Sclerocarya birrea (A. Rich) Hochst:
A Wild Fruit Bearing Multipurpose Tree Species

by

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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This dissertation is being submitted in partial fulfilment of the requirements for the degree of MSc in Environmental Forestry (Agroforestry Option).

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This dissertation is the result of my own independent work/investigation, except where otherwise stated.

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DEDICATION

TO MY FIANCÉE, MARGARET R. MACHONGA

My Source of Inspiration and Encouragement for Continuous Study

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ABSTRACT

The dissertation investigates, based on literature review, the resource, domestication and agroforestry potential of Marula [***Sclerocarya birrea*** (A. Rich) Hochst], which is a wild fruit bearing multipurpose tree species. Notes on current classification and synonyms, including some vernacular names and its general description, as well as distribution, ecology, site requirements, phenology and life cycle are highlighted. *Sclerocarya birrea* is one of the most common and important wild fruit tree species of sub-Saharan Africa. It is most abundant in the eastern and southern Africa region. *Sclerocarya birrea* is not domesticated but it is protected and preserved by local people in areas of occurrence. The species bears pale-green, oval fruits which ripen to pale yellow after falling to the ground. The flesh is juicey and greatly appreciated when made into drinks, with flavour between that of the mango and litchi; the nuts within the stone are also delicious. Fresh Marula fruit have a higher vitamin C content than orange.The fruits, including nuts have become more important for market and industry, at the present. The branches and trunk are carved for making grain mortars, stools, ritual plates and spoons; while the bark is used to obtain fibres, dyes, saponins and local medicines. Some research on its domestication, cultivation and improvement are also reported, but they are either on a pilot basis or in a very restricted part of the species range.

RESUMO

Com base na revisão da literatura, a presente dissertação investiga o recurso, domesticação e o potencial agroflorestal do Canho (***Sclerocarya birrea*** (A. Rich) Hochst), fruteira silvestre pertencente ao grupo de especies de uso múltiplo. Igualmente são feitas referências à corrente classificação e sinonímia, incluindo nomenclatura vernácula, descrição geral, distribuição, ecologia, exigencias da especie, fenologia e ciclo de vida. *Sclerocarya birrea* è uma das mais vulgar fruteira silvestre e das mais importante espécie da Africa a Sul de Sahara. Esta especie è abundante na Africa Oriental e Austral. Embora *Sclerocarya birrea* não esteja domesticada, esta è protegida e preservada pelas populações nos locais de ocorrência. Os frutos são de forma oval e de côr verde-pálido quando verdes, passando a amarelo-pálido após a maturação. O fruto produz bastante sumo com sabor entre a manga e o pêssego e que è muito apreciado como bebida; a castanha contida dentro do carouço è também bastante deliciosa. O fruto do canho possui maior teor de vitamina C que a laranja. Quer o fruto, quer a castanha interior revertem de grande importância comercial e industrial no presente momento. Os ramos e tronco são esculpidos para pequenas obras tais como pilão, bancos, pratos e talheres; enquanto que da casca se obtém fibra, tintas e medicamentos tradicionais. Pesquisas na domesticação, bem como no cultivo e melhoramento são também reportados, mas sob forma piloto ou restrita parte da amplitude global desta espécie.

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Chapter One

INTRODUCTION

Wild fruit tree species, although undomesticated, play many important roles in rural areas of many developing countries. They are important traditional sources of fruits, nuts, spices, condiments, leafy vegetables, edible oil, and beverages (Okafor, 1985). According to FAO (1991) and Maghembe *et al.* (1994) they help to supplement existing staples, maintain balanced nutrition throughout the year and provide food in time of scarcity. In addition to fruit production and cash, the extensive list of benefits includes fuelwood, building materials, shade and medicines to local communities.

Available information on the nutritional value of several wild fruit bearing tree species show many to be rich in sugars, essential vitamins and minerals while some are high in vegetable oils and proteins (FAO, 1982; Maghembe and Prins,1994). According to these authors, wild fruits have received little attention in research and development when compared with exotic species

due to their slow growth rates and long periods between germination and fruiting, a low ratio of edible to non-edible parts and irregular fruiting.

Nagy *et al.* (1990) went far indicating that probably one major reason why so many tropical and subtropical fruits were not distributed and domesticated worldwide was simply due to being overlooked by Portuguese, Spanish and Dutch traders during their seafaring explorations between the 15th and 18th centuries.

Presently, there is rapidly growing international interest and concern about the role and domestication of wild tree species (Sinclair *et al.*, 1994; Maghembe *et al.* 1994; Minae, 1991). Studies on identification, phenology, morphology, ecology, germination, domestication and uses of selected wild fruit species (e.g. *Adansonia digitata*, *Boscia senegalensis*, *Mimusops angel*, *Moringa oleifera*, *Tamarindus indica*, *Sterculia africana*, *Uapaka* spp, *Ricinodendron rautanenii*, *Parkia biglobosa*, etc.) have been developed and published in the last two decades (e.g. FAO, 1982; FAO, 1983; FAO, 1984; FAO, 1986; FAO, 1988; FAO, 1991; Hans *et al.* (s.d.); Maghembe *et al.*, 1994; Von Maydell, 1990; Nagy *et al.*, 1990; Vivien, 1989). However, there is still too much to be done. The selection of wild species for possible improvement and development within specific environments can only be carried out successfully when based on adequate information.

Sclerocarya birrea (A. Rich) Hochst, commonly named Marula, is one of the best known wild fruit tree of sub-Saharan Africa region, particularly in the Southern Africa (Gous *et al.*, 1988). However little information is available regarding reproduction, management, different uses and socio-economic status of the species (Peters, 1988).

The fruits of Marula are extremely popular with humans, livestock and game (MacCourt, 1985). They are eaten raw, and made into juice, jam or beer ("mukumbi" or "ucanho"[1]), which is very much appreciated by rural communities in the Southern Africa, especially for traditional rituals and work parties (ENDA, 1991; Palgrave, 1991; Guerra, 1938). Also limited volumes of juice and liqueur prepared from wild collected fruits are already available commercially (Gous, *et al.*, 1988). The nuts can be eaten raw, and may be made into paste or pounded for oil. Concerning studies in dietary use of the species in Swaziland, A-Ogle (1990) reported that it was used as a substitute for groundnuts in vegetable relish by local communities. The branches and trunk are carved for grain mortars, stools, ritual plates and spoons; while the bark is used for medicinal purposes by local people (FAO, 1983; Von Maydell, 1990). In Southern Africa, particularly in Mozambique, Swaziland and Zimbabwe the species has been protected by local communities for many reasons, including traditional rituals (Palgrave, 1991; Macucule, 1991).

Sclerocarya is widespread fruit tree in Africa. It is found from South Africa to Ethiopia, in East Africa and extended throughout central Africa up to Senegal in the Western Africa (FAO, 1983; Von Maydell, 1990, Peters, 1988). It grows in different ecosystems; in open, mixed deciduous woodland (e.g. in open miombo Zambia, Zimbabwe, Malawi and Mozambique) and drier African savanna regions (Kokwaro and Gillett, 1980; Cardoso, 1960).

Sclerocarya birrea is an important indigenous tree with high social and economic values. However, very little work has been done in research and

[1]"mukumbi" - *the beer of Marula in Shona and Venda, Zimbabwe and RSA (ENDA, 1991; Shone, 1979)*; "ucanho" - *the juice or beer from Marula in Tsonga, Mozambique (Guerra, 1938).*

development when compared to its importance. To quote Peters (1988): "considering the apparent nutritional value of the fruit of this tree, it is perhaps surprising that we know virtually nothing about its absolute density and productivity over time".

The purpose of this study is to compile information on the species based on literature. The dissertation is written in a monograph form to bring together current knowledge on the species for use by researchers and development agents for further research and for promoting the species as a component of agroforestry.

Chapter Two

CLASSIFICATION AND DESCRIPTION

2.1. Systematic position

Current Name:	*Sclerocarya birrea* (A. Rich) Hochst (1844)
	(a) Subsp. *birrea*
	(b) Subsp. *caffra* (Sond.) Kokwaro
	(c) Subsp. *multifoliolata* (Engl.) Kokwaro
Class:	Dicotyledoneas
Family:	ANACARDIACEAE
Genus:	*Sclerocarya* Hochst
Synonyms:	*Spondias birrea* A. Rich (1831)
	Poupartia birrea (A. Ridi.) Aubrév. (1950).

Sclerocarya birrea (A. Ridi) Hochst. var. *multifoliolata*. Engl. (1921)

Sclerocarya caffra Sond. (1850)

Sclerocarya caffra Sond. var. *dentata* Engl. (1883)

Sclerocarya Caffra Sond. var. *oblongifoliolate*. Engl. (1895)

Commiphora subglauca Engl. (1912)

Poupartia caffra (soud.) H. Pennier (1944)

(***Sclerocarya birrea*** sensu van der Veven in F.C.B. 9: 67 (1960), non (A. Rich.) Hochst, Sensu stricto)

2.2. Classification overview

Sclerocarya birrea was so named by C.F. Hochstetter in 1844, after A. Guillemin and G.S. Perrotet has named the tree as *Spondias birrea* in 1832 (Shone, 1979). The author indicates also that previously A. Richard had tentatively called it *Spondias sp.* in Senegal Flora. In 1850 the species was also classified into the family Anacardiaceae (the cashew nut - *Anacardium*

occidentale; and mango - *Mangifera indica*; family) by O.W. Sonder as *Sclerocarya caffra* (Anon., 1985; Anon., 1980; Shone, 1979). The name of *Sclerocarya* is original from Greek words (ΣΚΛΗΡΟΚΑΡΥΑ) "skleros" and "karyon" which means the hard stone of the fruit and the nut contained within it (Gous *et al.*, 1988; Shone, 1979; Weinert *et al.*, 1990).

Kokwaro (1986), identified three subspecies namely: *Sclerocarya birrea* subsp. *birrea*, *S. birrea* subsp. *caffra* and *S. birrea* subsp. *multifoliolata*. The criteria used for this classification is the number of leaflets, which also vary from one author to another. As an example, Kokwaro (1986) reported 7-13 leaflets for subsp. *caffra*, while Exell *et al.* (1966) as well as Shone (1979) have recorded 7-17 leaflets for the same subspecies. The interesting differences between the subspecies *birrea* and *caffra* are also reported by Shone (1979). Table 2.1 indicates the main characteristics of the subspecies reported by the authors.

However, some authors recognise that *Sclerocarya birrea* subsp. *caffra* and *Sclerocarya birrea* subsp. *birrea* are not easily distinguishable *per se*. Shone (1979) notes that the differences are not noteworthy. As a consequence, both names are treated as synonyms by Hutchinson and Dalziel (1954); Exell *et al.* (1966); Pinner and Bence (1987); Hedberg and Edwards (1989); Vivien (1989) and Robbertse *et al.* (1986). According to Shone (1979), the differentiation between the subspecies *birrea* and *caffra* is based on the number of leaflets in each leaf, the length of the petioles and the fruit. The author notes also that the real differences between these subspecies are vague.

TABLE 2.1: The differences between *Sclerocarya birrea* subsp. *caffra*, *Sclerocarya birrea* subsp. *birrea* and *Sclerocarya birrea* subsp. *multifoliolata* (Adapted from Shone, 1979; Rodin, 1985; and Kokwaro, 1986).

Characteristic Species	*Sclerocarya birrea* subsp. *caffra*	*Sclerocarya birrea* subsp. *birrea*	*Sclerocarya birrea* subsp. *multifoliolata*[1]
Number of leaflets	7-17 foliate; 3-23 leaflets (11 average); acuminate or cuspidate at the apex	11-37 foliate; 9-23 leaflets obtuse to acute	29-37 leaflets, average 25; up to 1.5 cm. long, rotundate to broadly elliptic
Length of petiolules	leaflets virtually sessile; petiolules 5 mm long	petiolules up to 13 mm long	shortly petiolulate
Bark	rough, flaking off in characteristic disc-shaped flakes; colour pale grey in immature trees and brownish in older trees		
Leaves and fruits	fruit less than 10 mm in diameter; leaf less than 76 mm.	fruit slightly larger (10 mm) in diameter; leaf slightly longer (76 mm)	

[1] This subspecies was only recorded in Tanzania

The use of the genus name *Poupartia* and *Commiphora* for *Sclerocarya* (e.g. Laurens and Paris, 1977; Laurens *et al.*, 1984/5; Laurens *et al.*, 1985) is not only confusion for unified classification, but also a source of complication in the literature search and research. According to several authors (FAO, 1988; Von Teichman and Robbertse, 1986; Von Maydell, 1990; Palgrave, 1991), the most acceptable denomination is now *Sclerocarya birrea* (A. Rich) Hochst.

