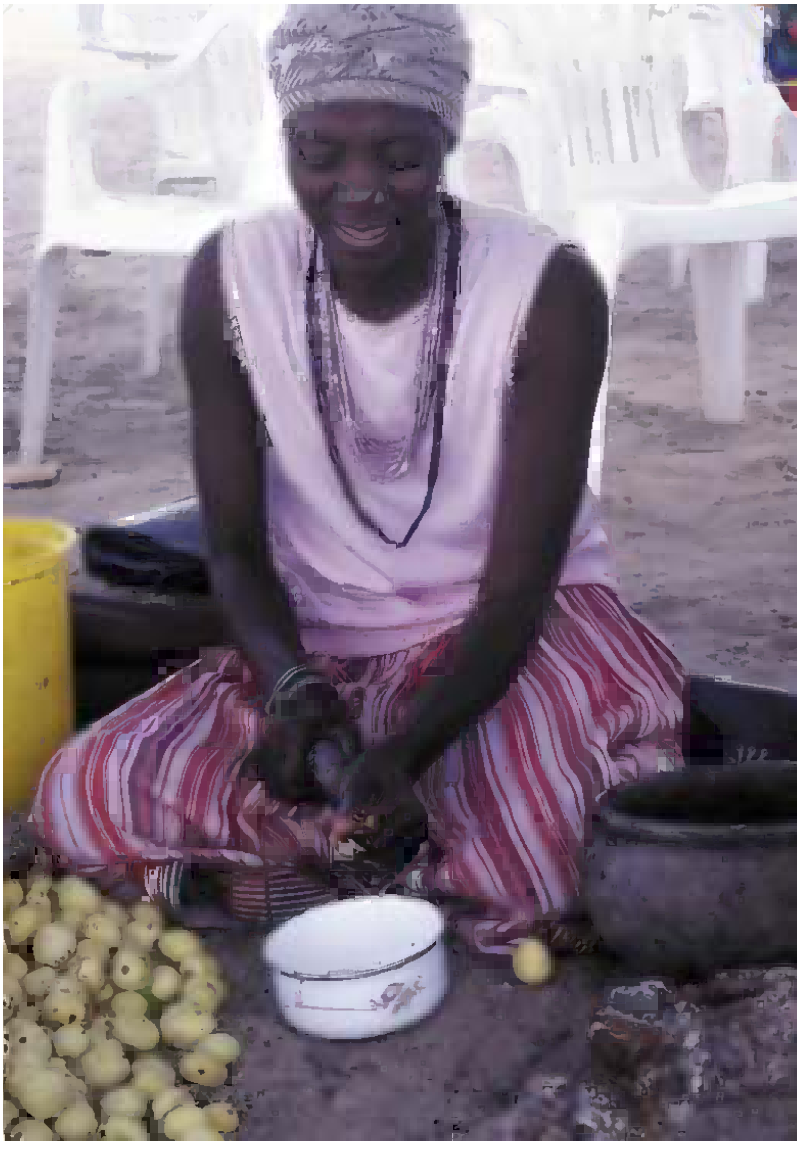
SCLEROCARYA BIRREA



A MONOGRAPH

SCLEROCARYA BIRREA

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Edited by John B. Hall, E. M. O'Brien and Fergus L. Sinclair

School of Agricultural and Forest Sciences,
University of Wales, Bangor, U.K.

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Front cover: Extracting marula juice manually in Namibia, using a cow horn to separate the skin from the flesh. Oil is later extracted from the kernels. (PRshots.com and The Body Shop)

Back cover: Sclerocarya birrea subsp. *caffra*: extracted whole kernels – South Africa (C Geldenhuys)

DEDICATION

This monograph is dedicated to the memory of Dr Abdou-Salam Ouédraogo, whose knowledge of the ecology and biology of the economic trees of West Africa's parklands was unrivalled. Dr Ouédraogo, of the Centre National de Semences Forestières, Burkina Faso, and the International Plant Genetic Resources Institute, was tragically a victim of the air disaster off the West African coast on the 30th January 2000.

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Permission for Eileen O'Brien to examine holdings of *Sclerocarya* at the Royal Botanic Gardens (Kew), the Natural History Museum (London), the Daubeny Herbarium (Oxford), Muséum National d'Histoire Naturelle (Paris) and the National Botanic Garden of Belgium (Meise) is gratefully acknowledged.

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FOREWORD

Sclerocarya birrea ranks among a select group of wide-ranging African trees that have remained essentially wild, despite having had major cultural and economic roles dating back for centuries. *Sclerocarya* is still important for sustaining rural livelihoods today and there is much recent interest in its domestication and commercialisation, both to protect the tree as a resource and to sustainably exploit it to increase the income and food security of rural people within its natural range. A little over 20 years ago, A K Shone drew together a wealth of information about this fascinating tree in a Bulletin published by the South African Department of Forestry, which remains an indispensable study for anyone concerned with the species in the South African part of the range. There have been many developments involving *Sclerocarya* since Shone wrote his bulletin, notably a burgeoning interest in its commercial potential and increasing awareness of its significance elsewhere in Africa, on both sides of the equator. This new monograph on the species re-assesses our knowledge of the species and brings it up to date, expanding the context in which the tree is considered to cover the whole of its vast natural range, and covering its emerging commercial potential that is making the tree significant far beyond the local communities which have used and conserved it into present times.

