2002) also lists amino acids and shows significant levels of leucine, not recorded in table 4.5, as well as threonine, valine and isoleucine with good values for nutrition.

For fatty acids, Glew *et al.*, (1997) recorded total lipid content of 155 mg/g dry weight, and stated that significant linoleic acid is present. Mineral contents are shown in table 4.6 (Glew *et al.*, 1997). Becker (1983) and Odetokun (1996) recorded high potassium levels, not present in the assay in table 4.6, as well as a trace of copper. Mineral analysis of fruits in Malawi also showed high contents of calcium, magnesium and traces of manganese and copper (Saka *et al.*, 1994). More recent analyses collated by the Baobab Fruit Company (2002) show diverse data for minerals: in particular calcium content is ca. 295-300μg/100g, phosphorus varies 96-210mg/100g; iron content was 7mg/100g, magnesium 0.10 mg/100g, zinc 0.064mg/100g and manganese 2.07 mg/100g.

Table 4.6 Mineral contents of baobab pulp

Mineral	μg/100g dry weight
Iron	17
Calcium	3410
Magnesium	2090
Zinc	10.4
Sodium	54.6
Phosphorus	733

Special attention has been given to measuring vitamin C in baobab fruit pulp due to occasional reports of high content. Ighodalo *et al.*, (1991) recorded 337 mg ascorbic acid/100g pulp for fruits in Nigeria, the Baobab Fruit Company (2002) recorded 34-200mg/100g; and Palmer and Pitman (1972) stated levels were higher than in orange. Joint efforts between the Malian Agronomic Research Institute and the Novartis Foundation for Sustainable Development reveal a range from 1505-4991 mg/kg (Sidibé *et al.*, 1996). However, contents remained similar in the same plant source from year to year. Results from bulked samples provided consistent results of about 2200 mg/kg but fruits bulked only from individual trees kept the range of values. However, full statistical analysis did not show consistent differences in vitamin C between regions or between types of trees. The types of trees were selected accordingly to a folk classification of black bark, red bark and grey bark.

Pulp sweetness is provided by fructose, saccharose and glucose contents. Fruit pulp is also acidic and this is due to the presence of organic acids including citric, tartaric, malic, succinic as well as ascorbic acid (Airan and Desai, 1954). This accounts for the tree often being called the Cream of Tartar tree. There are reports of pulp possessing significant amounts of thiamine (Toury *et al.*, 1957), and the Baobab Fruit Company (2002) records content at 0.038 mg/100g (also riboflavine at 0.06mg/100g, vitamin B6 2.13μg/100g, niacin 2.16mg/100g and total carotene at 200mcg/100g).

4.3 Seeds

Seed kernels are widely used, despite the need to remove the relatively thick shell. They are eaten fresh, dry or ground and used in cooking. Kernels have an energy value of 1803 kJ/100g (Arnold *et al.*, 1985) approximately 50% higher than leaves. Arnold *et al.* (1985) also provided data on chemical composition: moisture 8.1%, protein 33.7%, fat 30.6%, carbohydrates 4.8%, fibre 16.9% and ash 5.9%. However, higher levels of carbohydrates have been recorded (Palmer and Pitman, 1972).

Glew *et al.*, (1997) reported that lipid content was 155 mg/g of dry weight with 1-2 mg/g linoleic acid. Amino acids and mineral contents are shown in tables 4.7 and 4.8.

Table 4.7 Amino acid composition of baobab seeds

Amino acid	Mg/g dry weight	% of total protein		
		WHO ideal	Baobab seed	
	A		A	B
Aspartic acid	21.1			
Glutamic acid	48.9			
Serine	11.4			
Glycine	10.4			
Histidine	5.05			
Arginine	2.21			
Threonine	6.98	4.0	3.6	4.1
Proline	9.55			
Tyrosine	5.59			
Valine	11.6	5.0	5.9	6.0
Methionine	2.29			
Isoleucine	8.27	4.0	4.2	3.7
Leucine	14.0	7.0	7.1	7.6
Phenylalanine	10.3			
Cysteic acid	3.60			
Lysine	11.2	5.5	5.7	6.6
Tryptophan	2.81	4.0	1.4	1.4
Alanine	10.6			
Phenylalanine + Tyrosine		16.0	8.1	1.4
Methionine + Cystine		3.5	3.0	1.8

A = data from Glew *et al.* (1997)
B = data from Addy and Eteshola (1984)

The essential amino acids showed similarities between samples from Burkina Faso and from Maiduguri, Nigeria. The content of the sulphur-containing amino acids was 57-86% of the ideal.

Table 4.8 Mineral contents of baobab seeds (µg/g dry weight)

Mineral	µg/g dry weight
Iron	18.3
Calcium	3950
Magnesium	3520
Manganese	10.6
Zinc	25.7
Sodium	19.6
Phosphorus	6140

Significant potassium and measurable copper were recorded by Arnold *et al.* (1985) and potassium by Odetokun (1996).

In view of the shortfall in vegetable oils, especially in the Sahel, studies on seeds of lesser known species have received attention in recent times. Baobab is no exception. β-carotene, a fat-soluble vitamin, was usually studied as well as the oils. Essien and Fetuga (1989) provided overall physical and chemical characteristics of the seed oil (table 4.9).

Table 4.9. Characteristics of the seed oil of baobab compared with palm kernel oil and refined corn oil.

Characteristic	Baobab	Palm kernel	Corn oil
Refractive index (n_D 40°C)	1.468	1.454	1.457
Volatile matter %	1.65	1.56	1.61
Moisture %	2.08	3.93	0.83
Iodine value	85.2	16.3	71.1
Saponification value (mg KOH/g)	157.1	204.7	161.9
Unsaponifiable matter %	0.82	1.80	1.03
Peroxide value	1.86	11.63	21.38
Free fatty acid %	15.53	8.44	0.51

The mean iodine value showed a similar degree of unsaturation when compared with corn oil. The low peroxide value points to a higher level of unsaturated fatty acids. This study, in Nigeria, also showed that β-carotene content was 43.36µg/100g, twice that of palm kernel oil and 7 times that of corn oil.

The Baobab Fruit Company (2002) has collated data from a series of publications and provides the most comprehensive overview of seed oil properties and constituents (tabel 4.10).

The vitamin C content of seeds has not been researched extensively but they are known to contain thiamine (Abbiw, 1990).

Table 4.10 Properties and constituents of the seed oil of baobab

Composition	Quantity
Specific Gravity (SG)	
25/25°C	0.937
Refractive index (RI)	
25°C	
40°C	1.4596-1.4633
Iodine value	55-96
Saponifiable Value	133-195
Unsaponifiable matter %	2.8-3.8
Fatty acid Composition (%)	
12:0	0-0.3
14:0	0.3-1.5
16:0	25-46
16:1	0.3-1.7
18:0	0.4
18:1	21-59
18:2	12-29
18:3	0-8
20:0	0.5-1.0
20:1	0-3.6
Others	
Malvalic	1-7
Sterculic	1-8
Dihydrosterculic	2-5
Sterol Compostion (%)	
Cholesterol	2
Camperterol	6
Stigmasterol	1-2
β-Sitosterol	75
△5-Avenasterol	0.5
△7-Stigmasterol	0.6
△7-Avenasterol	12

4.4 Other constituents

4.4.1 Mucilage

Numerous foodstuffs, particularly in West Africa, are mucilaginous: this provides a desired slimy consistency to local soups and stews. Woolfe *et al.*, (1977) in Ghana conducted a detailed study of the mucilage produced from baobab leaves.

The most interesting feature is the high protein and mineral content both in crude and purified mucilage. The mucilage contains a very small amount of neutral sugars: rhamnose and galactose. Uronic acid is present as a mixture of galacturonic and glucuronic acids. The relatively high proportion of uronic acids classifies the mucilage as a galacturonorhamnan polysaccharide which is acidic.