2.3. Vernacular names

Different names are used for *Sclerocarya birrea* and these vary according to region and country. According to Shone (1979), the popular name Marula is derived from the Northern Sotho name *Morula.* Table 2.1, summarises some vernacular names, indicating language and country of occurence.

TABLE 2.2: The vernacular names of *Sclerocarya birrea* in different countries and languages.

COUNTRY	VERNACULAR NAMES	LANGUAGE	REFERENCES
	marula, cider tree, cat thorn, maroola nut, maroelaboom, morula	English	FAO (1988); Palgrave (1991); Brandwijk (1928); Nagy *et al.* (1990)
	canho, ocanho, canhueiro	Portuguese	Guerra (1938); Cardoso (1960); Gomes e Sousa (1967)
Tanzania	m'ngongo, mongo, mungano	Swahili	FAO (1988)
Malawi	mafula[1], mtondowoka[2], musele[3]	[1] Chichewa [2] Yao; [3] Nkonde	FAO (1988) Shone (1979)

TABLE 2.2: Continued

Mozambique	n'kanhu or nkanyi[1], canhe[1], tsula[1], mefula[2], mepepe[2], mudangua[2], metula[3], merula[3], mecoco[4],	[1]Tsonga; [2]Sena, Ndau [3]Chuabo, Macua [4]Maconde, Macua	Gomes e Sousa (1951); Gomes e Sousa (1967); Guerra (1938); Cardoso (1960); Shone (1979);
Zimbabwe	mupfura[1], mutsomo[1], umganu[2]	[1] Shona [2] Ndebele	FAO (1988); ENDA (1991); Cardoso (1960); Shone (1979)
Zambia	mulala or mulula[1], muyombo[1], muongo[1/2/3], msebe or musebe[4], mgamu[5], msewe[5]	[1] Lozi; [1/2/3] Lozi, Kaonde, Tonga; [4]Bemba; [5]Nyanja	FAO (1988); Fanshawe (1962); Shone (1979); Parker (1978)
Uganda	vine: ekajakaiti; fruit: enaimu[1], ijakait[2]	[1] Karamojong [2] Lango	FAO (1988)
Ethiopia	kumal[1], gamels[1], abengul[2]	[1] Amharic [2] Tigrigna	FAO (1988) Hedberg and Eduards (1989);
Swaziland	um'ganu[1], umtelemba[1], marula	[1]Swati	Cardoso (1960) A-Ogle (1990)
Angola	uongo; ngongo		Cardoso (1960); Ferrão, (1960; 1976)
Namibia	omuongo (tree), omoongo (fruit); ongongo or eegongo	Kwanyama (Ovambo)	Rodin (1985)
South Africa	marula, maruela, um'ganu[1], maroela, olifantsappel[2] mufula[3]	[1]Zulu and Swazi (which means friend) [2]Afrikaans [3]Venda	Cardoso (1960); Anon. (1947); Shone (1979)

2.4. General description of the species

Sclerocarya birrea is by comparison, a tree of average height reaching 10 m to 15 m (Palgrave, 1991; FAO, 1988). However some authors (e.g. Kokwaro and Gillet, 1980; Rodin, 1985; Weinert *et al.*, 1990) have recorded 18 m to 20 m height under favourable conditions. Shone (1979) recorded 95 cm of diameter at breast height; 21 m of spreed and 1.8 m length of bole to fork. It has a well formed light green, rounded crown and very thick branches (Von Teichman and Robertse, 1986). The main morphological characters are as follows:

2.4.1. Stem and bark

Marula has a broad and even trunk and mottled bark (ENDA, 1991). It has normally a single and erect stem, which can reach 80 to 100 cm diameter, but it may be multi-stemed (Cardoso, 1960). The bark of young trees is smooth and grey or pinkish-grey in colour, while the bark of older trees is reddish-grey, irregularly scaly and flakes to give a characteristic and mottled appearance (Exell *et al.*, 1966; Fanshawe, 1962; Von Maydell, 1990; Palgrave, 1991).

Describing the bark of young comparatively to old Marula tree, Shone (1979) stated that it is so unlike that identification of the younger trees is even confused. According to the same author an incision into the stem reveals three distinct layers: (a) the greyish brown corky mature bark; (b) inner living phloem which is red; and (c) a thick soft spongy pink xylem. The thickness of the bark varies considerable, but it is in average 20 mm. Plate 2.1, illustrates the general form of trunk and the appearance of its bark in mature tree.

The bark contains tannin and a bitter principle (Fanshawe, 1962). Investigation on its chemical composition of the bark by Brandwijk (1928) and Shone (1979) indicated 20.5 % tannin and trace of alcaloides, while a detailed analysis of a specimen from a tree of about 10 years old in South Africa resulted in 10 per cent moisture content, 72.8 per cent of insoluble matter, 6.5 of soluble non-tanning matter, 10.7 per cent of tanning matter, 15.8 units red colour, 19.1 units yellow, and 1.0 unit black.

PLATE 2.1: General form of trunk and appearance of the bark of *Sclerocarya birrea.*

2.4.2. Leaves

The *Sclerocarya* leaves are blue-green and grow at the end of the branches (figure 2.1), but the juvenile and new leaves are light green colour (Shone, 1979). The author describes the stem of the leaf and the leaflets as pink on the upper surfaces, when just produced. The size of leaves is also variable but it ranges from 180 mm to 250 mm length and 80 mm to 150 mm width.

The leaves are compound, alternate or in terminal rosettes, imparipinnate and with usually 7-13 pairs of opposite leaflets (Fernandes and Fernandes, 1966). The petiole and rachis is 15 to 30 cm long. 2-23 leaflets have been recorded, but in average they are 11 (Shone, 1979). The leaflets are ovate to elliptic, 2 to 3 cm long, acuminate, alternate to opposite, dark green (Kokwaro, 1986) or discolours (Fernandes and Fernandes, 1966) on the ad-axial surface. However, Shone (1979) recorded 40 to 60 mm leverage length with a width of 20 to 30 mm. The margin of leaflets is entire or dentate-serrate, rounded at the base and petiolulate. Lateral nerves are distinct above and impressed or slightly raised below. Leaflets of coppice growth and in the juvenile stage reddish, frequently toothed, otherwise entire (Kokwaro, 1986; Palgrave, 1991; Von Maydell, 1990).

2.4.3. Flowers

The Marula's inflorescences are axillary and terminal in the male, and subterminal and shorter in the female (Fernandes and Fernandes, 1966; Shone, 1979). Flowers are yellow to dark-yellow, arranged in small racemes (7 to 22 cm long) (Kokwaro, 1986). Male and female flowers are usually found on separate trees (dioecious species). The male flowers are small,

yellow or red and scented, while the female are not scented and are pink or green. Female flowers are on short peduncles, in clusters of about 3 at the end of the twigs. The flowers produce a relatively large amount of nectar, which attracts hoards of insects. Flowers appear from September to November in the East and Southern Africa and from January to May in the Western Africa region (Fanshawe, 1962; Cardoso, 1960; Palgrave, 1991; Weinert *et al.* 1990; Kokwaro, 1986).

2.4.4. Fruits and seeds

Figure 2.1 illustrates the fruits and leaves of *Sclerocarya birrea*, according to Palgrave (1991). Peters (1988) notes that the fruits of the three subspecies appear to be indistinguishable. Von Teichman and Robbertse (1986) describe the fruit of *Sclerocarya birrea* that the mature exocarp comprises the outer epidermis with stomata and lenticels, subepidermal collenchyma and parenchymatous layers with secretory canals. The fleshy parenchymatous mesocarp or sarcocarp also contains secretory tissue. The mesocarp develops after endocarp differentiation and lignification. The developmental sequence within the pericarp corresponds to general pattern in drupes. The endocarp or sclerocarp, which is not stratified, consisting mainly of brachysclereids, fibres and vascular elements, develops from the inner epidermis and adjacent tissue of the young ovary wall including the precambium strands. The operculum represents a well-defined part of the endocarp.

The seed anatomy is described by Von Teichman (1988) and Von Teichman and Van Wyk (1988) as follows: the pendulous, bitegmic, anatropous ovule with dorsal raphe is suspended at the tip of a massive funicle. A group of micellar cells with intensively staining cell walls, the hypostasis sensu stricto, is present. The mature seed-coat is formed by the raphe, extensive chalaza, adjacent, well developed, cup-like hypostase sensu lact, remnants of two integuments and a cuticular layer. The exalbuminous seed of *Sclerocarya birrea* subsp. *caffra* (the Marula) is regarded to be a derived and phylogenetically advanced type. According to Shone (1979), the usual diameter of seed is 20 mm and the average mass 4 g.

The Marula's fruit is drupe, obovoid, yellow (when mature) with three obscure points at the apex, approximately 4 cm in diameter. The fruits grow on female trees only (Gomes e Sousa, 1967; Palgrave, 1991). However, Shone (1979) reported cases of male trees having produced a few fruit, but these fruits are smaller and usually drop off. They contain a very juicey mesocarp and white fibrous flesh which surrounds a large whitish stone with 2.5 cm long in diameter. A single stone contain two or three nuts (Carr, 1957; Exell *et al.*, 1966; Gomes e Sousa, 1967; Von Teichman, 1987).

Fruits mature from February to June in the East and Southern Africa and from April to June in the Western Africa (Exell *et al.*, 1966; Shone, 1979; Kokwaro, 1986). The flesh contains 2-3 seeds (kernels) obolavate and compressed. The seeds are very small, about 2 cm long and 0.4 to 0.8 cm wide.

FIGURE 2.1: Leaves and fruits of *Sclerocarya birrea* on a small branch (Adopted from Palgrave, 1991).

Source: Palgrave (1991)

Chapter Three

THE ENVIRONMENT OF THE SPECIES

3.1. Origin and distribution

Figure 3.1 represents the geographic distribution of *Sclerocarya birrea* in Africa, where the species mainly occurs.

There is no known unique origin point of *Sclerocarya birrea*. While Palgrave (1991) indicated that the species probably originated from north-eastern African region (Ethiopia, Kenya, Tanzania), FAO (1988) pointed out that it is originally from Sahel zone and open dry savanna, including Ethiopia, Tanzania and Senegal. Peters (1988) reported also the occurrence of Marula in Madagascar and Australia.

Sclerocarya is widespread in different African ecosystems and associated vegetation types including open and deciduous woodlands and wooded grassland. In the "miombo" ecozone the species is commonly associated with several species such as *Cordyla africana*, *Albizia* spp,, *Diospyros mespiliformis*, *Trichilia emetica*, *Anacardium occidentale*, *Acacia* spp., *Combretum* spp., *Terminalia sericea*, *Afzelia quanzensis*, *Adansonia digitata*, *Brachyategia* spp, *Julbernardia globiflora*, *Chlorophora excelsa*, *Uapaca* spp.,

and many other species (Cardoso, 1960; Walker *et al.*, 1986; Minae, 1991; Maghembe and Prins, 1994; Maghembe and Seyani, 1991).

FIGURE 3.1: Geographic distribution of *Sclerocarya birrea* (A. Rich.) Hochst in Africa, according to Peters (1988).