Fergus L. Sinclair
School of Agricultural and Forest Sciences
University of Wales, Bangor

LIST OF CONTRIBUTORS

Name	Institution
Professor O.T. Edje	Crop Production Department, Faculty of Agriculture, University of Swaziland, Luyengo, Swaziland
Dr John B. Hall	School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd, LL57 2UW, UK Tel: +44 1248 382446; Fax: +44 1248 38 2459 Email: j.b.hall@bangor.ac.uk
Dr Hannah Jaenicke	World Agroforestry Centre, PO Box 30677, Nairobi, Kenya
Mr Moses Munjuga	World Agroforestry Centre, PO Box 30677, Nairobi, Kenya
Dr Bernard Muok	Kenya Forestry Research Institute, P O Box 892, Kitui, Kenya
Dr Eileen M. O'Brien	School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd, LL57 2UW, UK
Mr Kago Phofuetsile	Veld Products Research & Development, Box 2020, Gaborone, Botswana
Dr Fergus L. Sinclair	School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd, LL57 2UW, UK
Ms Margaret K. Thiong'o	World Agroforestry Centre, P O Box 30677, Nairobi, Kenya
Ms Emma Youde	School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd, LL57 2UW, UK

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1 IMPORTANCE

E.M. O'Brien, John B. Hall and Fergus L. Sinclair

Sclerocarya birrea stands out in the African landscape, now and in the history of the continent, as a large tree in every way, in terms of its stature, its range and its value to people. Still a wild resource, the explosive spread of interest in its commercial potential in the last few years has made it a high priority for domestication. Aptly described as one of the great trees of Africa (Palmer & Pitman, 1972-1974), it is noteworthy for the extensive geographic range over which it is a highly valued resource, and remarkable in terms of the antiquity of its role and the exceptional variety of useful products that are obtained from it.

Sclerocarya birrea has a vast geographic range, incorporating three subspecies: *caffra* in the south, *birrea* further north and in West Africa, and *multifoliolata*, which occurs only in a comparatively small area where the ranges of the other two subspecies overlap. The overall range of the species covers approximately half of White's (1983) two main woodland-dominated phytochoria, the Zambezian and the Sudanian centres of endemism, giving an area of 3.75 x 10^6 km^2, which almost certainly underestimates actual coverage. The natural range of the tree is a broad crescent, cradling Africa's equatorial forest block. At its widest spread, the range extends 8000 km from the Senegal coast to south-eastern Madagascar and *Sclerocarya birrea* is present more or less everywhere within this area where conditions are suitable. Within the present range, there are populations associated with periodically very high temperatures as in West Africa, lower temperatures as in subtropical southern Africa or long periods of soil water deficit, especially in parts of West Africa. This range incorporates all or part of the heartland of many cultures which attach value to *Sclerocarya birrea* as a resource, and where interest and usage continue, although to differing degrees. Many of Africa's peoples, from Senegal to Ethiopia and from Angola to the continent's eastern seaboard and Madagascar could benefit from progress in the domestication and improvement of the species. This necessarily assumes adequate attention to local circumstances, particularly in much of West Africa where *Parkia biglobosa* and *Vitellaria paradoxa*, both absent south of the equator, are the pre-eminent semi-domesticated fruit tree resources. However, even in West Africa, there are people living in conditions too dry for *Parkia biglobosa* and *Vitellaria paradoxa* for whom subsp. *birrea* is a vital source of vegetable oil (Seignobos, 1982).

With the exception of the study by Neumann *et al.* (1998) in Burkina Faso, published comments on the historical role of *Sclerocarya birrea* all refer to subsp. *caffra*. There has been speculation that endocarp material recovered from archaeological deposits aged at 150 000 years in today's Zimbabwe could signify resource usage around the time that *Homo sapiens* was emerging as a species. There is much wider acceptance that much younger material (9000 - 11 000 years old), from the same area near Bulawayo, reflects the earliest organized exploitation (Walker, 1989). This period is believed by Walker to span the transition from nomadic activities to longer-term residence enabled by abundant wild fruits, including those of subsp. *caffra*, among other resources. At some later date, tools to extract the kernels efficiently from the endocarps were developed. Fragments of endocarps dated at around 1000 years old in both southern (Palmer & Pitman, 1972-1974) and western (subsp. *birrea* - Neumann *et al.*, 1998) Africa testify to use of tools to extract kernels, presumably for their oil. Tools themselves have been recovered at several archaeological sites in South Africa. Preparation of fermented beverages from fruits of subsp. *caffra* followed the development of pot-making skills and early awareness that some trees were superior to others, for larger crops of preferred fruit quality, leading to the emergence of the distinctive cultural significance of the tree. The strength of the so-called "Morula culture" (Krige, 1937) has prompted suggestions that brewing skills and systematic use of subsp. *caffra* trees date back many centuries (Palmer & Pitman, 1972-1974).