Viscosity depends on the mix of carbohydrates, proteins and minerals in the mucilage and is lowered with cooking at high temperatures. Nonetheless, baobab mucilage has great potential as a thickening agent.

4.4.2 Pectin

Fruit pulp is rich in pectin, most of it being water soluble with a low content of protopectin. It was found to have a low degree of esterificaton. Intrinsic viscosity values of the water soluble pectin are about one fifth of those of commercial apple pectin and hence does not give a good jelly of high solids content because it tends to precipitate rapidly in acid media to form irregular gels (Nour *et al.*, 1980).

4.4.3 Anti-nutritional factors

Upon cooking or frying, polyunsaturated fatty acids of seed oil undergo transformations such as oxidation, polymerisation and cyclisation. Some of the cyclic components may be toxic. The species of *Adansonia* contain cyclopropene and cyclopropane fatty acids. Whereas cyclopropane fatty acids appear to have no adverse effect on normal fatty acid metabolism, cyclopropene fatty acids or sterculic acid can have adverse effects. This summary is abstracted from Sebedio and Grandgirard (1989) who provided the data in table 4.11 based on earlier analysis by others.

Table 4.11. Cyclic fatty acid content seeds of *Adansonia* species

Species	% oil	Malvalic	Sterculic	Dihydrosterculic
A. digitata	8.4	3.1	1.2	5.1
	13.2	5.1	1.6	1.5
A. grandideri	37.0	6.2	8.1	No data
	30.7	6.3	7.6	4.4
	36.4	6.9	7.4	1.8
A. za	10.9	6.7	2.9	4.6
	11.4	4.9	2.1	4.5
A. madagascarensis	13.8	5.9	2.2	4.0
A. suarezensis	46.2	7.7	4.3	1.7
A. rubrostipa	10.5	5.1	1.6	2.6

The cyclic fatty acids are many times the contents found in cotton seed oil where values for the three compounds in table 4.11 would all be less than 1.0.

Seeds are also known to contain tannin, a trypsin inhibitor and an alkaloid, adansonine. Normal processing in cooking renders most levels acceptable and there are potential methods for reduction if oil is processed (Addy *et al.*, 1995). However, amylase inhibitor is seen in seeds but is considerably reduced when dehulled (Igboeli *et al.*, 1997).

4.4.4 Medicinal compounds

In many medicinal uses, stem bark is used. When prepared it is made into a decoction for internal use and functions due to its soluble and insoluble tannin, and gummy and albuminious constituents. β-sitosterol has been studied and this occurs in the bark and also the seed oil (for reference see Asolkar *et al.*, 1992). The mucilage of leaves has been discussed by Gaiwe *et al.* (1989). Adansonin, with formula $C_{48}H_{36}O_{33}$, in the bark is thought to be the active principle for treatment of malaria and other fevers.

Root bark is also used in India in traditional medicine. This contains β-sitosterol and two glycosides (Ramesh *et al.*, 1992). Other analyses have shown that leaves, as well as bark, contain lupeol acetate as well as β-sitosterol, scopoletin, friedelin and baueronol. Bark additionally contains betulinic acid (Dan and Dan, 1986)

Bark has, in the past, been exported to Europe, for use as a fever treatment.
It was traded as cortex cael cedra.

CHAPTER 5. UTILISATION

Baobab provides food, emergency water, fibres and medicines. This chapter summarises the major uses of baobabs.

5.1 Domestic food uses and local processing

5.1.1 Leaves

Young fresh leaves are cut into pieces and cooked in a sauce. Sometimes they are dried and powdered and used for cooking. The powder is called lalo in Mali and is sold in many village markets in Western Africa. There is a marked seasonality in use of leaves. Nordeide *et al.*, (1996) surveyed two villages and a town neighbourhood to compare rural and urban use of wild foods in southern Mali. Out of over 100 rural households, 26% used baobab leaves in the rainy season, and 56% in the dry season; and out of over 150 urban households, 6% used baobab leaves in the rainy season and 13% in the dry season. Use of fruits was much lower and ranged from 0.5-6% of households, with roughly a two-fold increased use in the dry season.

In Mali, use of the leaves in sauce is usually in association with seeds of *Parkia biglobosa*, onion, okra, pepper, ginger, sometimes meat, but more often fish. The sauce is used with a thick porridge made from millet, sorghum or maize, but also for couscous and rice (Nordeide *et al.*, 1996). In other areas leaves are used for soup e.g. miyan kuka of the Hausa in northern Nigeria and ground leaves are boiled in salt water (Yazzie *et al.*, 1994).

Leaves are used throughout the African distribution of baobab e.g. in Malawi they are boiled with potash (Williamson, 1975). In Zimbabwe, they provide fresh vegetables that are substituted for the commercially grown leafy vegetables such as cabbages ans lettuce (Dovie *et al*., in press), but they do not appear to be used in Madagascar, and not used for food purposes in India.

There are no major reports on storability and quality of powdered leaves. Moreover since leaves are an important source of iron and other minerals, the bioavailability of the minerals requires further study. The high content of tannin may be acceptable in terms of normal usage of the leaves due to an emollient present.

5.1.2 Fruit pulp

The dry pulp is either eaten fresh or used to add to gruels on cooling after cooking – a good way of preserving the vitamin contents. It can also be ground to make a refreshing drink with a pleasing wine-gum flavour. In Tanzania, it is added to aid fermentation of sugar cane for beer making (Fleuret, 1980).

When the fruit is ripe, the pulp is removed from the fibres and seeds by kneading in cold water: the resulting emulsion is seived. This is then added to thick grain preparations to make thinner gruels. The cattle-owning Fulani and the Hausa of northern Nigeria use the fruit pulp emulsion to mix with milk as a drink.

Pulp can be stored for fairly long periods for use in soft drink production but it needs airtight containers. Storage is improved by the use of sodium metabisulphite (Ibiyemi *et al.*, 1988). It can also be frozen if ground to a powder (Obizoba and Amaechi, 1993). Baobab powder mixtures are commonly available in many public markets but quality can be poor and some can be fraudulent.

Fruit pulp is usually sundried, but occasionally fermented, for use in cooking.

5.1.3 Seeds

In general, seeds are used as a thickening agent in soups, but they can be fermented and used as a flavouring agent, or roasted and eaten as snacks (Palmer and Pitman, 1972; Addy and Eteshola, 1984). When roasted, they are sometimes used as a substitute for coffee. In some cases, seeds are de-hulled by boiling, rubbing by hand, then sundrying the kernels before grinding.

Seeds are also a source of cooking oil but this is not widespread, although there has been interest in expanding such use due to deficits of vegetable oils. Oil is extracted by pounding the seeds.

Fermentation of powdered de-hulled seeds is known to increase protein digestibility. It also reduces the trypson inhibition activity sixfold, but increases tannin content (Addy *et al.*, 1995).

Frequently, baobab seeds are ground with peanuts and water and sugar added to make a sauce used with porridge (Pele and Berre, 1967).

Seed pulp is sometimes known as monkey bread is eaten and traded in the region (Dovie *et al*., 2001).

5.2 Domestic non-food uses, other than medicinal

5.2.1 Fibre

Fibre from the inner bark is strong and widely used for making rope, basket nets, snares, fishing lines and is even used for weaving. Fibres are also available from disintegrated wood and have been used for packing. Other fibres used for rope are obtained from root bark.

5.2.2 Dye

In East Africa roots are used to make a soluble red dye. The green bark is also used as a dye and for decoration (Dovie *et al*., in press).

5.2.3 Seed shell

The hard fruit shells are used in the manufacture of pots for food and drink (Dovie *et al*., 2001).

5.2.4 Fuel

The wood is a poor source of fuel; however, fruit shells are used as fuel in Tanzania and they are used as water dippers (Nkana and Iddi, 1991).