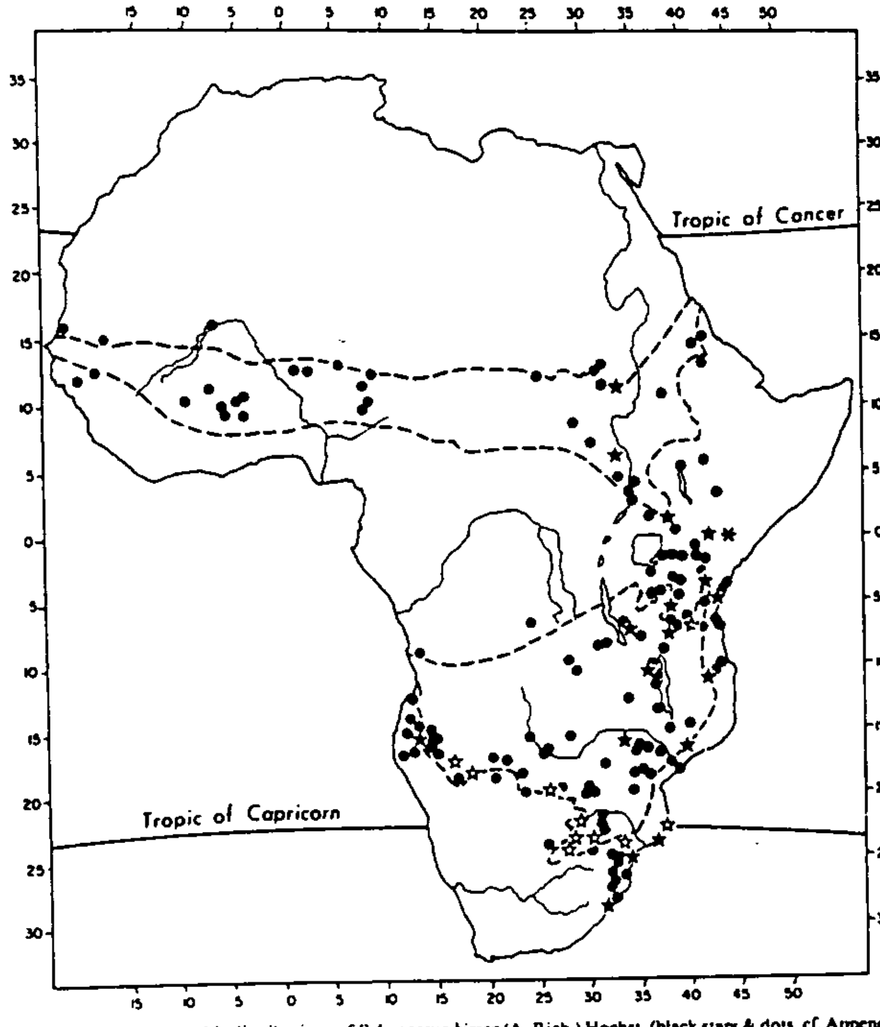


FIGURE 1. Geographic distributions of *Sclerocarya birrea* (A. Rich.) Hochst. (black stars & dots, cf. Appendix I) and *Sclerocarya gillettii* Kokwaro (asterisk near the equator in east Africa). Stars denote presence of localities where the trees are relatively common or scattered but frequent: black stars based on herbarium vouchers; open stars based on other reports, see text. The Zambezian and Sudanian Phytochorial Regions (cf. White, 1981) are indicated by dashed lines. The map is an equal area projection.

Reporting the distribution of the three subspecies of *Sclerocarya birrea*, Hubbard *et al.* (1987) and Peters (1988) indicated that *Sclerocarya birrea* subsp. *birrea* is found mainly in Sahel zone of the North Africa, while *Sclerocarya birrea* subsp. *caffra* is found in the Eastern and Southern Africa, including Madagascar, growing along rivers and open savannas. Fernandes and Fernandes (1966) indicate also that *Sclerocarya caffra* is commonly found in the South of Zambesi river. *Sclerocarya birrea* subsp. *multifoliolata* was only recorded in Tanzania.

The distribution of the species includes the following countries: Ethiopia, Kenya, Tanzania, Zambia, Malawi, Zimbabwe, Mozambique, Madagascar, Botswana, Swaziland, South Africa, Botswana, Namibia, Angola, Gambia, Burkina Faso and Senegal (Palgrave, 1991; Von Maydell, 1990; Exell *et al*, 1966, Gomes e Sousa, 1967, Peters, 1988).

3.2. Ecology and site requirements

Sclerocarya birrea occurs widely in the drier African savanna regions (FAO, 1988). Nevertheless, Gous *et al.* (1988) observed its occurrence in high-lying areas which experience very short sub-zero temperature spells in winter. According to Shone (1979) the controlling factor concerning its distribution in South Africa is frost. The author notes that young trees are sensitive to medium and heavy frosts.

Marula is not a demanding species of soil types. The species grows in sandy soils, heavy sand or clay, lateritic crusts, and in hotter, lower altitudes. While Palmer and Pitman (1972) noted that it is not frost tolerant, Hubbard *et al.*

(1987) as well as Von Maydell (1990) reported that it grows in open, mixed deciduous; in occasional stands, on wooded grassland and rock outcrops. Studying the environment of the species in South Africa, Coetzee *et al.* (1976) reported that it grows as an occasional tree in secondary communities on abandoned native settlements and recently ploughed lands, where it is associated with *Acacia tortilis.* Plate 3.1. shows *Sclerocarya birrea* in its natural habitat open "miombo" woodland in Báruè district, central region of Mozambique.

Unfortunately, in some regions, *Sclerocarya* populations are reported to have ecologically unstable age structure, a possible consequence of which may be a decline in its status and distribution, including the disappearance of the species. Research conducted by Walker *et al.* (1986) reporting population dynamics of several species of South African savanna, including *Sclerocarya birrea*, concluded that most of the species show approximately stable age structures, except *Sclerocarya birrea.* The author pointed out that reduced numbers in some size classes have been indication of possible future fluctuations of populations of mature trees. As the author observed, *Sclerocarya birrea* revealed markedly unstable structure, with no immature trees and no evidence of successful natural regeneration.

A study on dynamics and natural regeneration of Marula associated with other woody species in Burkina Faso, revealed the average monthly shoot density (vegetative regrowth) of only 1 shoot ha $^{-1}$, while seedling density (generative regeneration) was 2 seedlings ha $^{-1}$ (Gijsbers *et al.*, 1994). The author indicate also that during the survey period, the observed traces of browsing were 20 % for monthly shoot and 15 % for the seedlings. These

figures may again, confirm the probable instability of the structure of the species in some ecological regions.

PLATE 3.1: *Sclerocarya birrea* in its natural habitat open miombo woodland in Báruė district (Nhamatema location), central Mozambique.

Courtesy of A. Sitoe

According to Kokwaro and Gillett (1980), the species performs well on altitudes between 600 and 1200 m. Nevertheless, notable range on rainfall requirements is recorded from different authors. While FAO (1988), indicated 200 mm as minimal and a maximum of 1100 mm rainfall requirements for subsp. *caffra* and subsp. *birrea*, Kokwaro and Gillett (1980) pointed out that subsp. *multifoliolata* grows only at 500 mm rainfall and 750 m to 1800 m of altitude in Tanzania. According to Peters (1988), in East Africa, *Sclerocarya birrea* ranges in elevations from 5 m to 1800 m and it experiences the maximum rainfall of 1500 mm.

Shone (1979) stated that Marula is best suited to the drier areas receiving an annual rainfall of between 250 mm and 800 mm, but notes also that during periods of extremely severe drought large number of the bigger trees have died. Its well-developed root system plays an important role against most drought periods. The author indicated also that under favourable conditions the tree grows about 1 m per year.

The growth and distribution of the species may be influenced by climate, especially in the form of rainfall, but fire is also a major ecological factor affecting the region of its occurrence (Shone, 1979). Most dry regions are dominated by perennial grasses which burn fiercely almost every year and the chance of survival of tree seedlings or saplings are low. *Sclerocarya birrea* is a drought and fire resistant species and it has a very strong coppicing power and capable to regenerate from suckers after burning (Peters, 1988; Von Maydell, 1990). This may be an important adaptability across the region of its occurrence.

Weinert *et al.* (1990) and Coetzee *et al.* (1976) state that the species performs well in tropical or subtropical conditions, with a preference for deep and well drained sands and loams. This explains its more widespread and relative abundance in association with hills, rocky ridges, alluvial soils near rivers, and coastal plains (Peters, 1988). The species shows 4 to 8 months of dry season adaptability.

3.3. Phenology and life cycle

Throughout its distribution, *Sclerocarya birrea* shows distinct phenologies according to climatic conditions. The species sheds its leaves from October to July in the Sahel and produces new leaves from August to November in West Africa (Von Maydell, 1990), while it sheds from April to September and produces new leaves from September to February in Eastern and Southern Africa (FAO, 1988; Palgrave, 1991; Shone, 1979; Cardoso, 1960). Shone (1979) notes also that although Marula is definitely deciduous species, it is not unusual to see a single branch in an otherwise leafless crown carrying leaves during drought period.

The species starts flowering one to two months after new leaves. Reporting the phenology of the species after experimental observations in Malawi, Hall-Martin and Fuller (1975), indicated coincidence on outset of flowering and the beginning of rainy season. The authors note also that the period during which the plants bore fruits was much longer than the flowering period.

Flowers appear from September to November in the East and Southern Africa and from January to May in the Western Africa region and the species is pollinated by insects. However, no specification of the insects is made in the

literature. Fruits fall towards February to June in the East and Southern Africa and from April to June in the Western Africa (Ogbobe, 1992; Palgrave, 1991; Kokwaro, 1986; FAO, 1988; Cardoso, 1960). This cycle is repeated in all regions of its occurrence due to bimodal climate.

Sclerocarya birrea begins to bear fruits after 6 to 8 years. However, Campbell (1986) and Maghembe *et al.* (1994) note that it comes into full production after 10-12 years, while FAO (1990) indicate that productivity of the species declines steadily in the elder trees. Fruit production per tree and number of seeds per kg are reported in Chapter four. There is no well documented information about its life span, but it is a long lived tree and may reach more than 80 years.

Chapter Four

RESOURCE ROLE OF THE SPECIES

4.1. Fruit and kernels as food

4.1.1. Domestic uses

Fruits and kernels are the most useful resources of the species. The flesh, which is the most important product, can be eaten fresh or alternatively mixed in equal proportion with water and fermented to produce a delicious, potent and very appreciated beer ("mukumbi" or "ukanho") (FAO, 1990; ENDA, 1991; Rodin, 1985; Shone, 1979; Cardoso,1960; Guerra, 1938). It is also boiled down to make a syrup for sweetening porridge, and brewed to make an intoxicating drink (A-Ogle, 1990). While in Sothern Africa fruits are very popular, in Western Africa (e.g. Nigeria) they are less known for dietary uses (Ogbobe, 1992).

The juice and beer are the most common ways of fruit consumption. However, Shone (1979) stated that the name beer for Marula's beverage is a misnomer, and that Marula cider or wine would be more appropriate as the beverage is unlike beer in taste, colour and appearance. The denomination "wine" for Marula's beverage is also used by Rodin (1985), reported in an

ethnobotanical study in Namibia. The method used for preparation of beer in the Southern Africa region is clearly explained by FAO (1988) as quoted below:

> " Ripening fruits are collected and placed in a clay pot until the pot is half-filled with fruit; cold water is added; the pot is left to stand for 2 days. Then the skins are discarded and the fruits squeezed back into the pot, which is covered with a plate. The outside of the pot is sealed with mud. After 4 days the brew is ready for drinking ".

However, various other methods of making Marula beer are reported in the literature. According to Shone (1979), the beer known as *toshitowatowa* or simpler *xitowatowa* (Tsonga) is a preparation to which no water has been added. This beer is considered more potent than that to which water has been added. The author reported also that old women invariably prepare the fruit using fork or spatula.

In Namibia, Marula's alcoholic beverage is really popular and it is an important part of the Ovambo's diet and culture (Rodin, 1985). The author pointed out that making wine is a communal event, where women from several kraals, along with their infant children, gather under one big tree and bring all the fruit on the ground into the central area. Similarly to other Bantu tribes in Southern Africa, old women and their children will sit, talk and sing joyously and laugh while they squeeze out the juice (plate 4.1).

According to Rodin (1985), Ovamboland celebrates the "Month of the Marula" when these fruits are ripe and this is reported as time of great festivity over Namibia. Many social aspects take place during this time. The author indicated that this is a moratorium on crime: no one steals or is supposed to fight, and no court sessions are held before headmen. No one makes complaints if his neighbour's cattle accidentally get into his millet field.

The Tsonga people celebrate the Feast of the First Fruits every year, by pouring a libation of the fresh juice over the tombs of their dead chiefs (Palgrave, 1991). They invoke their ancestors and ask for rain, followed by drink and traditional dances. Plates 4.2 and 4.3, illustrates the ceremony of "ukanho" by Shangaan people (Tsonga), Southern Mozambique.