As subsp. *caffra* gained significance for the societies using it, sophisticated understanding of the tree developed. Recorded uses, particularly in its social and medicinal roles, have been linked to the attributes of potentially prolific yields, dioecy and the vivid reddish coloration revealed when bark is stripped from the bole (Shackleton *et al.*, 2002). Indications of the strength of understanding are the extensive vocabulary associated with the tree, including strong calendar associations (*e.g.* in Botswana, Namibia and Swaziland), male/female distinction, ethnotaxonomic terminology, suites of related names in different languages over a wide area of southern Africa and independent terms for different parts of the tree (Shackleton *et al.*, 2002). The extent of the vocabulary is further evidence of a very long period of organized usage. Reverence, ensuring a protected status for the tree, and cultural significance have often made the tree an important venue for ceremonial activity. This is likely to have arisen from appreciation of the majestic stature of old trees, their great longevity in comparison with the human life span, and the many years of fruit production of vigorous female trees. Linked to this has been the progressive development of bonds amongst people maintained and expressed through hospitality centred on consumption of the traditional beverages made from the fruit. In Bushbuckridge, South Africa, this has recently been documented as a major element of social capital (Shackleton & Shackleton, 2002).

Impacts of change in the way rural people allocate time seem to have affected use of subsp. *caffra* fruits in some areas, and for increasing numbers of people exotic alternatives are more conveniently accessible. Other factors are reduced opportunity for children to collect fruits because of attendance at school, and a wider reluctance to engage in time-consuming kernel extraction. Apart from social changes, in places fruit supplies have declined as female trees are felled or receive insufficient pollen as male individuals in the vicinity are cleared for carving wood or firewood. Nevertheless, despite such changes, subsp. *caffra* remains a significant resource. Long-established practices which bring produce into households and markets persist, and recent surveys in South Africa confirm that over 75% of households continue to use wild fruits as important dietary items (Shackleton *et al.*, 2002). In addition, there is increasing commercial involvement with subsp. *caffra* products, as households and traders take advantage of customers willing to pay cash for ‘beer’ prepared by fermenting the fruits, setting aside the old tradition prohibiting sale of this product. Emerging industrial enterprises are also seeking to purchase supplies of raw material.

The range of products, and the appreciation and attractiveness of their quality alongside the available alternatives, set *Sclerocarya birrea* apart as an economic tree of the African drylands. From fruit-bearing shoot tips to medicinal roots, from annual forage to perennial wood production, from palatable seedling foliage to dead stumps harbouring edible larvae and from fresh fruits to extracted oil, household roles are diverse and significant (Tables 1.1-1.3). Table 1.1 identifies chapters in this monograph which consider products in a wider context and in more detail.

Table 1.1. Spectrum of products from *Sclerocarya birrea*

Item	**Major uses**	**Comments**	**Further consideration**
Seeds	food; oil source	household and commercial interest	Chapters 4, 5
Fruits	food; juice and fermented juice	household and commercial interest	Chapters 4, 5
Flowers	bee forage	continuing but minor household level significance	Chapters 4, 6
Foliage	support for edible larvae; browse; medicinal	minor household interest	Chapters 6, 7
Branches	propagation material; haustorial ornaments; fuelwood	domestication programme significance; minor commercial interest	Chapters 2, 5, 8
Bark	medicinal	household significance; commercial exploration of potential	Chapter 6
Gum	no current significance		Chapter 7
Bole	rotting stumps source of edible larvae; wood for utensils and furniture; fuelwood	household significance	Chapters 6, 7
Roots	medicinal	household interest	Chapters 2, 6
Intact tree	sustainable fruit supply	household and cash generation interest	Chapter 8

With regard to subsp. *caffra*, Shone (1979) shrewdly observes that it is South Africa's only indigenous tree producing fruits in such substantial quantities that the very way of life of the rural people is affected. Several key products from the tree offer more than the mere convenience of local availability by virtue of properties and qualities unmatched by alternatives. The wood is favoured as splinter-free and soft, and is easily worked or carved into the shapes required for domestic articles, from large items, such as mortars and trays, to spoons and forks (Shone, 1979). These practical attributes of the wood far outweigh its lack of durability and its unsuitability for outdoor use. The fruit flesh has several attractive features, the most noteworthy being the combination of fleshiness and juiciness with a high concentration of vitamin C. Whilst fruit composition varies, even the lower vitamin C levels recorded compare favourably with other wild dryland tree fruits (Carr, 1957). As oil seeds, the kernels of subsp. *caffra* and subsp. *birrea* are very rich in fat (*ca* 60%) and crude protein (*ca* 30%), and the dominance of unsaturated acids in the fat fraction is a further desirable characteristic. Other wild dryland oil seeds (*e.g. Balanites aegyptiaca* and *Ziziphus mauritiana*) contain lower proportions of either protein, unsaturated fatty acids or both and lack edible outer flesh of comparable flavour and nutritional value.

In southern Africa, subsp. *caffra* is already a focus for commercial development because it is locally recognised as a priority species while further north subsp. *birrea* represents an underutilised resource with as yet untapped development potential. Shackleton *et al.* (2002) have collected and collated recent survey and questionnaire information on household interest in subsp. *caffra* in southern Africa, a previously much neglected issue (Table 1.2). The continuing significance of subsp. *caffra* is evident, although by no means in every community assessed. Comparable information for subsp. *birrea* is not available but in a broad survey where West African farmers ranked preferences among indigenous trees several other fruit trees (including *Adansonia digitata*, *Lannea microcarpa*, *Parkia biglobosa*, *Tamarindus indica* and *Vitellaria paradoxa*) were consistently given higher priority (Bonkoungou, 1997). In Mali, the priority ranking for subsp. *birrea* was sixth and in Burkina Faso, Niger and Senegal around tenth. In another survey of farmer perceptions in Burkina Faso (Ki, 1994), a minority (14 of 168 farmers) ranked subsp. *birrea* as a third priority; none assigned a higher rating.