5.2.5 Animal browse and feed

Leaves of baobab are routinely browsed especially in the agrosylvipastoral systems in the Sahel. The high tannin content of the leaves has a significant effect on *in vivo* dry matter digestibility. Optimal dry matter degradation in sheep feed was at a level less than 30% of the browse, and browse digestibility of the leaves was 47% (Touré *et al.*, 1998). Since the tannin level is more than twice the critical level, the amount of baobab leaf in the browse has to be kept to a reasonable level; however, an emollient is present in the leaves which may cause acceleration in the ruminant digestive tract.

Shells from the fruits and the seedcake, left after pounding to extract seed oil, are usually fed to animal stock.

5.3 Medicinal uses

5.3.1 Traditional use

Baobab is used in folk medicine as an antipyretic or febrifuge to overcome fevers. Both leaves and fruit pulp are used for this purpose. Fruit pulp and powdered seeds are used in cases of dysentery and to promote perspiration (i.e. a diaphoretic).

Powdered leaves can be used as an anti-asthmatic and they are known to have antihistamine and antitension properties. They are variously used to treat fatigue, as a tonic and for insect bites, guinea worm and internal pains, and to treat dysentery.

Leaves are used for many other conditions: diseases of the urinary tract, opthalmia and otitis. Seeds are also used in cases of diarrhoea, and hiccough.

Oil extracted from seeds is used for inflamed gums and to ease diseased teeth.

Maybe the widest use in folk medicine is the use of the bark as a substitute for quinine in cases of fever or as a prophylactic. Decoction of the bark decomposes rapidly due to the mucilaginous substances present. This can be prevented by adding alcohol or a small quantity of sulphuric acid (Kings, 2002). Recently a summary of the traditional medicinal uses was provided by Dweck (1997).

5.3.2 Antidote to poison

Bark, fruit pulp and seeds appear to contain an antidote to poisoning by *Strophanthus* species. The juice of these species has been used widely as an arrow poison especially in East Africa. In Malawi, a baobab extract is poured onto the wound of an animal killed in this way to neutralise the poison before the meat is eaten (Wickens, 1982).

5.3.3 Use in Indian medicine

- In Indian medicine, baobab bark is used internally as a refrigerant, antipyretic and antiperiodic. It is used as a decoction, 30g/l of water, boiled down to two thirds. Powdered leaves are similarly used to check excessive perspiration. Pulp is used internally with buttermilk in cases of diarrhoea and dysentry.

- Externally, use is made of young leaves, crushed into a poultice, for painful swellings.

- Jayaweera (1981) records similar uses in Sri Lanka.

5.3.4 Use in cosmetic treatments

An infusion of roots is used in Zimbabwe to bathe babies to promote smooth skin (Wickens, 1982). Since seed oil is used to treat skin complaints, to a degree it is used cosmetically.

5.4 Potential for enhanced local use

Enhanced nutrition through promotion of baobab requires attention being paid to local processing e.g. of leaf powders mixed with local alkaline rock salts (Addy *et al.*, 1995), or careful storage of dry fruit pulp. There are many NGOs involved with women and nutrition that can take on this role.

Much of the enhanced use of baobab is low level knowledge transfer. For instance, to retain vitamin C in soft drinks it is important not to boil the pulp but to add the powder to previously boiled water. To retain high levels of pro-vitamin A in dried leaves it is important to dry the leaves in the shade and not in full sun. Also for storage it is recommended to store dried whole leaves rather than leaf powder.

In relation to medicinal properties, attention needs to be paid to standardised preparations – already seen in India and Sri Lanka. Colleges in Africa need to promote this, as, for instance, was the case of the Nigerian College of Arts, Science and Technology in 1959 (*vide* Oliver, 1960). There are now adequate pharmacological results on which to base such preparations e.g. anti-inflammatory and antipyretic effects (Ramadan *et al.*, 1996).

5.4.1 Processing

The Baobab Fruit Company, located in Stallavena, Verona, Italy, promotes the fruit as a healthy food. It has been obtaining supplies from Gambia, Mali and Senegal in collaboration with the Universitites of Pisa and Bologna and African contacts through the Internaitonal Centre for Underutilised Crops (ICUC). This collaboration has led to developing a machine to separate the fruit pulp from the rest of the fruit. This technique could be applied more widely.

Plate 18. Selling baobab dried leaves (Kati livestock market)

Plate 19. Kati livestock market (Mali)

Plate 20. Morphotype '*Sirafing'* in local language (Bamanan), named because of the black bark (Cinzana area, Mali)

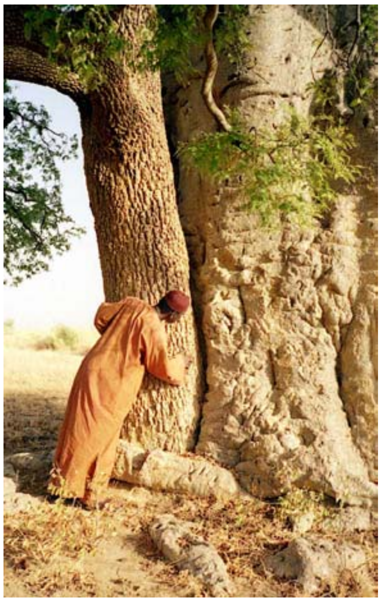
Plate 21. Morphotype *'Sirable'* in local language (Bamanan), named because of the red bark (Mali)

Plate 22. Morphotype *'Siradie'* in local language (Bamanan), named because of the white bark (Cinzana area, Mali)

Plate 23. Hybrid morphotype between *'Sirable'* and *'Siradie'*

Plates 24 and 25. Morphological variation in Baobab trees

Plates 26 and 27. Morphological variation in Baobab trees



Plates 28 and 29. Baobab associated with *Tamarindus indica* (Cinzana area, Mali)

Plate 30. Baobab is associated with many species growing in parkland

Plate 31. Growing on a rocky area (Bandiagara) (Dogon Village, Mali)

Plate 32. Baobab trees intercropped with pearl millet (*Pennisetum glaucum*)

Plate 33. Morphotype *'Sirable'* growing in an irrigated area associated with rice (Niger)

Plate 34. Baobab transplant at Cinzanan Research Station (Mali)

Plate 35. A grafted baobab tree with short stature, allowing easier access for harvesting

The Southern African Natural Products Trade Association aims at promoting eco-trade (*http://www.sanprota.com/products/baobab.htm*). Members of this trade association are actively promoting baobab oil production and fruit beverages produced using standardised processing. The Southern Alliance for Indigenous Resources (SAFIRE), in Zimbabwe, is commercially marketing oil and the Malawi Society for Wildlife (WSM) has been producing fruit juice commercially. The Association is currently studying longer-term marketing and production.

5.4.2 Marketing

Baobab products on the whole, are sold in local, informal markets. The products commonly sold are leaves (fresh and dried) (plate 17 and 18), fruits, craft products and bark (fibre) products. Intermediaries also operate and trade in the larger urban markets. The market chains and infrastructure, however, are poorly developed and inconsistent and as such it is difficult to assess the demand and supply factors which underlie the market.

Harvesting and marketing of baobab products is not the primary activity for most people (Dovie *et al*., in press). These activities reach their peak in the dry season when other field crop production is low. Marketing of baobab products is a secondary means of income generation for most people and can provide a much needed buffer in times of drought and famine.

An overview of the market activities for bark fibre products in Zimbabwe is reported by Dovie *et al.* (in press).

There is a small export industry, particularly for cosmetics (plate 13). Some larger companies are becoming more interested in the 'ethnic' and 'exotic' products which raise a good price in the international market. The export trade for baobab is still very small, however a few products are now available in Europe and the USA.

5.5 Use of the other *Adansonia* species

In Madagascar, at a local level, *A. grandidieri* and *A. za* are used for water cisterns. Both species are also used for food (fruit pulp) and *A. grandidieri* seeds are eaten. A summary of sources and recent observations is provided by Baum (1996).