PLATE 4.1: Women making Marula wine. This is the common procedure among Bantu tribes of Southern Africa (Picture: Kwanyamas women of Namibia making Marula wine. Adopted from Rodin, 1985)

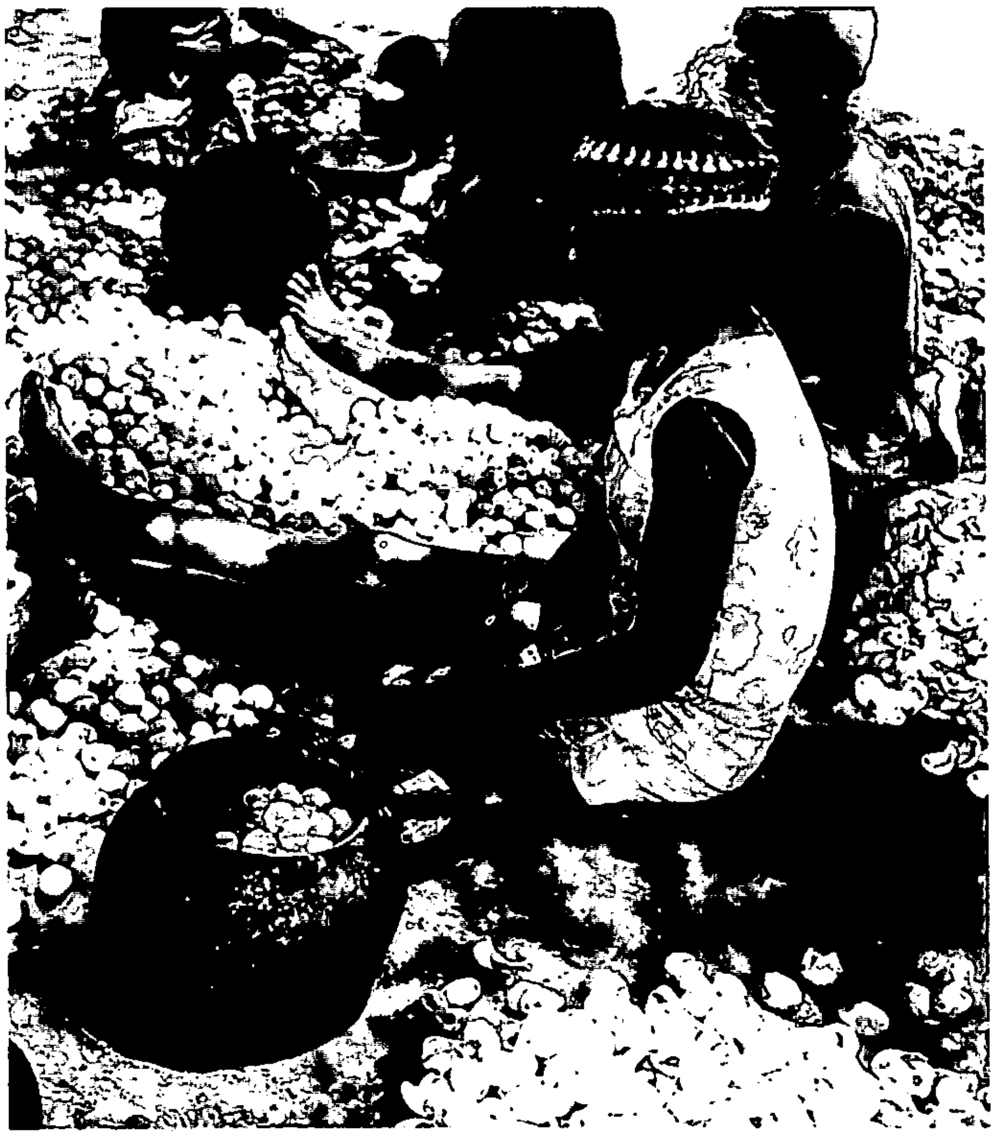


PLATE 4.2: For the Tsonga people, Southern Mozambique the ceremony of "ukanho" is one of the most important ritual every year. The picture is showing the invocation and the First Drink in 1995.

PLATE 4.3: Dancing after the ceremony of First Fruits is part of the ritual of "ucanho" by Tsonga people, Southern Mozambique.

Courtesy of A. Sitoe

According to Shone (1979) the fresh juice is not normally drunk by people but it is used in certain Shangaan religious ceremonies. The author indicated also that the making of jelly from the fruit was popular in South Africa, but it is seldom made nowadays. The productivity of jelly is estimated in 3 kg of fruit to yield 1 kg of jelly.

Although fruits are the main product of the species, there is no clear indication of the productivity of Marula tree. Estimates on fruit yield given in the literature are variable. Peters (1988) reporting a study on productivity of the species indicates that one season's productivity for 11 trees in Botswana ranged from 17,445 to 66,822 fruits, while in Transval productivity ranged from 21,667 to 91,272. These figures are more than those reported by FAO (1988) according to which an adult tree may produce from 5,000 to 20,000 fruits.

Judging by the information provided, the research was probably conducted in different geographic locations. Factors involved for the variation in fruit yield may include the age of the tree and climatic conditions. Fruit yield is more likely to increase with age, but it decreases in older tress. However, no indications of age limit for tree productivity is provided from the literature. Peters (1988) indicated that the annual productivity of smaller trees in apparently less favourable circumstances may be as high as 2,000 fruit tree $^{-1}$ year $^{-1}$. Campbell (1987) reports that *Sclerocarya caffra* trees with 14 years old being studied for domestication, produces about 1000 fruits tree $^{-1}$ year $^{-1}$. These figures may probably give a better indication on productivity of younger trees.

Fruits are normally collected after falling and they fall from the tree while still pale green, and ripen on the ground to a pale, waxy yellow colour. In East and Southern Africa, ripe fruits are available during February to June, while in the Sahel region, flowering occurs from January to April/ May, and fruits are mature from April to June (Von Maydell, 1990; Palgrave, 1991; Exell *et al.*, 1966).

Peters (1988) reports that the fruit constitutes an important seasonal source of vitamin C (ascorbic acid), food energy, fat, protein and minerals, while FAO (1990) and Palgrave (1991) note that the pulp contains four times as much vitamin C as orange juice. According to these authors, the nuts are very rich in protein, over 30 % and also contain 57 % of oil.

Studying the chemical composition of the fruit of Marula Carr (1957) reported that the species contains 62.3 to 254 mg/100 g of ascorbic acid. These figures are less than those observed by Eromoselle *et al.* (1991) who recorded 403.3 mg/100 g. Marula fruit is, therefore, an important source of nutrients. Nevertheless, Saka and Msonthi (1994) recognise that information on chemical composition of *Sclerocarya birrea* is still limited.

The stones, which are difficult to crush, contain 2 to 3 nuts or seeds which are edible too. Shone (1979), stated that to break the stone it is necessary the use of hammer which usually results in a mixture of kernel and shell as well as bruised fingers. They are cracked open and the kernel eaten fresh or dried, cooked with porridge or ground into a flour (Peters, 1988; FAO, 1988; Rodin, 1985; Shone, 1979).

TABLE 4.1: Fatty acid composition of *Sclerocarya birrea* kernel oil, expressed as percentages of total fatty acids, together with standard deviation (Adapted from Burger *et al.*, 1987; and Engelter and Wehmeyer, 1970)

Fatty acids	Average (in g/100 g)	Standard deviation	Average (in % of total fatty acids)	Standard deviation
C14:0	0.10	0.01	trace	
C16:0	12.9	1.07	12.0	0.60
C16:1	0.10	0.09	trace	
C16:2	-	-	trace	
C17:0	0.10	0.01	-	-
C17:1	0.10	0.01	-	-
C18:0	6.10	0.75	9.20	0.30
C18:1	72.10	1.55	69.9	0.90
C18:2	7.10	1.70	7.80	0.40
C18:3	0.10	0.01	-	-
C20:0	0.60	0.05	0.60	0.10
C20:1	0.4	0.10	0.30	0.10
C22:0	0.10	0.03	-	-
C24:0	0.20	0.10		
Total saturated	20.0	1.00		
Total mono-unsaturated	72.7	1.52		
Total poly-unsaturated	7.20	1.71		
References	(Burger *et al*, 1987)		(Engelter and Wehmeyer, 1970)	

Kernels are therefore, an important source of oil and proteins for humans. Investigation conducted by Burger *et al.* (1987) on composition of Marula seed obtained from 7 locations in South Africa and Namibia, indicated that kernels constitute 7.8 % of the seed, and they contain 45.9 % oil and 33.3 % protein. The authors note that oil extracted from Marula, had a high stability against oxidation and was very suitable for frying. Table 4.1 indicates the fatty acid composition of the Marula kernel oil.

From the previous table, it can be seen that C18:1 is the main fatty acid of Marula kernel oil, which is followed by C16:0 and C18:2 respectively. C16:2 was shown as a trace element in the study by Engelter and Wehmeyer (1970). The rates of fatty acids may vary with the methods of analysis, as well as the origin of the fruits. Ogbobe (1992), for example, identified nine fatty acids by using standard methods. The fatty acid distribution (% by weight) of the most dominant acids are as follows: stearic (50.76); palmitic (22.56); arachidonic (8.46); behemic (5.14); oleic (4.13) and lignoceric (4.13).

The methodology of analysis conducted by Ogbobe (1992) consisted by extraction of Marula oil by soxhlet from the ground seed using low boiling petroleum ether (40-60 °C) and immediately analysed for iodine value, saponification value, refractive index, unsaponifiable matter, acid value and peroxide value. The author indicated that specific gravity, water, nitrogen and ash contents of the seed were determined according to Association of Official Analytical Chemists, while fatty acid distribution was done on a Varian aerograph series GC-MS in which a gas liquid chromatography (GLC) was coupled to a mass spectrometer. Thus, identification of fatty acids in the oil was by comparison of obtained mass spectra with those of standard samples

as well as molecular mass correspondence. The physicochemical properties of *Sclerocarya birrea* seed oil reported by the author are illustrated in table 4.2.

TABLE 4.2: Physicochemical properties of *Sclerocarya birrea* seed oil, according to Ogbobe (1992).

Assay	%
Saponification value	162.70
Iodine value	100.25
Acid value	33.70
Peroxide value	4.58
Unsaponifiable matter	3.06
Refractive index	1.46
Melting point (°C)	26-28
Solidification point (°C)	-1-(-4)
Specific gravity	0.88

Investigation in oil composition conducted by Ferrão (1976) reported also twelve fatty acids identified from *Sclerocarya*, namely (expressed as percentages of total fatty acids) C14:0 (trace); C16:0 (11.5); C16:1 (0.2); C17:0 (0.1); C17:1 (trace); C18:0 (6.9); C18:1 (74.9); C18:2 (4.9); C20:0 (0.6); C20:1 (0.4); C20:2 (0.5); C22:0 (trace). The fatty acids identified in

Marula were similar to those reported for the composition of olive oil. The total saturated fatty acids was 19.9 %, while the total unsaturated ones was 80.9 %. Previous study on chemical composition conducted by Ferrão (1960) indicated that in spite of its high oil and protein content, a marked deficiency in lysine renders it unsuitable for use as a supplement to human diet in Angola. However, the author recognises that Marula seeds contain a high percentage of edible oil which is comparable to other vegetable oil.

According to A-Ogle (1990) the nuts of *Sclerocarya birrea* are used as substitutes of groundnuts in vegetable relishes in Swaziland, while Peters (1988) and Storey (1958) note that on the Maputoland coastal plain in Natal (South Africa) the nuts are still stored and provide a major source of protein during drought periods. Peters (1988) reports also that they have been used as a famine food in Zambia and Tanzania.

Many authors report other valuable roles of Marula for human use. To quote Palgrave (1991): "the Zulus crush and boil them with water, skimming of the oil which they massage in to the skin as a cosmetic, while Shangaan witch doctors regard the stones as 'medicine' in their divining dice".

The nuts are very much appreciated by children despite the difficulty of extracting them from the hard shelled stone. According to FAO (1988), in South Africa some people subsist on these nuts, which may be mixed with spinach or meat, while in Botswana they are cooked with sorghum and maize. In Zimbabwe, the nuts are highly desired and has a ready market, both locally and in the urban areas. The nuts are cracked manually and sold

in 3 gram containers for 20 cents [2] in the local areas and up to 30 or 40 cents in the urban areas (Gumbo *et al.*, 1990).

According to Weinert *et al.* (1990), nuts are very rich in nutrients. A study on proximate and nutrient composition revealed that on average they contain 56 % of oil, 28 % of protein and amino acids and 3.9 % of minerals. However, investigation conducted by Ogbobe (1992) founded that Marula seed contains 11.0 % crude oil; 17.2 % carbohydrates; 36.7 % crude protein; 3.4 % fibre and 0.9 % crude saponins. The amino acid composition of Marula nuts, defatted Marula meal and two fractions of nut protein are also provided by Weinert *et al.* (1990). For instance, the amino acid valine revealed 12,42 g/16 gN, 3.9 % for defatted meal, 4.31 (F12.8) and 1.82 (F1.6).