Few data have been collected which quantify the potential for earning income from *Sclerocarya birrea* (Table 1.3). The 'beer' production aspect of this has been examined in some depth through a recent case study carried out in the Bushbuckridge District in the north of South Africa (Shackleton, 2002).

Complementing the familiar cultural and practical values of *Sclerocarya birrea* is a less widely publicised role in ecosystem function. There are several facets of this, all linked to the relatively large size of the tree at maturity. Mature trees in most parts of the range are tall enough, and have sufficiently large crowns, to serve as shade trees, with pruning of low branches an option for the farmer. The understorey vegetation beneath crowns is modified by a combination of shade and related local soil amelioration. Mogg (1969b) notes exploitation of the modified sub-canopy environment under subsp. *caffra* for growing sweet potatoes on Inhaca Island, Mozambique. As a fruit tree particularly attractive to large animals, notably elephant, a keystone function has been assumed in Kruger National Park, South Africa. Selective use by elephant of subsp. *caffra* for bark, and seasonally for fruits, has been demonstrated (Jacobs & Biggs, 2002b). The large crowns of mature old individuals offer a relatively safe habitat for a dependent, although not host-specific, community of invertebrates, flying and arboreal vertebrates and loranthaceous parasites, enhancing local biodiversity. More significantly, the prominent and emergent crowns create stepping stones and, collectively, corridors linking populations across landscapes.

Traditional measures adopted to protect trees of subsp. *caffra* impressed 19th Century European visitors to South Africa (Holub, 1881) and underlined the unrivalled status of the tree. Nevertheless, several decades elapsed before its qualities attracted scientific attention, around 1920, in the form of laboratory analyses of oil extracted from the kernels (Shone, 1979) and a patenting of a method to derive khaki dye from the bark. Neither of these initiatives progressed, and commercial interest for the next half century was in the timber – that of subsp. *caffra* in southern Africa and that of subsp. *birrea* in Senegal (Giffard, 1974; Shone, 1979). Meanwhile, the wide rural use of the fruits had prompted

Table 1.2. Rural usage of *Sclerocarya birrea* subsp. *caffra* products in southern Africa

Action	Proportion (%) of households/ respondents involved	Comments
Tree retention	40	On household land holding; for Bushbuckridge, South Africa
Harvesting fruits	65	For subsistence – figures cover other wild products, too; Makua, South Africa
Harvesting fruits	25	For subsistence – figures cover other wild products, too; Manganeng, South Africa
Fruit consumption	59-77	4-5 times per week in fruiting season; the most commonly consumed wild fruit; probably underestimate as opportunistic use excluded; Bushbuckridge, South Africa
Fruit consumption	83-100 (respondents)	For subsistence; range of surveys: Mozambique, South Africa, Zimbabwe
Kernel extraction	2	One household of 50 surveyed in Zimbabwe
Kernel extraction and consumption	100 (respondents)	40 persons interviewed; Inhaca Island, Mozambique
Kernel extraction and consumption	95	Owambo, Namibia
Kernel extraction and consumption	97	Northern South Africa
Kernel extraction and consumption	98	Mbengarewa, Zimbabwe
Kernel extraction and storage	11	Limpopo Province, South Africa
Sale of *Sclerocarya* products	2	Mainly 'beer' (cider) and kernels; Bushbuckridge, South Africa
Medicinal material	2-48	Bark and foliage; southern Africa
Crafting utensils from wood	0	Nor used as fuelwood; Inhaca Island, Mozambique
Crafting utensils from wood	55	Mbengarewa, Zimbabwe
Fuelwood	97	Sihangwane, South Africa
Fuelwood	65	Mainly to fire bricks; Zimbabwe

Source: tabulated from Shackleton *et al.* (2002)

Table 1.3. Retail values of *Sclerocarya birrea* subsp. *caffra* products in southern Africa

Reported values (US $)	Valued item	Comments
30	Wild fruit harvest	Annual value per household; mostly *Sclerocarya*; Bushbuckridge, South Africa
41	36 kg of fruit	Gross annual value per household per season; principal wild resource sold; 65% of households involved; Makua, Sekhukhuneland, South Africa
7	4.5 kg of fruit	Gross annual value per household per season; principal wild resource sold; no resource in or close to village; 25% of households involved; Manganeng, Sekhukhuneland, South Africa
0.02	kg of fruits	Retail value in local market; Bushbuckridge, South Africa
3.71	kg of extracted kernels	Retail value in local market; Bushbuckridge, South Africa
116	*Sclerocarya* products	Average annual value for products from trees on home plots and fields; 40% of households involved; Bushbuckridge, South Africa
87-149	Raw and processed fruit products	Aggregate value for seasonal (summer) trading of wild fruits (*Sclerocarya* a major component); 15% of households involved; Bushbuckridge, South Africa
1	Two litres of 'beer'	Roadside retail value of 'beer' between Bushbuckridge and Thulamahashe, South Africa
0.23	One litre of 'beer'	Retailing in rural areas, South Africa
0.37	One litre of 'beer'	Retailing in urban areas, South Africa
0.62	One litre of 'beer'	Superior/early season 'beer' retailing in urban areas, South Africa
1	One litre of 'beer'	'beer' retailing in urban areas remote from source areas, South Africa
820	'Beer'	Exceptional monthly (winter) value for household trading of 'beer'; Bushbuckridge, South Africa