A. gibbosa, in Australia, is used locally as a water resource, the bark is used to make rope, and fruit is eaten as food (Armstrong, 1983). There are a number of more minor uses.

CHAPTER 6. GENETIC RESOURCES, VARIATION AND SELECTION

Despite its wide distribution very little is known about the genetic variability of baobab.

6.1 Taxonomic variation

It has been suggested that fruit type and geographical distribution can be reflected by distinct forms of baobab, but this is not generally accepted.

6.2 Folk classification/selection

In Mali, rural populations differentiate different types of baobab with the colour of bark (Sidibé *et al.*, 1996). Those with black bark (sirafing) (plate 20) are said to have mild tasting fruits; those with red bark (sirablé) (plate 21) have the most delicious fruits; and those with grey/white bark (siradiè) (plate 22) are used for fibre production rather than having the best fruits.

People look for particular traits including fruit taste, leaf taste, leaf availability and height of the tree. Green leaf availability is less important in the humid areas, because of the availability of other products to serve similar purposes. It is not possible at this time to characterise zones where taste of leaves and taste of fruit can be easily determined in any pattern.

The major types of phenotypic variation relate to: size and colour of leaves; size, form and colour of fruits, seed colour, fruit pulp colour; taste of fruits, and colour of bark. It is important to record characteristics of mature trees. For instance, trees in Mali with a dark shining bark (siramoloni) may be juvenile types, although they are valued for leaf production.

6.3 Germplasm collections

A limited number of forest seed centres hold samples e.g. national centre in Burkina Faso, Mali and Senegal. None of these contain more than a few samples.

Characterisation is not routinely carried out because the highly heritable characters and patterns of genetic variation have not been adequately studied. Some initial work is underway in Mali to see whether the broad types classified on bark colour are genetically based.

Germplasm can be stored as seeds. They are orthodox in behaviour and can be stored at reduced temperatures after drying, thus permitting storage for nursery use and *ex situ* conservation (Some *et al.*, 1990).

6.4 Chromosome numbers

Chromosomes are very small and numerous in Bombacaceae and there are frequently heterochromatin blocks. This has led to a range of chromosome counts in baobab of 2n = 96-144. Baum *et al.*, (1994) reviewed these counts and carried out new ones, finding that 2n = 160. *A. digitata* is now recognised as an autotetraploid that has undergone aneuploid reduction from 4x = 176.

The 6 species of *Adansonia* from Madagascar all show 2n = 88 and the single Australian species also shows 2n = 88 (Baum *et al.*, 1994).

The recent counts of chromosomes of *A. digitata* were made on materials from Burkina Faso, Senegal and East Africa.

6.5 Challenges to selection

In general, trees are selected based on leaves. For this reason wild trees are chosen with a desired quality and seedlings (wildlings), occasionally cuttings, are transplanted to fields near homes where they can receive ‘protection’.

Leaf production is a major challenge due to its seasonality. Production from protected trees does not meet local needs, hence collecting from the wild. Irrigation can extend the leaf production and in Mali the local black bark type responds well to this.

Selection for seed production and use of seeds due to their advantages in nutrition has not been a traditional practice. Also selection of types with fruit pulp with higher vitamin C content is now underway in Mali, but it remains to be seen how this can be transferred through extension.

Traditionally leaf production can be increased through pollarding. It could be that genotypes may be selected to increase leaf production in trees in more remote areas. Also height of tree presents constraints in gathering fruits and accidents are not at all uncommon. Grafting presents an opportunity to reduce this risk.

Constraints are likely to be overcome by due attention to:

1. identification of well-characterised multi-purpose genotypes
2. distribution of such genotypes, with extension packages, including methods to ensure quality preparation of leaves, fruit pulp and seeds
3. vegetative propagation/grafting of desired types

Furthermore, it is possible to produce plant material geared for specific leaf, fruit or fibre production, but extension would require major change in traditional practices.

In the first instance, the major imperative is to improve the human diet, especially in dry areas. This is vividly shown by available data (table 6.1).

Table 6.1. Coverage of nutritional needs in Mali

Calories and nutrients	Rural area coverage rate	Urban area coverage rate
Calories	93.0 %	93.3 %
Proteins	19.5 %	4.6 %
Calcium	6.1 %	85.3 %
Phosphorous	-	-
Iron	92.7 %	263.8 %
Vitamin A	9.4 %	89.5 %
Vitamin C	92.7 %	4.0 %

Source: Mali DNSI, 1988-89

These data point to major lack of protein, calcium and vitamin C in rural areas, and lack of proteins and vitamin C in urban areas.

Selection of baobab would be important in filling these gaps.

CHAPTER 7. AGROECOLOGY

7.1 Eco-climatic zones

FAO has characterised the eco-climatic zones in Africa and these fall into bimodal climates of East Africa and monomodal climates of West Africa. The subdivisions relate to total annual rainfall amount and duration of the rainy season. The distribution of baobabs in relation to climatic zones can be seen in table 7.1 (and figure 7.1).

Table 7.1. Baobab in relation to climatic zones of Africa

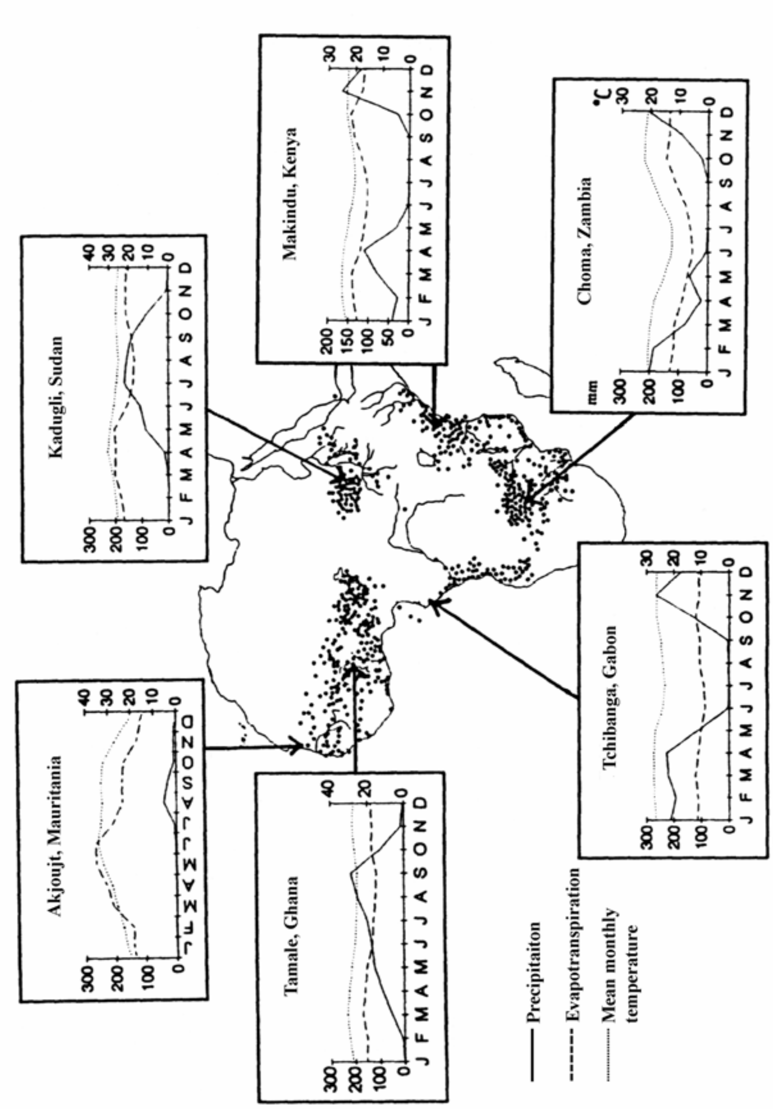
Baobab growth	Climate type	Annual rainfall mm	Rainy season (months) E. Africa	Rainy season (months) W. Africa
1. Baobab growth very marginal	Typical	90+		
	Very arid	100-400	1-3	1-3
2. Baobab growth typical	Typical	300-800		
	Arid	200-400	2-3	2-3
	Semi-arid	400-600	4-5	3-5
	Dry sub-humid	600-800	5-6	4-5
3. Baobab growth occasional	Typical	800-1000		
	Sub-humid	800-1200	6-7	5-7

Source: FAO, 1981; FAO, 1988

Those areas included in row 2 in table 7.1 comprise, in West Africa, the Sahelian, Sudano-Sahelian, northern Sudanian and Southern Miombo ecological zones. In East Africa they include the *Acacia-Commiphora* and *Combretum-Acacia* woodland ecological zones (FAO, 1981) as well as semi-desert grassland.