However, nut chemical composition varies from region to region. The authors indicated that differences in ripeness of fruit, geographical origin as well as methods of analyses are the causes of variation. Table 4.3 indicates proximate and nutrient composition of Marula nuts from different regions of Southern Africa.

[2] *One Zimbabwan Dollar = 100 Cents; (1 USD ≅ 8 ZIM D; July 1995)*

TABLE 4.3: Proximate and nutrient composition of *Sclerocarya birrea* nuts from different regions of Southern Africa (Adapted from Weinert *et al.*, 1990).

	REGION			
	Angola	South Africa	South Africa	Moçambique
	g/100 g			
Moisture	3.9	4.0	3.9	9.0
Protein	27.6	30.9	25.9	27.6
Oil	56.2	57.0	57.6	54.3
Ash	4.1	4.2	3.5	3.7
Fibber	4.5	2.4	3.5	2.8
Carbohydrate		1.5	5.7	5.3
Caloric value			645.4	

Source: Weinert *et al.*, (1990)

From these figures it can be noted that the level of proteins and oil tend to be similar from different regions. A similar situation is revealed for moisture content, although the sample from Mozambique was of a higher moisture content. According to Burger *et al.* (1987), on average, the Marula has a moisture content of approximately 85 % and the moisture of the skin is relatively less than that of the flesh.

Studies conducted on chemical composition revealed high levels of ascorbic acid in the fruit of Marula, when compared to other fruits of some wild plants. The species revealed also significant levels of minerals. Table 4.4 represents a comparative summary on mineral elements and ascorbic acid content of some species, including *Sclerocarya birrea.*

TABLE 4.4: Comparative concentrations of mineral elements and ascorbic acid of *Sclerocarya birrea* and some other wild fruits (Adapted from Eromosele *et al.*, 1991; and Weinert *et al.*, 1990).

Fruits	mg/100 g weight of mesocarp								
	Mg	Ca	Zn	Mn	Cu	Co	Fe	P	Ascorbic acid
Zizyphus spinachristi	90.7	225.0	1.18	0.61	0.64	0.43	2.86	18	98.0
Sclerocarya birrea [1]	**31.9**	**36.2**	**0.34**	**0.11**	**0.10**	**0.13**	**1.12**	**18**	**403.3**
Sclerocarya birrea [2]	**10.5**	**6.2**	-	-	**0.04**	-	**0.10**	**8.7**	**230.0**
Ximenia americana	25.3	3.3	0.63	0.51	0.17	0.17	1.97	-	60.3
Adansonia digitata	208.8	60.0	2.40	0.60	0.60	-	4.40	5	337.0
Annona senegalensis	42.2	28.9	0.64	0.43	0.17	-	1.33	28	10.5
Zizyphus mauritiana	227.0	712.5	1.55	3.5	0.60	-	6.30	13	-

[1] Fruit sample from Nigeria; Eromosele *et al.* (1991)

[2] Fruit sample from Botswana; Weinert *et al.* (1990)

Weinert *et al.* (1990) stated also that mineral composition of the fruit tends to vary with geographical origin. As an example, the levels of calcium, magnesium and phosphorus in the flesh of Marula were 20.1, 25.3 and 11.5 mg/100 g respectively from fruits collected in SWA-Namibia, and 10.4, 14.8 and 9.6 mg/100 g in fruits from Sibasa, South Africa. The most notable minerals in the fruit are Mg, Ca and P.

Of nutritional information, the vitamin C is the most relevant nutrient which attract most attention for researchers. A summary of vitamin C content of various parts and products of Marula is provided by Weinert *et al.* (1990), as indicated in table 4.5.

From the table 4.5 it can be seen that the skin provides high levels of vitamin C, whereas relatively low level was identified from jelly. The fruit itself is shown also with high levels, but there is notable difference between the figures provided by Carr (1957); 179.1 mg/100 g; and Grivetti (1982); 61 mg/100 g. According to Weinert *et al.*, (1990), relatively small amounts of other vitamins were also identified in fruits samples from Botswana and Namibia. These are thiamin (0.03 mg/100 g in each sample), riboflavin (0.05 and 0.02 mg/100 g) and nicotinic acid with 0.25 and 0.27 mg/100 g respectively for Botswana and Namibia samples.

TABLE 4.5: Vitamin C[1] content of *Sclerocarya birrea* fruit or its parts and some products prepared from the fruit (Adopted from Weinert *et al.*, 1990).

References [2]	Vitamin C content (mg/100 g)						
	Fruit	Skin	Flesh	Juice	Beer	Jelly	Jam
Carr (1957)	179.1				97.1	70.7	105.0
Unripe	127.2						
Ripe	133.7						
Over ripe	52.7						
Grivetti (1982)	61				140.0		
Wehmeyer (1967)	67.9						
NFRI (1967)					49.0		
NFRI (1971)	166.0						
NFRI (1976)							
Unripe		150.4	198.2				
Ripe		237.6	194.4				
NFRI (Shone, 1979)		230.0	194.0				
NFRI (1979)		227.0	161.0	192.0			
NFRI (1980)				129.0			

[1] Ascorbic acid + dehydroascorbic acid Source: Weinert *et al.* (1990)

[2] References are also from the original table by Weinert *et al.*, (1990)

Studies on volatile components are also revealed for Marula. Weinert *et al.*, (1990), quoting Quin, Palmer and Pitman characterised the flavour of Marula

as pleasant, sour-sweet, guava-like, while Shone (1979) notes its turpentine-like aroma, which increases during ripening and may be nauseating in over ripe fruit. Many volatile aroma components were identified in Marula skins and juice. About 40 compounds identified from skins, such as n-pentane, n-hexane, methanol, acetaldehyde, glicolic acid, etc., and more than 50 obtained from the juice are listed by Weinert *et al.*, (1990). Among the compounds identified from juice the following are included: ethylacetate, styrene, 3-methyl-1-butanol, α-copaene, linalool, α-humulene, geranion, benzenemethanol and others.

4.1.2. Industrial uses

There is little information on industrial uses of Marula in the literature. According to Hans *et al.* (s.d.), and Ferrão (1976) *Sclerocarya* is indicated as potentially useful for conserves and beverages (fruits), and oils, protein and carbohydrates (seed). However, Shone (1979) notes that there is little commercial future in the marketing of the fresh kernel, due to the difficulty of cracking the nuts and the small size of the kernel.

Industrial processing of fruit for juice, jams and alcoholic drinks is reported as being initiated in South Africa (Weinert *et al.*, 1990). The Marula fruit juice and Amarula liqueur, are already commercially available, and are regarded as a delicacy on account of their delicious taste (FAO, 1990; Von Teichman and Robbertse, 1986). The fruit juice is, however, vulnerable to volatile flavour components (Pretorius *et al.*, 1985; Weinert *et al.*, 1990).

Physical, chemical and sensory analyses of Marula fruit juice products was carried out by Gous *et al.* (1988). The study was based on three juice types of products which were prepared from seven selected wild Marula trees in three consecutive years. The fruit gathered was stored at 4-5 °C until processing into three juice type products, namely *puree*, *turbid* and *depectinized* juices. For puree, fruit was washed in tapwater, heat treated with steam at 96 °C for 4 min. The puree was refined using sieve pore diameter 1.14 mm, and divided into two parts. One portion was cooled to 45 °C and treated with 200 ppm Pectinex Ultra SPL for one hour at constant temperature and after centrifuged twice, it was pasteurised in water bath and frozen at 28 °C. Another portion was packed into polyethylene containers, frozen and stored at 28 °C. For turbid juice, after washing and heating at 96 °C for 4 min it was pierced with a stainless steel knife. The fruit was pressed in a Bucher rack, 10 kg/cm for 5 min. The sample was also frozen and stored at 28 °C.

For chemical and physical analyses, the samples of puree, turbid and depectinized juices were taken just before freezing and analysed. Moisture content was determined gravimetrically (vacuum oven 65 °C, 10 kPa for 18 hours). Total soluble solids (TSS), by using refractometer; while Total polyphenols, was determined by Folin-Ciocalteau method. Total titratable acidity (TTA), Formol value, and Pectins were determined according to International Federation of Fruit Juice Producers. Table 4.6, represents the summarised results of physical characteristics, while Table 4.7, illustrates the chemical characteristics reported by the authors.

TABLE 4.6: Physical characteristics of turbid *Sclerocarya birrea* juices from seven different regions of South Africa (harvest tears: 1985-1987), (Adopted from Gous *et al.*, 1988).

Sample		Yield (% m/m)	Moisture (g/100 g)	Density (g/l)	pH	TSS (°B)
Phalaborwa	Av.[1]	40.3	90.0	1.039	3.6	10.4
	Range	33.9	88.2	1.038	3.0	8.5
		46.5	92.7	1.040	4.3	12.0
Grey	Av.[1]	51.0	91.1	1.035	3.3	9.2
	Range	48.6	89.8	1.030	3.1	7.5
		54.4	93.0	1.040	3.4	10.2
De Klerk	Av.[1]	40.1	91.0	1.031	3.7	9.4
	Range	33.5	89.3	1.030	3.2	8.2
		44.2	93.0	1.032	4.3	10.5
Neethling	Av.[2]	40.6	89.3	1.045	3.7	11.5
	Range	40.3	87.2	1.040	3.3	10.4
		40.8	91.3	1.050	4.1	12.6
Kuschke	1986[3]	35.0	88.1	1.040	3.4	12.0
Koevoet	Av.[2]	39.5	86.9	1.044	3.8	13.1
	Range	39.3	86.8	1.040	3.6	12.9
		39.6	87.0	1.047	3.9	13.2
Barnard	1987[3]	44.4	88.2	1.042	3.8	11.9

Sample	TTA (gC/100 g)	Sugar : acid	Formol (ml NaOH)	Colour L	Colour a_L	Colour b_L	App. visc. (cP)
Phalaborwa Av.	1.73	6.1	24	36.40	−2.94	4.26	14.4
Phalaborwa Range	1.29	5.7	17	33.10	−2.29	3.71	8.8
	2.09	6.6	28	38.55	−3.42	4.89	24.5
Grey Av.	2.01	4.6	24	33.92	−2.83	4.13	10.7
Grey Range	1.88	3.4	20	28.40	−2.15	3.07	6.6
	2.18	5.4	30	40.11	−3.43	6.06	17.8
De Klerk Av.	1.71	5.6	26	38.31	−3.52	6.98	13.4
De Klerk Range	1.39	4.9	22	36.78	−3.08	5.51	11.9
	2.14	5.9	28	39.85	−4.06	8.19	14.1
Neethling Av.	1.75	6.6	10	40.70	−3.09	8.56	15.5
Neethling Range	1.48	6.2	9	37.54	−3.02	6.63	14.3
	2.02	7.0	11	43.86	−3.15	10.49	16.7
Kuschke 1986	1.16	10.3	15	40.16	−3.36	4.69	9.7
Koevoet Av.	5.22	12.6	8	41.20	−3.30	9.23	16.6
Koevoet Range	1.18	11.2	8	39.61	−2.79	8.87	16.3
	9.25	13.9	8	42.78	−3.80	9.58	16.8
Barnard 1987	1.19	10.0	14	57.49	−3.95	1.791	11.9

[1] Average of three years (1985–1987).
[2] Average of two years (1985–1986).
[3] Value of a single year.
TSS = total soluble solids.
TTA = total titratable acidity (expressed as g citric acid/100 g).
Formol = formol value.
App. visc. = apparent viscosity at 20°C and shear rate 2705 s^{-1}.
Av. = average

TABLE 4.7: Chemical characteristics of turbid *Sclerocarya birrea* juices from seven different regions of South Africa (harvest years: 1985-1987) (Adopted from Gous *et al.*, 1988).