Source: tabulated from Shackleton *et al.* (2002)

initial analyses of their quality during the 1930s (Krige, 1937). These revealed the high vitamin C content now recognized as such an exceptional and positive feature, explaining how seasonal onset of fruiting in subsp. *caffra* enabled isolated user-communities to counter risks of scurvy during severe droughts (Shone, 1979). It was also noted that this antiscorbutic character was preserved in the 'beer' produced from the fruits. It was not, however, until the 1980s that there was any major research relevant to commercial exploitation of *Sclerocarya birrea*. Commercialisation has since moved swiftly with liqueur production using *Sclerocarya* flavouring dating back to 1982 being the most widely publicised.

Shone, in 1979 concluded that commercial potential lay primarily with the juice, reflecting his awareness of research activity by South Africa's National Food Research Institute. He also commented on 'beer' as a commercial product but expressed doubt that it would be a saleable commodity. Teichman (1983), too, perceived commercial potential in the juice but also drew attention to the emerging interest of medical researchers. At the present time, as foreseen by Shone and Teichman, the range of drinks of various sorts, with flavour or juice of subsp. *caffra* as a vital ingredient, is being diversified and refined by commercial enterprises. Commercial 'beer' production has been attempted on a pilot scale and has attracted interest from multinational cider producing companies. Commercial interest in the oil is also developing fast, with an emerging international market for cosmetics based on kernel oil of subsp. *caffra*. Although information is not in the public domain, a medicinal dimension to commercial development is also in prospect. Having played a major role as a traditional resource for millennia, *Sclerocarya birrea* is now poised to assume new roles in rural development in the 21st Century.

2 ECOLOGY

John B. Hall and E. M. O'Brien

The familiarity of *Sclerocarya birrea* gives the impression of an abundant wild resource. Indeed, past confidence that supplies of *Sclerocarya* products were secure in the longer term made formal attention to management strategies appear irrelevant. Recently, however, the significance of destructive usage and land use changes, with their associated *Sclerocarya* population declines or disruption of regeneration, have been acknowledged. A need for management strategies appropriate for natural populations, including those retained in agricultural landscapes, is now emerging. The effective management of such populations must take account of the ecology of the species, an aspect of its character given little attention in the past, despite the wide distribution. Here, a broad view of the ecology has been taken, including consideration of the systematic and phytogeographical context. We have also attempted to provide an integrated picture, through synthesis and interpretation of comments in the literature and with herbarium specimens, of the character of populations of the species and how the species relates to, and interacts with, its environment and the communities of which it is part.

2.1 DISTRIBUTIONAL CONTEXT

2.1.1 Affinities

Sclerocarya birrea is a member of the Anacardiaceae which, with the Burseraceae, forms one of the three subclades constituting the Eurosid order Sapindales (Soltis *et al.,* 2000). In the past, the Anacardiaceae has usually been divided into four or five tribes – Anacardieae, Spondiadeae, Rhoeae, Semecarpeae and, sometimes, Dobineae. Recent phylogenetic studies have, however, prompted review of the relationships within and involving the family (Gadek *et al.*, 1996; Terrazas & Chase, 1996; Pell & Urbatsch, 2000). At family level, it has been suggested (Judd *et al.*, 1999) that separation from the Burseraceae makes the Anacardiaceae paraphyletic, with the Burseraceae as a sister group (Gadek *et al.*, 1996). For the sample of Anacardiaceae the molecular data indicated two clades, but only genera from the Anacardieae, Rhoeae and Spondiadeae were included. A monophyletic clade, with many plesiomorphic features (Judd *et al.*, 1999), corresponded to the Spondiadeae. The second clade was polyphyletic, combining the representatives of the Rhoeae and the Anacardieae (Terrazas & Chase, 1996).

Sclerocarya is one of the seven genera (out of 18) of the Spondiadeae which occur in Africa (Mabberley, 1997). *Spondias* is a suspected introduction to Africa (Trochain, 1940; Aubréville, 1950). Only one species, *Antrocaryon amazonicum* (Ducke) B.L.Burtt & A.W.Hill, of any of the other African genera of the Spondiadeae is recorded from the Neotropics and this generic placement may be treated with caution. White (1983) lists *Antrocaryon* as an endemic genus of Africa's Guineo-Congolian regional centre of endemism. Links towards the east are somewhat stronger, with *Lannea* represented by one species in south Asia and the apparently closely related genera *Operculicarya* and *Poupartia* present on Madagascar and other Indian Ocean islands. Within the African Spondiadeae, *Sclerocarya* and *Lannea* are the most widely distributed genera. *Lannea* is also the most diverse of the African Spondiadeae, with around 40 species recognized, a few (*e.g. Lannea welwitschii* (Hiern) Engl.) successional or secondary rain forest species, but most (like *Sclerocarya birrea*) typical of dryland habitats. The remaining genera of the Spondiadeae consist of bushland, riparian forest or forest edge species (*Haematostaphis, Harpephyllum*) or forest species best represented in seasonal lowland rain forest (*Antrocaryon, Pseudospondias*). *Sclerocarya birrea* is one of the two species of *Sclerocarya*, the other being *Sclerocarya gillettii* Kokwaro which is restricted to a small area of arid eastern Kenya.