In terms of temperature baobab can tolerate very high temperature (mean maximum 40-42°C in West Africa) and for minimum temperatures, can survive as long as there is no frost (Simpson, 1995). Typically mean annual temperature is 20-30°C.

Figure 7.1. Climatograms from a range of locations at which *Adansonia digitata* has been mapped by Wickens (data from FAO)



7.2 Elevation

The most common altitudes appear to be 450-600m, but various authors have pointed out baobab distribution from 1-1500m including 1500m in Ethiopia (Wickens, 1982; Wilson, 1988; von Carlowitz, 1991).

7.3 Soils

Baobab can grow on a wide variety of soils. It often occurs on stony, non agricultural soil (plate 31); Thompson (1910) indicated that the baobabs are usually found on rocky and lateritic soils. The baobab tree has been recorded from clays (Harrison and Jackson 1958), sands (Rosevear, 1937; Jenik and Hall, 1976), alluvial silts (Astle *et al.*, 1969) and loams of various kinds (Bogdan, 1958). It is found on quite poorly drained soils in Zimbabwe and on the poorly drained plains of the Zambezi delta (Wickens, 1982) and is also reported on sandy soils overlying compacted silt, liable to flooding in heavy rain, in Nigeria (Keay, 1949)

7.4 Adaptation to drought and fire

Adansonia digitata has an outstanding ability to withstand severe drought and fire, two of the major hazards to plant life in dry areas of Africa (Owen, 1974). Early shedding of the leaves, a water-conserving device of many plant species in areas of low rainfall is seen in baobab. It is also observed that the trunk of the tree contracts when the environment becomes dry and it expands in the wet season. Owen (1974) reported a marked increase in the circumference of a baobab after heavy rainfall, which followed a long drought in South Africa. He also reported that the trunk of baobab is covered by a thick fire resistant bark with regenerative powers. The regeneration results in a thickened uneven integument, which gives the baobab its distorted appearance resembling elephant skin.

7.5 Mycorrhizae

An experiment was carried out to test the dependency of a number of multipurpose fruit trees on arbuscular mycorrhizae (Bâ *et al.*, 2000). Baobab showed that roots could be colonised by *Glomus* sp., but there was low dependency and no increase in biomass as a result.

CHAPTER 8. AGRONOMY

8.1 Seed propagation

Baobab has traditionally been propagated by transplanting naturally regenerated seedlings. However, seedlings are rare due to intensive browsing by livestock. In the field, seedlings do not emerge immediately after seeds are released from fruits due to a dormancy imposed by the hard seed coats which appear to be non-permeable.

8.1.1 Collecting seeds

According to Arum (1989), several methods can be employed in collecting baobab seed. The simplest is collecting dropped fruits from the ground, but this has disadvantages since some immature fruits may have fallen from the tree. The fruits may also have stayed on the ground for a long time, thereby causing the seeds to lose viability or become infected.

Fruits from short trees can be harvested from the ground or by climbing up a ladder. The most common method of harvesting fruits from tall trees is by climbing the trunk and plucking from the crown. As a result of this practice, many trees are found pitted along the trunk where sticks were stuck in to aid climbing the tree.

Poles and sticks can also be thrown into the canopy to dislodge fruits. The collected seeds are air-dried, then stored in clean, dry, sealed and labelled containers in cool dry places to protect them from moisture, insects, fungal infection, or attack by rats and mice.

8.1.2 Seed sowing and germination

Seeds require pretreatment, and the normal method is to scarify with concentrated suphuric acid for 6-12h. This leads to germination of more than 90% (Danthu *et al.*, 1995). Alternatively concentrated sulphuric acid or nitric acid for only 15min gave germinations of 98 and 86% respectively (Esenowo, 1991). In Mali, the Forest Research Institute uses sulphuric acid for 90min followed by water rinsing for 24h, giving germination of 92% or more.

Seeds are sown in nursery potting mixture (3 parts topsoil, 1 part sand and 1 part compost); they can be sown in beds, pots or polybags. After pretreatment, emergence is 4-6 days after sowing, and all those that will germinate will have emerged by 18 days.

In rural areas the acid pretreatment can be replaced by manual scarification (chipping). In some cases seeds are boiled in water for 15 min, but this is a more risky procedure.

When seedlings emerge it is best to shade them for 8 days, provide half shade for 4-7 days and then expose to full light at 12-15 days after emergence. Seedlings require watering morning and evening (but not excessively otherwise there is a danger of stem rot) and also protection from rodents such as rats and mice by using a small mesh wire netting.

Early transplanting is not possible. Normally seedlings need to be at least 3-4 months old, when they have reached a height of 40-50cm, for transplanting. Nursery seedlings can be fertilised using bi- or tricalcic phosphorus and urea with 46%N.

8.1.3 Planting and spacing

Direct seeding into the field has not been very successful; hence seedlings are mainly raised and transplanted into the field at 10x10m spacing. The hole size is 60x60x60cm, but smaller may be suitable (40cm^3) and organic matter is added during planting. Planting is done when the rainy season has started. Protection has to be provided against animal grazing and fire.

8.2 Vegetative propagation

The advantage of vegetative propagation is that identified, superior, mother trees can be grown, thus avoiding a great deal of heterogeneity which results from seed propagation.

8.2.1 Stem cuttings

Since pruned branches frequently sprout young leaves when minimal conditions are present, stem cuttings may be taken, rooted in the nursery and transplanted to the field.

8.2.2 Grafting

The Forestry Department of Mali has shown that it is easy to graft baobab. A veneer graft is used with a plastic film to control transpiration. Rootstocks used are 3 month old nursery seedlings.

Scions were collected in Ségou and Koutiala region from high vitamin C content fruit trees. A success rate of 46% was found with scions kept for 8 days. However the best rate of success (92%) was found with 1 to 2 day old scions. The use of a cap to control transpiration is required in the case where scions are conserved for some time (Sidibé, 1992).

Use of grafting resulted in trees of a lower height than those developed from seeds (plate 35). This facilitates the access for harvesting leaves and fruits. First flowering after grafting was at 3 years. This is extremely significant because grafting noticeably shortens the time to first flowering (8-23 years in plants raised from seed) (Wickens, 1982).

8.3 Growth and production

Data on growth rates relate to seed-propagated trees. On average, a height of 2m is reached in 2 years and about 12m by 15 years (von Maydell, 1986). Young trees add 30cm per year in diameter. Sidibé *et al.*, (1996) reported that transplanted individuals of 0.5m height grew to 2m in the first year after transplanting.

There are few data on production. Arum (1989) estimated that, allowing for variation in site conditions, genotypes, and amount of leaf harvesting incurred, an average mature fruiting baobab produces 200kg of fruit per season. However, it has been noted that wild trees may go several years not fruiting and this is probably due to ecological factors (Swanapoel, 1993).

Harvesting of leaves is constant during the vegetative period, but there are no data relating to production or production related to harvesting frequency and intensity.

There are no data relating to fibre production.