Sample		Sugars (g/100 g) Suc.	Glu.	Fru.	Unkn	Total	Organic acids (g/100 g) Citric	Malic
Phalaborwa	Av.[1]	4.43	0.70	1.13	0.07	6.33	1.63	0.28
	Range	3.80	0.54	0.88	0.00	5.22	1.44	0.13
		5.50	0.86	1.40	1.13	7.89	1.90	0.39
Grey	Av.[1]	3.16	0.79	1.06	0.28	5.29	1.84	0.28
	Range	3.00	0.61	0.69	0.20	4.68	1.52	0.10
		3.30	0.97	1.30	0.35	5.92	2.01	0.42
De Klerk	Av.[1]	3.16	0.53	0.80	0.09	4.58	1.71	0.28
	Range	2.65	0.44	0.70		3.79	1.42	0.11
		3.70	0.62	0.84	0.18	5.34	2.00	0.43
Neethling	Av.[2]	5.55	0.59	0.97	0.09	7.20	1.92	0.43
	Range	5.24	0.47	0.83		6.54	1.84	0.39
		5.90	0.70	1.10	0.19	7.89	2.00	0.46
Kuschke	1986[3]	6.10	0.80	1.20	0.21	8.31	1.20	0.34
Koevoet	Av.[2]	6.36	0.70	1.20	0.17	8.42	1.19	0.35
	Range	6.32	0.68	1.19	0.33	8.19	1.10	0.32
		6.40	0.72	1.20		8.65	1.27	0.37
Barnard	1987[3]	4.98	0.95	0.89		6.79	1.09	0.02

Vitamins (mg/100 g) Vit. C	Vit. B_2	Pectins (mgGA/100 ml) Water	Oxal	Alkal	Total	Polyphenols (mgTA/100 ml)
205	0.01	2238	90	121	2438	282
174	0.01	1879	83	93	2136	77
237	0.01	2621	97	149	2871	434
167	0.01	2897	18	38	3061	236
148	0.004	2249	0	0	2254	54
199	0.01	3467	82	80	3709	336
192	0.01	2499	101	104	2958	414
185	0.01	1983	7	65	2266	129
199	0.01	3251	194	142	4343	662
215	0.01	3085	172	80	3363	414
183	0.01	2795	108	48	3144	294
247	0.01	3374	236	111	3582	533
149	0.01	2249	69	46	2295	234
185	0.01	3802	51	30	4033	226
143	0.01	3216	102	60	3649	82
227	0.01	4387			4417	370
244	0.01	2259			2254	85

[1] Average of three years (1985–1987).
[2] Average of two years (1985–1986).
[3] Value of a single year.
Suc. = sucrose; Glu. = glucose; Fru. = fructose; Unkn = unknown.
Water = water soluble; Oxal = oxalate soluble; Alkal = alkal soluble.
Polyphenols = polyphenol content.
Av. = average.
TA = tannic acid.
GA = galacturonic acid

Although Marula fruits have become increasingly important for industry, they are still collected from the wild. According to Weinert *et al.* (1990) there is no commercial production of the Marula's fruits. Current fruit and nut production consists of harvesting from wild stands of trees. Marula processing industry is also reported to have high potential for high capacity commercial production. The authors estimated 600 MT (Metric Tones) of Marula juice processed in South Africa in 1986.

4.2. Other uses

4.2.1. As fodder

The fruits are appreciated by livestock and game. In the forest, marula's fruit are relished by elephants, bush pigs, goats and cattle (Parker, 1978; FAO, 1988; ENDA, 1991). There is no doubt that Marula is one of the most important fodder species found in Africa. A survey conducted in Mali by Sissoko *et al.* (1993) indicated that *Sclerocarya birrea* provides good fodder and the species was among the farmer preferences, while Ferrão (1960) reports also the valued features of fruits as fodder for both domestic and wild animals in Angola.

Since the species is drought tolerant and rapidly coppiced, its leaves provide forage in the dry season and they are appreciated by goats and wild animals, especially new leaves. As Shone (1979) reported, animals go to the trees in the hope of finding fallen fruit during periods of drought. Therefore,

Marula leaves are familiar for the animals. The author points out that some animals develop a taste of the fruit, which they devour with relish.
Domestic animals such as goats, sheep, donkeys and pigs are also partial to the fruit, the edible matter being chewed off the nut, which is spat out. No special selection or preference of fruits is made by animals. In some cases the fruit is eaten whole and even rotting fruit is eaten (Shone, 1979).

Reporting fodder importance in South Africa, Shone (1979) recognises the role of Marula fruit, the green leaves and even for the leaves lying on the ground during winter, which are eagerly sought by wild and domestic animals. The author points out that Marula is more important to wild animals than to their domestic counterparts. However, they may become intoxicated after eating the over-ripe, fermenting fruits lying on the ground in large quantities (Palgrave, 1991; Von Maydell, 1990). Apart from alcohol content reported from different chemical analysis of ripen Marula fruits, no other toxic components are indicated by the authors. Even the alcohol content, the amount is considered to be a minimal to cause toxicity of animals. It is estimated that a baboon would have to eat 400 over-ripe Marula fruit to consume the amount of alcohol contained in a 340 ml can of beer (Shone, 1979).

The toxicity effect of Marula fruit is therefore, a controversial matter from different authors. While Von Maydell (1990) and FAO (1988) reports that leaves and fruits are slightly poisonous, Shone (1979) as well as Peters (1988) note that some animals, such as baboons and elephants still enjoy its benefits, but they get drunk from eating the rotting fruit of Marula. Similar statement is also made by Parker (1978) who indicated that fruit eaten by

animals, particularly elephants, ferments in their stomach, makes them drunk and rampant. However, investigation reported by Shone (1979) indicated no definitive evidence that animals, particularly elephants do get drunk from eating the fruit.

Many other animals, such as Burchell's zebra, black rhino, giraffe, porcupine, warthog, bush pig, kudu, nyala, impala, bushbuck, grey buiker, monkeys and various antelope are reported to be exceedingly fond of the fruit.

Indirect benefits of Marula tree on fodder regeneration are also reported in the literature. The species play an important role for regeneration and growth of buffalo grass or "capim elefante" (*Panicum maximum*), one of the most valuable fodder grasses in the tropical and subtropical regions. It is stated that the grass performs successfully under the tree. Therefore, Marula can also be considered as a promoter tree species for regeneration and growth of grasses. The grass under the Marula trees is usually overgrazed, due to the animals seeking the shelter and fruits (Shone, 1979).

4.2.2. As folk medicines

In the developing countries, and particularly in the rural areas and among the urban poor, medicinal plants, are in most cases, the only form of health care (FAO, 1983). Most of the wild fruit plants, including *Sclerocarya birrea*, are source of medicine for local communities.

The bark of Marula is reported to have an important medicinal properties. Both stem and root bark are used for a number of medicinal purposes. Both decotions from stem bark and root bark are used to treat dysentery, diarrhoea, toothache, infections and an important antidote for local people (Palgrave, 1988; Von Teichman and Robbertse, 1986; Von Maydall, 1990; Galvez *et al.*, 1991; Galvez *et al.*, 1993; Galvez-Peralta *et al.*, 1992). However, a different statement is produced by Shone (1979) who reports that Marula does not play an important role today in medicine, but recognises the medicinal importance in the past.

Many different authors report the medicinal importance of Marula in either present or in the past. Brandwijk (1928) as well as Von Maydell (1990), stated also that Marula produces benefits in the treatment of malaria in rural communities. Gumbo *et al.* (1990) noted that the availability of such products reduces the requirements for purchased medication by poor resource farmer.

The bark of *Sclerocarya birrea* is widely used in Southern, as well as Western Africa as an antidiarrhoel remedy (Ayensu, 1978; Shone, 1979; Palgrave, 1991). Investigation of medicinal effect of the Marula's bark by Galvez *et al.* (1991) in Burkina Faso revealed its significant activity against two models of experimentally-induced diarrhoea. Diarrhoea is a common cause of death in babies in particular although sometimes symptomatic of relatively minor bacterial infections of the intestine (Galvez-Peralta *et al.*, 1992). Antidiarrhoel remedies can often reduce baby mortality by stabilising the conditions of colon. The author notes that the condensed tannin isolated from the crude drug inhibited intestinal mobility; its monomer, obtained by acid hydrolysis, was identified as procyanidin. According to Shone (1979),

the bark of Marula contain tannin and a trace of alkaloides and is therefore certainly astringent as well as coagulant.

Previous studies in medicinal properties of Marula bark have shown that in its crude form the drug effectively slows down intestinal function and increases the time of intestinal transit of ingested substances (Galvez *et al.*, 1991; Galvez-Peralta *et al.*, 1992). In laboratory experiments the process of fractionation has been used to isolate the compound Procyanidin which has been shown to inhibit the peristaltic reflex of the ileum of Guinea-Pigs. Side effects have been shown to be increased secretion of fluids and electrolytes in the colon of rats (Galvez *et al.*, 1993).

Medicinally the drug is highly useful because the effects of the compound are rapid once administered and short-lived as the intestinal condition is stabilised. Additionally, the drug produces a physiological response which relates to its concentration therefore doseage is easily calculable.

Apart from the bark, Shone (1979) indicated also that an extract of the leaves is made and applied to boils and abscesses, while the skins of the fruit are dried in the sun, ground up and sometimes used as snuff. In addition, a concoction of the bark is also used by south African communities for purification rites to remove defilement from food eaten in the house of relatives where there has been a death without the performance of the necessary purification rites.

The role of traditional medicines in developing countries is worldwide recognised. Unfortunately the medicinal attributes claimed of folk remedies

are seldom supported by clinical evidence as effective cures, that no placebo effect or auto-suggestion was involved, i.e., proof that the treatment administrated in and of itself was effective (FAO, 1981).

4.2.3. As timber resource

The stem of Marula is well developed and it is one of the indigenous trees which was used for packing and for making lavatory seats during and after World War II, therefore, it is commonly stated that this is the main reason for its devastation (Shone, 1979). The wood of Marula is frequently used by local communities for carvings, kitchen furniture, stools, pillows, drums and ornaments, pestles and mortars, heavy crating and pattern making, due to its easily worked properties (FAO, 1988).

Several studies on structure, wood properties and applicability of Marula's wood were conducted during the last three decades (e.g. Cardoso, 1960; Anon., 1947; Hartwig, 1965; Anon., 1964?; Gomes, 1984; Freitas, 1986; Nasroun and Elzaki, 1987; Prior and Gasson, 1993). Thus, information on anatomical, physical and mechanical properties, as well as study in wood-boring insects is already available from the literature. The timber is pleasant to work and unlike many other woods of similar grain, it does not rough up during working (Shone, 1979).

The wood of *Sclerocarya birrea* is reported to be greyish-white to greyish-rosy or whitish-brown, very soft and light to medium (D= 0.590 to 0.720) (Cardoso, 1960, Hartwig, 1965). According to Shone (1979) and Cardoso

(1960) the texture is fairly even, tends to be slightly coarse. The authors indicated also that the growth ring formation usually presents a good figure on tangentially-sawn surfaces, while no special features are visible on the clean-cut transverse plane, except that the vessels are easily visible to the naked eye. No special odour is reported for the wood of Marula.

Using samples from Natal and Transval and also Zimbabwe and Mozambique, Hartwig *et al.* (1965) and Cardoso (1960) reported detailed study of physical, mechanical, working and finishing properties, structure, colour and markings, seasoning, durability and uses of Marula's wood. The micrography reported by Cardoso (1960) indicated growth rings distinct; vassels moderately numerous, medium sized; parenchyma not visible, rare, paratracheal; heterocellurar rays, medium numerous; libriformes fibres, septate, modertely short; secretory horizontal canals in the rays, numerous and isolated crystals in the rays. Physical and mechanical wood properties of Marula are also reported by Shone (1979) as illustrated in table 4.8.

The wood of Marula can be also used in some industries. A result of an inquiry in East and West Africa, and tests at the Forest Product Institute at Pretoria, Marula was one of recommended local wood for battery separators (Anon., 1947).

The timber is easily damaged by insects if not preserved. Among the wood-boring insects of Marula the genus *Lyctus* is the most common one causing damage to logs. According to Shone (1979) other recorded insects attacking also the logs and wood are *Sinoxylon bellicosum* and *Plioxylion plurispinus*. The author points out that freshly-felled logs and planks sawn from wet logs

are soon covered with mould and blueing appears almost immediately. Fungi enter easily through bark damage.

Sclerocarya birrea was also one of the "miombo" species tested by Tropical Production Institute for making particle boards (Anon.,1964?). Reporting the results of the investigation, the institute indicated that a good board was obtained from *Sclerocarya* sample, but a very high forming pressure was required. Three-layer boards revealed a better appearance than, and strength not less than, that of equivalent single-layer boards. However, their marketability was questioned due to their semi-dark colour and density, when compared to other particle board.

TABLE 4.8: Wood properties of Marula's (*Sclerocarya birrea)* wood recorded from tests carried out by the South African Forest Institute; Test values at 12 % M.C. (Adapted from Shone, 1979).