Differing, and unresolved, views (Hutchinson & Dalziel, 1954-1958; Kokwaro, 1986) on whether *Sclerocarya* should be sunk into the Madagascan/Indian Ocean genus *Poupartia* suggest different centres of diversity. Maintaining *Sclerocarya* as a distinct genus, as Kokwaro (1986) has done, results in variation centred in Kenya and Tanzania; treating *Sclerocarya* as synonymous with *Poupartia* (Friedmann, 1997; Schatz, 2001) shifts the centre of variation eastwards to Madagascar and Mauritius.

2.1.2 Fossil record

Müller (1981) has referred pollen of a type matching that of the tribes Rhoeae and Spondiadeae of early Tertiary age (Palaeocene, *ca* 60-55 MYBP), and of later epochs, to the Anacardiaceae. Lower Palaeocene macrofossils have been referred to the Anacardiaceae (Axelrod & Raven, 1978). Younger, but more definite, reports of fossil Spondiadeae material are of early Miocene (*ca* 22 MYBP) wood with the characteristics of *Lannea* (Hamilton, 1974) and of Miocene (19.5 MYBP) and Pliocene (3-4 MYBP) *Antrocaryon* fruits (Bonnefille & Letouzey, 1976; Williamson, 1985). For *Sclerocarya* as a taxon, too little information has been reported for a fossil record to be constructed, although the Lower Miocene Sardinian fossil wood of *Sclerocaryoxylon chiarugii* Biondi (approximately 10-15 million years old) has been described (Biondi, 1981) as very similar to that of today's *Sclerocarya birrea*.

2.1.3 Origin

The absence of *Sclerocarya* from other tropical regions strongly suggests that clues to its origin will lie in the history of Africa's savanna biome. Current understanding of this is somewhat fragmentary but the subject was ably treated by Moreau (1952). Moreau's review was updated by Axelrod & Raven (1978), on whose account much of this commentary has been based. The time when Gondwanaland fragmented is taken as the starting point. The major fragmentation of Gondwanaland took place in the mid-Cretaceous period (*ca* 100 MYBP) and by the end of the Cretaceous period (65 MYBP) numerous angiosperm families were in existence (Müller, 1981). Madagascar separated from the main African land mass in the Cretaceous period, long before there is evidence for the appearance of the *Sclerocarya* or other Spondiadeae. Given that the species is poorly adapted for long distance dispersal across water, this is consistent with the view (Bâthie, 1944) that presence in Madagascar has resulted from introduction.

Axelrod & Raven (1978) map a reconstruction of the African vegetation cover in the late Cretaceous-Palaeocene (75-55 MYBP), by the end of which interval the Anacardiaceae had evolved (Müller, 1981). The map shows a large area of savanna/subtropic woodland-scrub extending over what, today, is Gabon to northern Namibia eastwards to western Kenya and Tanzania, and another area in coastal western Madagascar. During this period, the equator crossed the African land mass at what is now latitude 15-18°N, which implied a climate influenced by high pressure cells over the savanna area. The savanna flora believed to have been present in Africa at this time is regarded by Zohary (1973) as retaining the floristic character of a Cretaceous Gondwanaland dryland flora and its modern successor is a pantropical "*Acacia-Combretum* flora". Compared with today's land surface, the terrain exposed to seasonal climatic conditions was relatively level but included depressions sufficiently marked to produce areas of rainshadow, and edaphically dry sites, that taxa tolerant of different degrees of aridity could occupy. There does not seem to be any evidence at present that *Sclerocarya*, or Spondiadeae from which it might have been derived, were part of the *Acacia-Combretum* flora or among the taxa developing from it in the Palaeocene or Eocene.

By the end of the Eocene epoch (38 MYBP), new areas of drier conditions were arising also in the northern half of Africa as the continent approached its present geographical position and the Tethys Sea retreated in the northeast. The late Oligocene-early Miocene (30-25 MYBP) reconstruction provided by Axelrod & Raven (1978) shows large areas to the north and south of an equatorial rain forest zone, extending from the Atlantic to the Indian Ocean coast, which supported a cover of savanna and woodland. Separate areas of savanna and woodland are mapped on the coast of south Kenya and north Tanzania and on the west coast of Madagascar. In the mid-Tertiary (Eocene/Oligocene epochs), the land surface was beginning to change with the formation of warps and basins. Volcanic activity in Ethiopia in the Oligocene (Wickens, 1976) was another early manifestation of a period of dramatic landscape change which continued through the Miocene, Pliocene and Pleistocene epochs and led to the differentiation of High Africa to the south and east and Low Africa to the northwest. At the start of the Miocene epoch, the African continental divide was low and forest extended across it, although interrupted locally by woodland and grassland, and the Atlantic drainage area reached western Kenya and Tanzania. Within the equatorial belt, changing terrain and air circulation were establishing a definite dry season, even west of the continental divide. The Ethiopian Plateau developed. The sea connection between Tethys and the Indian Ocean was broken (17-18 MYBP) and forest and savannas associated with dry conditions were spreading, occupying the newly forming rift valleys as the climate became drier. Along the northern part of the East African coast forest was probably being reduced to discrete patches separated by savanna vegetation (Axelrod & Raven, 1978). The palaeoendemic-rich eastern arc forests of East Africa (Lovett, 1993) became isolated from the main African forest block at this time. Current and, for *Antrocaryon*, fossil distribution patterns suggest that forest genera of Spondiadeae were represented in the main forest block but not on the eastern arc.