8.4 Husbandry

Baobab trees near habitation are ‘protected’ and therefore nurtured. They tend to receive more water than those trees scattered in the savannah. It has already been mentioned that the Dogon people of Mali used to transplant wild seedlings to areas arranged for showering so that adequate wet conditions were provided until trees were large enough to transplant to other protected sites.

The Forestry Department of Mali is experimenting to grow baobab in irrigated conditions as a market garden plant for leaf production. This means that relatively small trees can be used for intensive leaf production.

8.5 Pests and diseases

Numerous authors have stated that there are no serious pests and diseases of baobab. However, some fungal and viral diseases have been recorded and several insects attack the wood, fruit and young shoots (von Maydell, 1986). The following details are taken from Wickens (1982).

The most investigated common pests are:

- the cotton bollworms *Heliothis armigera*, *Diparopsis castanea* and *Earias biplaga;*

- cotton-stainer bugs such as *Dysdercus fasciatus*, *D. intermeius, D. nigrofasciatus*, *D. suberstitiosus*, *Odontopus exsanguinis*, *O. sexpunctatus;*

- *Oxycarenus albipennis* as well as flea beetles, *Padagrica* spp.

The baobab is also a host for members of the Pseudococcoidae, the mealybugs, which can be vectors for virus diseases of cocoa, also the cocoa capsid, *Distantiella theobroma*.

In Ghana, an unidentified black beetle can damage and eventually destroy branches by girdling. Also, from West Africa, there is a report of a longhorn beetle, *Aneleptes trifascicata*, which will attack and kill young trees by girdling.

In the Transvaal of South Africa a caterpillar, *Gonimbrasia herlina* can feed on the leaves.

The baobab is also a minor host of the mango mealy bug (*Rastrococcus iceryoides*) and the nematode *Rotylenchulus reniformis*. This nematode, in addition to the *Meloidogune* sp. nematode, has implications for Baobab as an inoculum source for newly developed agricultural enterprises in semi-arid areas of Africa (Taylor *et al.*, 1978).

There are few observations relating to fungi. The only macrofungi recorded are *Daldinia concentrica* (Bolt.) Ces. & Br.) and *Trametes socrotana* Cooke. There are only two records for fungal diseases; a leafspot in Sudan (*Phyllosticta* spp.) and a powdery mildew in Tanzania (*Leveillula taunica* (Lev.)) Arnaud.

In West Africa, the presence on the baobab of cocoa viruses has been thoroughly investigated. The conclusion was that the distributional data concerning the original outbreaks of virus infection in the cocoa crops indicate that the infection must have been transmitted by mealybugs from forest species of Bombacaceae, Sterculiaceae or Malvaceae rather than from naturally infected *Adansonia digitata* in the savannah.

Although not serious, mistletoe, *Loranthus mechouvii* Engl. has been recorded as a parasite on the baobab in Angola, and parasitic figs have also been seen.

8.5.1 Physiological 'disease'

In Zimbabwe, trees have been reported to be dying and which exhibit a blackened appearance ('sooty' baobab). There are sooty moulds present along with Homopteran insect exudates. It appears that the condition is a secondary manifestation of a physiological disorder which is episodic and related to lengthy periods of below average rainfall aggravated by increasingly intensive land use in arid areas (Piearce *et al.*, 1994). It is likely that such trees can recover if turgidity returns to normal.

8.6 Harvesting

The age of trees when leaves can be harvested for processing into leaf powder is variable and depends essentially on site conditions. Trees can be harvested from any age. In general, leaf exploitation could start before the sixth year when site conditions are favourable. Women traditionally start harvesting when leaves start to develop and the period varies according to agroecological zones (April to May) (plate 16). In South Sudanian zone, young leaves are available in March. In more humid zones (Bouaké zone in Ivory Coast) leaves are available all the year.

Mass leaf harvesting is done in September and October. When the main work in the fields has ended, the men will climb up in the trees to do the large harvest to keep leaves for use in the dry season. Trees with good-tasting leaves are cut regularly to prevent the development of branches and fruits, and to improve the food quality of leaves.

The tools used in harvesting leaves are sickle (96%), dolé (81%) and hand (18%). Some farmers estimate that dolé is better because it can only cut un-lignified shoots and small branches and resprouting is therefore fast. Some others indicate that the sickle is the best because it gives a clean cut without the damage which the dolé tends to cause. In fact each tool is well adapted to their respective season of use; the dolé is used when the petiole is fresh and easy to cut while the sickle is used towards the end of the harvesting season when the petiole is lignified. Harvesting by hand picking is done less since it is difficult to climb a baobab tree.

It is not easy to note the end of the adolescence period of baobab in Sudanian zone because of intensive pruning of trees for leaf production. In West Africa, baobabs flower and fruit from 8-10 years.

Elsewhere, there are diverse ages reported. In South Africa, baobabs started to flower at 16-17 years, while in Zimbabwe, first flowering has been suggested at 22-23 years. This high diversity could be due to climatic differences.

In general, fruits can be produced from 8-23 years onward. The first fruits are ripe in December and harvesting goes on until April. Baobabs fruit twice a year in Bouaké region in Ivory Coast.

Young men use a dolé tool commonly for fruit harvesting but sometimes fruits are harvested using sticks and are also picked by hand.

CHAPTER 9. PLANTING MATERIAL AND RESEARCH CONTACTS

There is a great need to increase the availability of planting material of baobab. This requires collection of seed. However, determination of ideal sampling strategy is limited by lack of knowledge of genetic variability. Inevitably a species occurring as single, widely spaced trees, with no large forest stands, requires individual collections to be maintained and documented as such.

At present, lack of provenance investigations means that seed available as planting stock relates only to the species and this is likely to include seed of poor quality and/or unsuitable provenances. Until seed is more widely collected and made available, selection of suitable planting material can be based on no more than informed guesses.

Since numerous problems can arise from attempts to develop a regular planting schedule based on imported seed, the clear solution is to develop and expand local seed production areas.

9.1 Current seed suppliers

The following can supply baobab seed:

Baobab Farm Ltd.
PO Box 81995
Mombasa, KENYA

Kenniex Ltd.
PO Box 50982
Nairobi, KENYA

Institute Sénégalais de Recherches Agricoles
76 Rue Mousse Diop
BP 320
Dakar, SENEGAL

All have data on collecting site locality.

Additionally a number of national forestry programmes listed in 9.2 can supply limited amounts of seed.

9.2 Research and extension contacts

At present the amount of effort expended on baobab is relatively limited. Nonetheless, the following are useful contacts.

9.2.1 Regional/International organisations

- CILSS, Ressources Génétiques, Oudgadougou, Burkina Faso
- ICUC, International Centre for Underutilised Crops, University of Southampton, UK
- ICRAF, (International Centre for Research in Agroforestry), P O Box 30677, Nairobi, Kenya
- WECARDA (West and Central African Council for Research and Development), 7, Ave Bourguika, BP 8237, Dakar, Senegal

9.2.2 Nationally-based organisations

BURKINA FASO

- Institut National de l'Environnement *et* de la Recherche Agricole (INERA)

- Université de Ouagadougou, 03 BP 7021 Ouagadougou 03; Tel: (226) 307159 / 381114; Fax: (226) 307242

- Centre National des Semences Forestières, Route de Kaya, 01 BP 2682, Ouagadougou; Tel: (226) 30 12 33; Fax: (226) 30 12 32

- Programme Amélioration Génétique des Ligneux, INERA/CNRST : 03 BP 7047; Tel: (226) 33 40 98; Fax: (226) 31 49 38 / 31 50 03

CAMEROON

- Centre de Recherches Agronomiques d'Ekona, Bureau d'Edea; BP 223 Edea; Tel: (237) 464 629 / 461 419

- Département de Foresterie; Tel (237) 45 14 36; Fax: 237 45 12 02, or Yaoundé (ECOFAC Cameroun); Tel (237) 21 42 73; Fax: 237 20 94 72
- Université de Dschang; PO Box 96, Tel: (237) 451 092 / 45 17 90; Fax: (237) 451 202