PROPERTY	UNIT	VALUE
Mass per m³	kg	550
Static bending		
Modulus of rupture	MPa	50.8
Fibre stress at proportional limit	MPa	32.3
Modulus of elasticity	MPa	5 020
Compression parallel to grain		
Maximum crushing strength	MPa	28.1
Hardness		
End surface	N	4 750
Side surface	N	3 750
Shear parallel to grain		
Maximum shearing strength	MPa	9.4
Compression perpendicular to grain		
Stress at proportional limit	MPa	7.5
Stress at 2.54 mm deflection	MPa	13.6
Toughness		
20x20x280 mm specimen tested on 240 mm span at 10.3 % moisture content	J (Nm)	12.3

Source: Adapted from Shone (1979)

4.2.4. Ornamental and shade purposes

Marula is commonly used for ornamental and shade purposes (FAO, 1988; ENDA, 1991). It is found around the house in Eastern and Southern Africa, where it is protected by farmers. Shone (1979) stated that Marula's leaves, mostly when they are new, are very attractive for ornamental purposes and it is recommended that trees for this purpose are grown in frost-free areas.

A survey conducted in Marracuene district, southern Mozambique, indicated that *Sclerocarya birrea* is among the commonly preferred tree species for shade around households (Macucule, 1992). In some villages the tree is also a focal point of traditional rituals which includes invocation and "contact" with their ancestors under its shade ("ganzelo" and "kuphahla"[3]). However, during fruit maturation, the shade may be not as good as reported in the literature, due to fruits falling.

According to Shone (1979), the shade of marula is also appreciated by wild and domestic animals during the hot seasons of tropical and subtropical environments. The form of the tree, gives a large shade covering and good protection against direct insolation. One of the advantages of Marula is that it is the first deciduous tree to produce leaves in the areas of occurrence.

[3] "ganzelo" - *In Tsonga: selected tree around homestead for the ritual*; "kuphahla" - *invocation to the ancestors.*

4.3. Gum exudates

The gum exudes of Marula are reported by Andersaon (1986). Although *Sclerocarya birrea* is not a noted species for gum yield, it was reported as giving a clear, colouress, friable gum. The species is also indicated to have an appreciable methoxyl content but relatively low nitrogen. Table 9 illustrates the analytical data for gum exudate of *Sclerocarya caffra* after Andersaon (1986).

TABLE 4.9: Analytical data for the gum exudates from *Sclerocarya caffra* (Adopted from Anderson *et al.*, 1986).

Parameter	Data
Loss on drying, 105°, %	13.2
Total ash, 550°, %*	5.1
Nitrogen, %*	0.06
Hence protein (Nx6.25), %*	0.4
Mathoxyl, %†	2.1
Specific rotation $[\alpha]_D$, degrees †	+ 12
Intrinsic viscosity, ml/g†	4.3
$M_r x10^4$†	5.6
Neutralisation equivalent (electrodialysis)	750
Hence uronic anhydride, %†‡	23.5
Sugar composition after hydrolysis (% of total sugars)	
4-O-Methylglucuronic acid§	12.5
Glucuronic acid	8
Galacturonic acid	3
Galactose	63
Arabinose	14
Rhaminose	0

* Corrected for loss on drying. Source: Anderson *et al.* (1986)

† Corrected for * plus protein content.

‡ If all acidity arises from uronic acids.

§ If all methoxyl groups located in this acid

Chapter Five

DOMESTICATION AND AGROFORESTRY POTENTIALS

5.1. The role of tree domestication

Indigenous plants are defined as members of the original flora that occur naturally in a specific region or environment (Stelling, 1993). Wild fruit trees contribute to the conservation of local biodiversity and preserve the genetic heritage.

Wild genetic resources are increasingly being recognised for their scientific and aesthetic values. In addition to satisfaction of farmers needs, local species are well adapted to local soils and climatic conditions than many exotic ones.

Domestication of indigenous trees species is being reported as an important issue for agroforestry in the present times (Maghembe *et al.*, 1994; Kamara *et al.*, 1993; Sinclair *et al.*, 1994). According to Kass (1993) the choice of tree species for plantation in forestry or agroforestry is influenced by knowledge of the species performance, their socio-economic and environmental benefits.

In the past, most exotic tree species were promoted due to good knowledge of their biology, cultivation and commercial uses. The plantation of conifers

throughout the world is an elucidative example. However, some authors (e.g. Sinclair *et al*. 1994; Kass, 1993; Maghembe, 1994; Campbell, 1987) recognise that several indigenous species, when managed correctly, may be more suitable than exotic trees because:

(a) they may be better adapted to local environmental conditions, including their resistance to fire, drought, and pests and diseases

(b) seeds and other propagules are locally available, and often easier to propagate; and

(c) they are locally preferred by farmers and people are familiar with them and their uses.

According to Lee (1993), a diverse utilisation of indigenous biological resources suited to local conditions could be more valuable than monoculture of exotic species. As Stelling (1993) observed, wild trees selected from local provenances can perform well commercially and provide many other benefits comparative to some exotic species already domesticated.

Although tree domestication has been practised by farmers for many years, the role of science is to promote it using modern techniques to protect and improve biodiversity. This goal can be achieved by combining the different components of investigation with needs or preferences of local people. Kass (1993) notes that for the success of domestication programmes farmers must

be involved in the process of selection, testing and propagation of Multipurpose Tree Species.

Sinclair *et al.* (1994) states that the maintenance and use of a broad genetic base has been a central theme in the development of agroforestry. Nevertheless, many problems associated with improvement and reproduction of multipurpose trees in agroforestry are pointed out in the literature, as well as the reasons of failure (Maghembe *et al*, 1994; Kass, 1993; Sinclair *et al*, 1994). The relevant problems observed by the authors include: (a) knowledge of reproductive biology of the species; (b) lack of knowledge of utilisation, protection and management; (c) lack of diverse and productive germplasm and (d) inability to biochemically test different species. Local species may not be able to re-establish where the environment has been significantly altered (Stelling, 1993).

Incentives aiming to promote wild fruit trees are now increasing world-wide. Several papers indicating the potential for selection and improvement, including constraints on uses and development of wild fruit tree resources have been published in recent years (Krishnamurthy *et al.*, 1993; Okafor, 1985). It seems likely therefore that domestication of wild fruit trees such as *Sclerocarya birrea* may be a relevant key to the success of agroforestry.

5.2. *Sclerocarya birrea* in agroforestry

Agroforestry is described as having the potential to increase productivity and provide many and varied products whilst conserving resources and the environment. The role of trees in fruit production, fodder, maintenance and improvement of soil productivity is considered central to the sustainability of many agroforestry systems (Young, 1989; Ingram, 1990). Some wild fruit trees may play an important role when combined with crops and/ or animals.

The *Sclerocarya birrea* is one of the most desired indigenous fruit trees. In some regions such as the rural areas in eastern and southern Africa, the species is that most preferred by farmers due to its multiplicity of uses (Gumbo *et al.*, 1990). A socio-economic study conducted by the same authors in Zimbabwe, revealed that about 80 % of all trees in the fields were fruit trees, all of which are indigenous. *Sclerocarya* was the first named important and preferred species by local people. Similar investigation was also conducted by Sissoko *et al.* (1993) in Mali. The study, which involved 5 villages, identified 28 wild fruit tree species among them *Sclerocarya birrea* was one of the most common and the most valuable multipurpose tree species.

The integration of fruit trees in farming systems has been practised around the world, including Africa, for many years (Kamara *et al.*, 1993; Campbell, 1986). Marula is, therefore, one of the most useful fruit tree and is protected by farmers. According to Campbell (1987) and Gumbo *et al.* (1990), most peasant households in Zimbabwe use edible fruits of indigenous wood plants

which are left when land is cleared for cultivation or establishment of houses. Marula is one of the most abundant wild fruit across the country.

Sclerocarya birrea is also reported to be a dominant fruit tree around the household rural areas of Zambia, Malawi, Tanzania and Mozambique (Maghembe *et al.*, 1994; Macucule, 1991). The species and many other indigenous fruit trees such as *Strychnos spinosa*, *Syzygium cordatum*, *Vangueria infausta*, *Uapaka kirkiana* and others, are normally selected and left during the establishment of the homestead or the field, and are protected by farmers.

In some countries the promotion of indigenous fruit trees, including non-domesticated species, has become increasingly an issue for forest and agricultural institutions. For instance, while in many countries wild fruit trees are left to natural regeneration, in Zimbabwe the enthusiasm for planting fruit trees is reported to be increasing with improved access to seedlings for local communities (Gumbo *et al.*, 1990). Programmes aiming to encourage propagation and cultivation of indigenous fruit trees are also reported by ENDA (1991), who also advise farmers on propagation techniques of several wild fruit trees, among them the *Sclerocarya birrea*.

The importance of Marula in agroforestry is therefore widely reputed and appreciated. It is one of the farmers preferences as a suitable indigenous species to consider for development. However, no references on agroforestry experiments using this species are cited in the literature.

5.3. Propagation methods

Little is known about silvicultural requirements of Marula (Weinert *et al.*, 1990). However it is successfully propagated by seed and cuttings (FAO, 1988; Weinert *et al.*, 1990; Von Teichman *et al.*, 1986). Von Maydell (1990) estimates on 400 seeds/ 1 kg, while Shone (1979) reports only 200 seeds/ 1 kg. The authors indicated also that *Sclerocarya* coppices very well and this may be an important adaptation for drought tolerance.

Marula also regenerates naturally in many regions of its occurrence. However, the foliage of young trees is relished by animals, killing the young trees completely. A great deal of the distortion in Marula trees is due to damage from browsing (Shone, 1979).

5.3.1. Propagation by seed

Sclerocarya birrea is easily propagated by seed and can provide 100 % germination (Shone, 1979). For good germination rates, it is recommended that seeds should be soaked in water for 12 hours before sowing (FAO, 1988, Von Teichman *et al.*, 1986). Although germination rate is considered to be very good, the overall survival rate is pointed out to be very poor by ENDA (1991).

Shone (1979) notes that seeds which are immature when dropped will not germinate even under favourable conditions. As an example, the seed sown in March did not germinate until November. The author recommended to sow only old seed or to store the fresh seed for seven to eight months.

The method of reproduction in the nursery is also recommended by Shone (1979) as follows: the seed should be covered with 30 mm of pure river sand and the nursery soil should be a sandy loam which is particularly well drained. Germination will commence within three weeks. Over-watering should be guarded against. From 25 to 30 seeds should be sown in a trial.

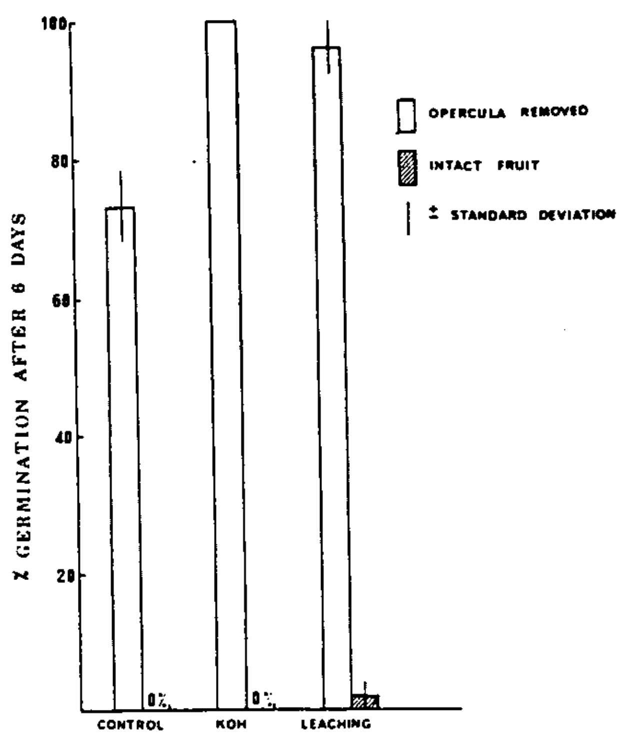
Under sound nursery conditions, growth is considered to be rapid. A well developed root system is produced and root pruning does not adversely affect the growth of *Sclerocarya*. Investigations on pre-treatment of Marula's seed with hot water did not show improved germination, while seed recovered from the beer-making process germinated satisfactory (Shone, 1979).