Axelrod & Raven (1978) associate the Miocene epoch with a major episode of rapid speciation in "expanding open areas" in an environmentally heterogeneous southern High Africa. *Sclerocarya* has a distribution pattern which makes it one of the southern elements, as distinguished by Moreau (1952), that eventually spread from a source area in the south to the savannas north of the equator. A Miocene origin for *Sclerocarya* would be consistent with this and would not be in conflict with such fossil evidence as exists. There is also African fossil evidence that potential dispersal agents (Mammalia: Proboscidae) for *Sclerocarya* were present by the Miocene (Bigalke, 1978). It remains far from clear where in southern tropical Africa *Sclerocarya* may have first appeared or its phylogenetic relationship with pre-existing taxa of the Spondiadeae. However, it is apparent that today's species of *Antrocaryon* and *Pseudospondias* are associated with relatively humid lowland forest conditions, and *Sclerocarya* and most of the species of *Lannea* are associated with dryland ecosystems, while the remaining Spondiadeae (*Harpephyllum, Haematostaphis*) are intermediate. Derivation from a forest ancestor of a species able to occupy the increasingly more extensive dryland areas of Miocene southern Africa is a possibility.

By the end of the Miocene epoch the Tethys and Eurasian seas had retreated from northeastern Africa which was now exposed to dry northeasterly and easterly winds. More generally, well-watered open lowland savanna was becoming widespread. In the reconstruction for the late Miocene-early Pliocene period (15-7 MYBP), the equatorial rain forest does not reach the continent's eastern seaboard. The western side of Madagascar supported savanna and woodland and along the Indian Ocean coast was a strip of savanna and woodland linking the extensive areas of this vegetation north and south of the rain forest block. This constituted a potential route for *Sclerocarya* to spread through the equatorial region to the savanna block north of the equator.

Through the Pliocene epoch (7-2.5 MYBP) the trends of change continued, lengthening and deepening rift valleys, and other basins, increasing the areas in rainshadow and facilitating the further spread of savanna and grassland. Major tectonic and volcanic activity resumed, mainly in High Africa, *ca* 2.8 MYBP. Parts of High Africa rose by as much as 1400 m (Wickens, 1976) but there was also major rifting from the Red Sea, through Ethiopia, and into East Africa. Upwarping increased elevation differences between Low and High Africa, transforming the Nile-Congo and Nile-Tchad divides into more significant biogeographical barriers, while high volcanoes formed near the edges of the widening rifts. These changes to the configuration of the land surface considerably increased the environmental heterogeneity of High Africa, especially the equatorial and northeastern part, imposing intensified patterns of climatic, drainage and soil variation. Uplift continued into the Pleistocene epoch, and by the early Pleistocene Africa's interior plateaux were around 1800 m above their Miocene levels (Axelrod & Raven, 1978). Aridity progressively increased through this period, although with a number of moister interludes. At the most arid times an arid corridor severed the south-north savanna connection with a gap at least as wide (700 km – White, 1965) as it is at the present time. The differentiation of the distinct subspecies *birrea* and *caffra* of the northern and southern savanna areas may reflect such events. The few localities known for *Sclerocarya gillettii* lie within a restricted section of the arid corridor, where the aridification effects would have been particularly intense, and perhaps indicate relatively recent differentiation from *Sclerocarya birrea*.

For the relatively short period of the last 0.5-1.0 MY, changes in Africa affecting the vegetation mainly arise from climatic cycles with alternating "glacial" and "interglacial" phases lasting, respectively 80 000-90 000 years and 10 000-20 000 years. In the process, interior basins have been breached and aridification has been furthered, especially in Low Africa. The northern boundary of the savanna retreated south when the Sahara area underwent dry intervals (glacial phases). South of the equator, the southern boundary of the savanna retreated north and the arid corridor was re-established from southwestern Africa to Kenya. In the fragmented topography of East Africa montane vegetation belts shifted downwards by around 1000 m (Wickens, 1976) and presumably replaced areas of savanna. These more recent climatic oscillations may have enabled populations of the different subspecies to become established in close proximity in East Africa's varied landscapes.

2.1.4 Present distribution

The most comprehensive distribution map for *Sclerocarya birrea* previously published is that of Peters (1988) but this does not include Madagascar and records at subspecific level are not separated. Aubréville (1950) maps subsp. *birrea* from Senegal to the Central African Republic and Mullenders (1954) maps subsp. *caffra*. Several maps at national level are also available: for subsp. *caffra* in South Africa (Shone, 1979; Palgrave 1983) and for subsp. *birrea* in Senegal (Trochain, 1940), Tchad (Grondard, 1964) and Niger (Urvoy, 1938). Both subsp. *birrea* and subsp. *caffra* have been mapped for Kenya (Beentje, 1994; Maundu *et al.*, 1999). The map prepared for this monograph (Fig. 2.1) takes into account the locations from which around 540 herbarium specimens were gathered, mostly specimens held by the Royal Botanic Gardens, Kew (K), the National Botanic Garden, Brussels (BR), the Muséum National d'Histoire Naturelle, Paris (P), the Natural History Museum, London (BM) and the Daubeny Herbarium, Oxford (FHO). On-line listings of holdings at the Missouri Botanical Garden, St. Louis (MO) and a listing of Madagascar specimens prepared by A. Randrianasolo at MO have also been used. Additional (*ca* 250) locations were retrieved from the ecological literature. At the scale of map reproduction in this monograph, however, some of these points coincide. Subspecies are distinguished, but those records from Kenya and Tanzania for which subspecies' identity is uncertain have been omitted.