CAPE VERDE

- Ministerio de Agricultura AGASP; c/o FAO: Fax: +238 615 654

CHAD

- Direction des Forêts, BP 447, N'Djaména; Tel: (235) 523 128; Fax: (235) 523 839

CÔTE D'IVOIRE

- IDEFOR, Station de Khorogho, 08 BP 31, Abidjan; Tel: (225) 44 28 58/59; Fax (225) 44 21 08

GHANA

- Department of Nutrition and Food Science, University of Ghana, Legon

GUINEA

- Direction Nationale des Forêts et Faune, BP 624, Conakry; Tel: (224) 463 248; Fax: (244) 465 637

KENYA

- Kenya Forestry Seed Centre, PO Box 20412, Nairobi; Tel: (254) 154-32891; Fax: (254) 154 32844

MADAGASCAR

- Silo National des Graines Forestières, BP 5091, Ambatobe Antananarivo.; Tel: (261-2) 41230; Fax: (261-2) 35118

MALI

- Institut d'Economie Rurale, Programme Ressources Forestières, BP 258 Bamako; Tel: (223) 222606/231905; Fax: (223) 223775/225575

- Institut d'Economie Rurale, Programme Ressources Forestières, BP 178, Sikasso; Tel: (223) 620 073; Fax: (223) 620 247

MAURITANIA

- Service Protection de la Nature, Direction de l'Environnement et de l'Aménagement Rural, Mauritanie, c/o FAO; Fax: (222) 253 467, Tel: (222) 253 157 / 251 172 / 258 314

NIGER

- Centre de Semences Forestières, Direction de l'Environnement, BP : 578, Niamey; Tel: (227) 72 3189; Fax: (227) 73 5591 or 723 189

- Institut National de Recherches Agronomiques du Niger, Département de Recherches Forestières, BP 578 ; Tel: +227 610 115 ; Fax : +227 735 591

NIGERIA

- Department of Forest Research Management, University of Ibadan, Ibadan.

- Department of Food Science and Technology, Faculty of Agriculture, University of Maiduguri, PMB 1069, Maiduguri.

- Department of Home Science and Nutrition, University of Nigeria, Nsukha.

SENEGAL

- Direction des Eaux, Forêts, Chasses et de la Conservation des Sols, Division Reboisement *et* Conservation des Sols, BP 1831, Dakar; Tel: (221) 832 0828; Fax: (221) 832 3880

- ISRA Productions Forestières, BP 2312, Dakar; Tel: (221) 8321 638 / 8323 219; Fax: (221) 8329 617

- Projet National de semences forestières, GCP/SEN/039/NET, km 20, Route de Rufisque, BP 3818, Dakar

- Baobab Fruit Company, 55, Ave Albert Sarrant X, Immeuble Allumette, Place de Independence, Dakar

SOUTH AFRICA

- National Nutrition Research Institute, Council for Scientific and Industrial Research, PO Box 395 Pretoria

- FORESTEX-CSIR, PO Box 395, Pretoria; Tel: (27 12) 841 3669; Fax: (27 12) 861 2689 / 841 2681/ 2

TANZANIA

- Natural Tree Seed Project, PO Box 4012, Morogoro; Tel: (255-56) 3903 / 3192; Fax: (255-56) 3275

- Sokoine University of Agriculture, Faculty of Forestry, PO Box 3009, Chuo, Kikun, Morogoro

ZIMBABWE

- Forestry Research Centre, Forestry Commissions, PO Box HG 595, Harare

CHAPTER 10. RESEARCH AND EXTENSION GAPS

Almost every aspect of baobab production and processing requires further research. The following are listed as priorities:

1. Seed collecting and provenance testing (see Chapter 9)

2. Patterns of genetic variation (see Chapter 6)

3. Selection and clonal propagation of specific genotypes for different production objectives (see Chapter 6).

Extension gaps relate to use of products as food and their correct processing in terms of nutrient contents; and promotion of local micro-industries for such products; and more use of intensive production (see Chapter 8)

10.1 Exploiting variation

Rather than choosing 'superior mother trees', what is essentially needed is a scientifically-based programme of evaluation which should identify desirable genotypes. This is because, on present knowledge, the characters of interest are likely to be quantitative and controlled by many genes. Identification of desirable genotypes will only be possible when the effects of the environment can be separated from genetic differences and this requires a long-term research commitment. An evaluation trial using a completely randomised design would be based on the premise that, like oil palm or rubber, the outstanding genotypes have been identified, not in the wild, but in well designed and managed evaluation trials of material collected from areas of diversity. Given that nursery techniques are known, initial layout of a trial could be by use of seedlings which later become vegetatively propagated (i.e. each genotype from a seed can be replicated 5 times as a clonal replicate). Each 'population' in the trial can be represented by a number of natural progenies, related as half-siblings, thereby permitting estimates of heritability. Evaluation for leaf characteristics and production would, of course, precede the wait for food production.

Almost certainly, in baobab, the widely spaced trees and their longevity would lead to them being treated as populations and genetic variation is likely to be as high within the progeny as between diverse trees. Selection of trees for a trial would rely on sampling environmental heterogeneity.

10.2 Promoting extension

There are many Non-Governmental Organisations (NGOs) involved with rural development, local nutrition and tree planting. Suitable manuals need to be developed for their use.

Under the Fruits for the Future project, ICUC is publishing extension manuals to complement the monograph series, of which this book is a part. Information is more focused on the practical aspects of production, propagation, harvesting, processing and utilisation, and methods are illustrated to ease understanding. Such manuals are targeted towards NGOs, extension organisations and agricultural departments of local government. These are a tool with which extension officers can learn and demonstrate the practicalities of tree production. Extension materials should be produced in partnership with NGOs, drawing on their field experience and contact with local comunities. Likewise, distribution of information should make use of the networks and relationships adopted by local based organisations.

10.3 Further information gathering

It is important that data on market values of products and supply and demand estimates are gathered. Additionally data are needed on the production / collecting to consumption chain to see the income derived by the various players and how better processing can lead to value-added products. Such data are essential for any promotion of microindustries. Data could be held by ICRAF and data gathering could be part of the partnerships to be developed with NGOs (see 10.2 above).

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GLOSSARY

abscission - the normal shedding of leaves, flowers or fruits from a plant at a special separation layer, the abscission zone.
acuminate - the shape of a tip or base of a leaf or perianth segment where the part tapers gradually and usually in a concave manner.
acute - terminating with a sharp or well-defined angle.
androecium - all the male reproductive organs of a flower; the stamens. cf. gynoecium.
androphore - a stalk bearing the androecium.
aneuploid - refers to the presence of an irregular number of chromosomes, higher or lower than multiples of the haploid number.
annual - a plant that completes its life cycle from germination to death within one year.
anterior - front; on the front side; away from the axis.
anther - the pollen-bearing (terminal) part of the male organs (stamen), borne at the top of a stalk (filament).
anthesis - flower bud opening; strictly, the time of expansion of a flower when pollination takes place, but often used to designate the flowering period; the act of flower bud opening.
apex - the tip of an organ, the growing point.
apical - pertaining to the apex.
apiculate - having an short point at the tip.
auricle (adj. auriculate) - small ear-like projections at the base of a leaf or leaf-blade or bract.
autotetraploid - relating to a plant or cell with four copies of a haploid set.
axil - the upper angle formed by the union of a leaf with the stem.
axillary - pertaining to the organs in the axil, e.g. buds flowers or inflorescence.
axis - the main or central stem of a herbaceous plant or of an inflorescence.
basal - borne on or near the base.
bisexual - having both sexes present and functional in one flower.
blade - the flattened part of a leaf; the lamina.
bract - a much-reduced leaf, particularly the small or scale-like leaves in a flower cluster or associated with the flowers; morphologically a foliar organ.
bracteole - a secondary bract; a bractlet.
buttress - a flange of tissue protruding from the trunk of a tree tapering outwards towards the base.
caducous - falling off early, or prematurely, as the sepals in some plants.