An interesting investigation conducted by Von Teichman *et al.*, (1986) on Marula's seed germination showed results of the effects of removal of opercula and leaching, the effect of oxygen, light, temperature and fruit age in germination. The same author reported that the endocarp of Marula's seed appears to restrict germination by offering mechanical resistance and it may also restrict the leaching of germination inhibition sand possibly as a barrier to oxygen diffusion. Optimum germination was obtained at 27 ° and 37 ° C of opercula-removed seeds, which seems to be consistent with the fact that Marula is a subtropical plant. The test of opercula-removed fruits was further increased by a preceding leaching in running tap water for 24 h. The authors indicated also that an increase in germination after removing opercula was also obtained by previous soaking for 24 h in 1 mol dm^{-3} KOH (figure 5.1). The effect of oxygen on germination is shown in figure 5.2.

The study concluded also that raising the concentration of oxygen to 100 % increased germination of intact fruits. However, maximum germination was only obtained with fruits from which opercula was removed. Leaching the fruit with tape water consistently gave a significantly higher germination percentage in comparison with that of the control (figure 5.1). The experiment concluded also that the barrier offered by the endocarp to oxygen diffusion is less relevant for the germination.

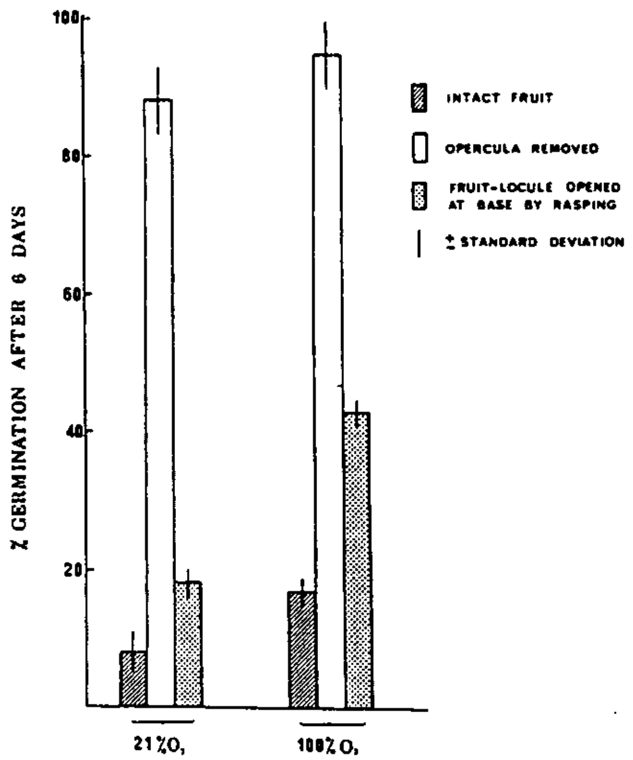
It was also concluded that the endocarp of Marula fruit does not restrict water uptake by seeds, which is considered to contrast with some other members of Anacardiaceae.

FIGURE 5.1: Effect of soaking for 24 h in 1 mol dm $^{-3}$ KOH and tap water leeching (24 h) on germination of *Sclerocarya birrea* in the dark at 27° C (fruit age 4,5 months) (Adopted from Von Teichman *et al.*, 1986).



Source: Von Teichman *et al.*, (1986)

FIGURE 5.2: Effect of oxygen on the germination of *Sclerocarya birrea* in the dark at 27° C (fruit age 10,5 months) (Adopted from Von Teichman *et al.*, 1986).



Source: Von Teichman *et al.*, (1986)

Experiment on identification and germination of the species, recently conducted by Maghembe, (1994) showed promising results and recommended propagation techniques. Maghembe (1994) and Maghembe *et al.* (1994) observed good performance of several indigenous trees in Malawi,

including *Sclerocarya birrea*. At 27 months after planting it showed 1.85 m height, 1.19 crown diameter, 2 stems, and 4,9 cm of root diameter. These figures are similar or even better than other species such as *Annona senegalensis*, *Strychnos spinosa* and *Tamarindus indica* which are reported for the same experiment. At 4 years old, Marula revealed a survival rate of 85 % also comparable to species such as *Parkia filcoidea*, *Syzygium cordatum*, *Bridelia micrantha* and *Zizipus abyssinica*, also investigated.

Germination and ecological distribution of *Sclerocarya birrea* is also reported to be influenced by animals. In natural forests of Southern Africa, particularly in the miombo ecozone, elephants (*Loxodonta africana*) are reported to have an important role on natural regeneration of *Sclerocarya*. Shone (1979) findings supported this and stated that most of the larger animals swallow the seed and large numbers a found in their droppings. The author points out that the passage through the animals does not affect the viability of the seed and that this explains the presence of young trees in the kraals and in gardens where the seed was brought in with manure.

According to Lewis (1987), in a study conducted in Luangwa Valley, Zambia, elephants have a positive influence on seed germination and early seedling growth from their fruit ingestion. Similar indication is also given by ENDA (1991), reporting the role of livestock on spreading of Marula's seed, while Lewis (1987) notes that younger trees are relatively scarce in areas browsed by mammals other than elephants.

5.3.2. Propagation from cuttings

Marula is reported to be successfully propagated by cuttings. It strikes well from truncheous or stem cuttings, and according to ENDA (1991) this is probably the best cultivation method.

Propagation by this method is very easy and commonly adopted by farmers in Zimbabwe. To be successful it is recommended that cuttings must be selected from trees with good quality fruits and/ or trees which bear both male and female flowers.

5.3.3. Coppice

Sclerocarya coppices well and grows through root suckers (FAO, 1988). Older and larger trees, however, do not generally coppice (Shone, 1979). The author also points out that young growth at the tips of branches is cut at the time of bud swelling. It is recommended that truncheons of 2 m in length and 10 cm in diameter are used. The material must be planted 0.6 m deep and must be kept damp.

FAO (1988) as well as Shone (1979) reported that the ability of coppice is notable in young Marula trees. They can be felled repeatedly and will continue to coppice. The authors pointed out that coppice shoots seldom appear to develop into full-sized trees. The adaptability of species in coppicing is reflected in its dispersion throughout open woodland savanna and open grassland where fires as well as browsing by animals are the most severe factor affecting vegetation every year.

5.4. Pests and diseases

Little information is available about pests and diseases of Marula from the literature. Nevertheless, a disease on leaves caused by fungi (*Phyllactinia gorterii*) is reported to be identified in South Africa (Eicker, 1988). The fungi caused damage in most of the youngest leaves of Marula tree.

In 1983 and 1984, a pyralid infesting fruits of Marula was reported in South Africa, as well as in Namibia (Schoeman *et al.*, 1987). The study was based in samples of fruits from both countries. The author indicated that about 20 % of the fruit examined was infested by the pyralid, identified as *Mussidia* sp. (*Lepidoptera*: Phycitidae). The larvae feed only on the flesh of the fruit and leave the peel and the pip intact.

Two years before the above mentioned investigation, another insect pest of Marula, the fly called *Pardalaspis cosyra* (Walker) was also reported by Annecke, quoted in Schoeman *et al.* (1987).

An investigation conducted by Parker (1978) on the pathology of *Sclerocarya* reported the following agents and their effects:

FUNGI: **Ascomycetes**

(a) Capnodiales: *Capnodium* sp., sooty mould;

(b) Erysiphales: *Phyllactinia* sp., occasional powdery mildew infection;

(c) Microthyriales: *Microthyriella* sp.;

(d) Pleosporales: *Guignardia citricarpa* Kieley;

(e) Pleosporales: *Herpotrichia australis* Bose;

Deuteromycetes

(a) Hyphomycetales: *Ovulariopsis* sp., a state of phyllactinia;

Indeterminead

Natural yeasts present in the fruit were identified.

INSECTS: **Coleoptera**

(a) Nitidulidae: *Carpophilus hemipterus* (L.), which feeds on sap of fruit pulp;

(b) *Lyctus* sp., one of the borers of Marula's wood;

Hemiptera

(a) Coccidae: *Andaspis laurentina De* Almeida,

(b) Tingidae: species not identified.

Lepidoptera

(a) *Gonimbrasia belina*, One of the hosts for the Mopane caterpillar, eaten by villagers in Southern Africa;

(b) Olethreutidae: *Cryptophlebia leucotreta* (Meyr.), larvae bore into fruits and seeds;

5.5. Research and extension

Research on Marula has been conducted since early 1950's, but only on chemical composition and nutritional value of fruit and kernel; wood structure, properties and its applicability; and germination and propagation of the species. The most recent information is reported on Maghembe *et al.* (1994), reporting domestication potential of several indigenous fruits trees of the miombo woodlands, including *Sclerocarya birrea*. According to the same authors, domestication or even the planting of wild fruit seedlings is not common.

Research of *Sclerocarya birrea* and other non-domesticated fruit trees are one of the main objectives of the International Centre for Research in Agroforestry (ICRAF), based in Kenya. Strategies for the improvement of

indigenous fruit trees through the multipurpose tree improvement and management programme of ICRAF is reported by Maghembe *et al.* (1994). Studies on selected wild fruit trees including *Sclerocarya birrea* are reported with promising results (Kass, 1993; Kamara *et al.*, 1993). However, there are still information gaps in knowledge on these materials.

A research program on introduction and domestication of *Sclerocarya birrea* and some other wild fruit trees in Israel, was established in early 1994 (Nerd *et al.*, 1990). *Sclerocarya* was one of the most suitable candidate species selected and its performance is reported as successful.

Although Marula is a popular fruit tree species, few references report its inclusion in extension programmes (e.g. ENDA, 1991). It is believed that farmers in general may improve plantation rates of *Sclerocarya birrea*, as well as other indigenous fruit trees if extension programmes are favourable to their promotion.

Chapter Six

CONCLUSIONS AND RECOMMENDATIONS

From the information provided in this literature review on *Sclerocarya birrea*, the following conclusions and recommendations can be drawn:

6.1. Conclusions

Sclerocarya birrea is one of the best known wild fruit tree species in African communities. It is one of the most important wild sources of human food. The value of the species is not only reported on provision of food, but also on medicinal , ritual purposes and applicability of its wood for local uses. Marula is also an important source of fodder for wild and domestic animals.

Although there is considerable information from laboratory analysis on the chemical composition of *Sclerocarya birrea*, much less is known about their exact values. Few references are available about the digestibility and the presence or absence of antinutritive factors of both fruits and leaves. The volatile components identified such as alcohols, esters, organic acids, furans, sequiterpenes and others may guide further investigations.

The fruit of marula contains substantial levels of ascorbic acid (vitamin C) and it is also evident that the species is an important source of essential mineral elements, particularly Mg, Ca and P. However, there is quite a large variation in the results reported by distinct authors.

Marula is a potential wild multipurpose tree species for tropical and subtropical environment due to its relatively less specific demands on soil type and rainfall. The species is also fire resistant. It may also help reduce soil erosion losses, maintain plant diversity, while providing a range of useful products and services.

Due to its multiplicity of benefits, Marula is a suitable tree species for use in agroforestry. It is also clear that local people are interested in the benefits provided by the species, but the general consensus is that wild fruit trees are only needed to the extent that they can produce edible fruits and some medicines. The use of Marula and other wild fruit trees for environmental purposes is less known.

The species offers remarkable opportunities to contribute to the development of agroforestry as well as to industry in Africa.

6.2. Recommendations

Judging from the performance and benefits reported about the species, it is clear that further studies and development of domestication techniques are urgently required. This will not only contribute to increased production of fruits, but will also help to preserve the genetic diversity of the species and achieve a good balance of the local biodiversity. The protection and even the propagation of the tree should be seriously considered by researchers and extensionists.

It is recommended that nutritional laboratories, research institutions and university departments should be make more effort to carry out research to obtain additional information and analyses on the species. Efforts must also be put into collecting data on phenology, yields, different uses per region, and periodicity of uses and fruiting.

Socio-economic research is a necessary complement to biological research and both are crucial ingredients for successful extension programmes. Therefore, a detailed socio-economic appraisal about the species is recommended for different regions where *Sclerocarya birrea* occur. It is also important to assess the production and marketing potentials of the species for farmers.

Sclerocarya birrea as a multipurpose tree must be preferred to single-purpose ones and therefore it may be desirable to focus attention on potential for its genetic improvement. This may be a key issue for increased productivity,

pests and diseases control, drought tolerance and better quality of fruits and tree structure.

Agroforestry research must be conducted in order to access its potentials on soil protection, fodder and the effect of the tree associated which crops. To achieve this goal, It is recommended that more research on propagation and improvement of the species are conducted.

Farmers, should be trained through extension services on improved management practices of the species, including regeneration methods, protection, and improved ways of fruit and nut processing.

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