calyx - the outer whorl of floral envelopes, composed of the sepals.
carpel - one of the flowers' female reproductive organs, comprising an ovary and a stigma, and containing one or more ovules.
ciliate - marginally fringed with hairs (cilia).
connate - united or joined; in particular, said of like or similar structures joined as one body or organ.
cordate - heart-shaped, often restricted to the basal portion rather to the outline of the entire organ.
corolla - the petals of a flower, it is normally coloured.
cotyledon - seed leaf; the primary leaf or leaves in the embryo.
crenate - shallowly round-toothed, scalloped.
crenulate - finely crenate.
cross pollination -the transfer of pollen from the anther of the flower of one plant to the flowers of a different plant.
deciduous - falling at the end of one season of growth or life, as the leaves of non-evergreen trees.
decoction - herbal preparation made by boiling a plant part in water.
decurrent - describes a leaf that extends down the stem below the insertion.
deflexed - bent abruptly downward; deflected.
dehiscence - the method or process of opening a seed pod or anther.
dichotomous - forked, in 1 or 2 pairs.
dicotyledon - a flowering plant with two cotyledons.
diploid - having two sets of chromosomes.
ecotone - a transition area between tow adjacent ecological communities containing characteristics species of each and sometimes species unique to the area.
elliptic - oval in outline.
endemic - confined to small area, limited in geographic distribution.
endocarp - the inner layer of the pericarp or fruit wall.
endosperm - the starch and oil-containing tissue of many seeds.
epicotyl - the stem of a seedling between the cotyledons and the first true leaves.
exocarp - the outer layer of the pericarp or fruit wall.
exserted - protruding.
falcate - scythe-shaped; curved and flat, tapering gradually.
fasicle - a condensed or close cluster.
filament - thread; particularly the stalk of the stamen, terminated by the anther.
fimbriate - fringed, usually with hairs.
foliate - bearing leaves.
genus - a group of related species, the taxonomic category ranking above a species and below a family.
genotype - the genetic constitution of an organism, acquired from its parents and available for transmission to its offspring.

glabrous - not hairy.
glaucous - bluish white; covered or whitened with a very fine, powdery substance.
globose - globe-shaped.
glabrescent - becoming glabrous with age.
grafting - a method of propagation for trees and shrubs by inserting a section of one plant, usually a shoot, into another so that they grow together into a single plant.
gynoecium - all the female parts of a flower.
haploid - half the full set of genetic material.
hypocotyl - the axis of an embryo below the cotyledons which on seed germination develops into the radicle.
indehiscent - not regularly opening , as a seed pod or anther.
indigenous - native and original to the region.
inflorescence - the flowering part of a plant and especially the mode of its arrangement.
lamina - a blade, the leafy portion of a frond.
lateral - side shoot, bud etc.
lanceolate - shaped like a lance head, several times longer than wide, broadest above the base and narrowed toward the apex.
leaflet - a single division of a compound leaf.
leaves alternate - leaves that are not opposite to each other on the axis but arranged at slightly different heights.
locular - havinga cavity or chamber inside the ovary, anther or fruit.
mealy - covered with a coarse flour-like powder.
medial - attached near or at the middle, especiallly midway between costa and margin.
membranous - thin in texture, soft and pliable.
mesocarp - the fleshy middle portion of the wall of a succulent fruit between the skin and the stony layer.
monophyletic - descended from a single ancestral line, see also: polyphyletic.
mucilage (adj. mucilaginous) – a viscous, slimy material secreted by some plants.
naturalised - to cause a plant to become established and grow undisturbed as if native.
nectar - sweet secretion of glands in many kinds of flower.
nectiferous - producing nectar.
node - the place on a stem which normally bears the leaf or whorl of leaves.
obovate - inverted ovate; egg-shaped, with the broadest part above.
obtuse - blunt or rounded at the end.
orthodox seeds - seeds that can be dried to moisture levels between 4 and 6 percent and stored without spoilng.
ovary inferior - with the flower-parts growing from above the ovary.

ovary superior - with the flower-parts growing from below the ovary.
ovate - egg-shaped, with the broader end at the base.
ovoid - a solid with an oval outline.
ovule - the body which after fertilisation becomes the seed.
palmately compound - having veins or leaflets arranged like fingers on a hand.
pantropical - spanning tropical regions around the world.
papillose - bearing minute, pimple-like projections.
-partite - suffix meaning 'deeply divided to the base or almost so, eg bipartite, tripartite, 5-partite etc.
pedicel - a tiny stalk; the support of a single flower.
pendulous - more or less hanging or declined.
peduncle - a primary flower stalk, supporting either a single or cluster of flowers.
pendulous - drooping to hanging downwards.
pericarp (syn. fruit wall) - the wall of the matured ovary.
persistent - lasting beyond maturity without being shed.
petal - a division of the corolla; one of a circle of modified leaves immediately outside the reproductive organs, usually brightly coloured.
petiole - the stalk of a leaf that attaches it to the stem.
petiolate - having a petiole.
petiolule - the stalk of a leaflet.
petiolulate - having a petiolule.
phenology - the study of flowering or fruiting periodicity of plants.
phenotype - the morphological, physiological, behavioural, and other outwardly recognisable forms of an organism that develop through the interaction of genes and environment.
photosynthesise -
pinnate - a compound leaf consisting of several leaflets arranged on each side of a common petiole.
placenta - a region within the ovary to which the ovules are attached.
pollarding - a process where tree tops are severely cut back each year to the same spots on the branches, this forms the growth of large, knobly stubs, from which young shoots can grow.
polygamous - bearing male and female flowers on the same plant.
polyphyletic - having members that originated, independently, from more than one evolutionary line.
polyploidy - having more than two sets of chromosomes.
propagate - to produce new plants, either by vegetative means involving the rooting or grafting of pieces of a plant, or sexually by sowing seeds.
protandrous - refers to a flower, when the shedding of the pollen occurs before the stigma is receptive.
protogynous - referring to a flower where the shedding of the pollen occurs after the stigma has ceased to be receptive.

pubescent - covered with hairs, especially short, soft and down-like.
rachis - the main stalk of a flower cluster or the main leafstalk of a compound leaf.
radicle - the portion of the embryo below the cotyledons that will form the roots.
reflexed - abruptly bent or turned downward.
reniform - kidney-shaped.
reticulate - in the form of a network, netveined.
rootstock - the root system and lower portion of a woody plant to which a graft of a more desirable plant is attached.
scarify - to scar or nick the seed coat to enhance germination walls, or to break down the seed coat using chemicals.
scion - a cutting from the upper portion of a plant that is grafted onto the rootstock of another plant, usually a related species.
self pollination - the transfer of pollen from the anther of a flower to the stigma of the same flower, or different flowers on the same plant.
sepal - a division of a calyx; one of the outermost circle of modified leaves surrounding the reproductive organs of the flower.
sessile - without a stalk.
stamen - one of the male pollen-bearing organs of the flower.
stellate - star-shaped.
stigma - that part of a pistil through which fertilisation by the pollen is effected.
stipule - an appendage at the base of a petiole, often appearing in pairs, one on each side, as in roses.
stipulate - having stipules.
style - the usually attenuated portion of the pistil connecting the stigma and ovary.
sub - prefix meaning 'not quite', 'almost', 'slightly' or 'somewhat'.
subulate - awl-shaped.
sulcate - grooved or furrowed.
tetraploid - having 4 sets of chromosomes (twice the normal number of chromosomes).
testa - the outer seed coat.
tomentose - covered with a thick felt of radicles; densely pubescent with matted wool.
tomentulose - rather tomentose.
tomentum - closely matted, woolly hairs.
truncate - ending abruptly, as if cut off transversly.
villous - bearing long, soft hairs.

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