Sclerocarya birrea occurs through most of subsaharan Africa (Fig 2.1). It is recorded eastwards from the Senegal coast (17˚02'W) and Mauritania through Cameroun and the Central African Republic to Eritrea and western Ethiopia. In Sudan the range reaches 16˚42'N at Abu Shendi and 17°15' N in the Aïr Mountains of Niger (Fabregues & Lebrun, 1976). From Sudan and western Ethiopia the range extends south, passing east of the Lake Victoria basin, to Tanzania, Mozambique and South Africa (the southern limit at 31˚00'S, near Port Shepstone – Shackleton *et al.*, 2002), and westwards from these countries to the Atlantic coast in Angola. To the east, the range extends to 50˚09'E in Madagascar.

The three different subspecies occupy different parts of this range but all occur in northern Tanzania, the southern limit for subsp. *birrea*. Subsp. *caffra* has been reported only south of the equator, the range broadly coinciding with that of subsp. *birrea* in northern Tanzania and southern Kenya. Subsp. *multifoliolata* is generally described as endemic to Tanzania but is possibly also present in the adjoining part of Kenya (Bally 621, from Kibwezi – Dale & Greenway, 1961).

Although the overall range of *Sclerocarya birrea* is very wide, there are areas from which few records have been traced and others where the species is known to be very frequent. Areas noteworthy for low numbers of records are the extensive flood-prone area of southern Tchad (subsp. *birrea*) and, perhaps because of limited botanical exploration (Hepper, 1979), eastern Angola (subsp. *caffra*). Subsp. *birrea* is frequent in Senegal, Burkina Faso, northern Nigeria and Cameroun and Kenya while subsp. *caffra* is frequent through the coastal plains of Mozambique and into South Africa. On the higher terrain of the southern/central African plateaux (subsp. *caffra*) and the Nile watershed (subsp. *birrea*) occurrences are more sporadic. Desert conditions limit the range of subsp. *birrea* to the north and at its eastern limit in Kenya and, in combination with the occurrence of regular frosts, the range of subsp. *caffra* to the southwest in Namibia. Equatorially, west of Lake Victoria, neither subsp. *birrea* or subsp. *caffra* penetrates the humid Guineo-Congolian region, although subsp. *caffra* is well-represented to the south, in Katanga, Democratic Republic of Congo, in the Guineo-Congolia/Zambezia transition zone.

Outside the natural range, subsp. *caffra* is grown as an experimental crop in Israel and has been planted occasionally on Reunion and Mauritius (Friedmann, 1997), on Mayotte, in the Comores (Pascal 930 – K, P). It has been argued that the Madagascar populations (also subsp. *caffra*) are the result of introduction (Bâthie, 1944). Trees are also reported to have been planted, often as botanical garden specimens, in the USA (Florida, Gillis 10438, BM – subsp. *caffra*), India (Dehra Dun - subspp. *birrea* and *caffra* – Chadha, 1976) and in Oman (Lawton 1009, BM) and Australia (subspecies uncertain).

2.2 ENVIRONMENTAL FACTORS IN DISTRIBUTION

2.2.1 Elevation

Sclerocarya birrea is a constituent of low elevation (mostly <1600 m) vegetation (Fig. 2.2). All three subspecies have, however, been reliably reported from elevations of at least 1500 m (*e.g.* subsp. *birrea* at around 1700 m in the Jebel Marra area, Sudan (Miehe, 1988); subsp. *caffra* at 1700-1800 m in East Africa (Kokwaro, 1986); subsp. *multifoliolata* at 1500 m in the Ngorongoro area, Tanzania – Kokwaro, 1986). Suggestions, without designation of subspecies, of occurrence at elevations above 2000 m in the Loita and Ngong Hills in Kenya require further investigation. Subsp. *birrea* (*e.g.* in Senegal) and subsp. *caffra* (*e.g.* in Mozambique) are also present in coastal areas within a few metres of sea level. Authenticated voucher specimens of subsp. *multifoliolata* are all referable to localities above 800 m.

2.2.2 Climate

Occurrence of *Sclerocarya birrea* in relation to climate is considered here in terms of rainfall and temperature conditions. These are represented by records for meteorological stations (FAO, 1984) at elevations below 1800 m in the vicinity (within 50 km) of known *Sclerocarya birrea* locations. For subsp. *birrea* 72 stations have been considered; for subsp. *caffra* 126 stations have been considered. Only the Kenya stations at Makindu and Mombasa are included in both lists. Stations at Arusha Airfield, Chunya, Igawa, Iringa Nduli, Kondoa, Mbulu and Mwanza Airfield (all in Tanzania) represent conditions with which subsp. *multifoliolata* is typically associated.

2.2.2.1 Rainfall, potential evapotranspiration and water deficits

The species is associated with a strongly seasonal rainfall pattern (Fig. 2.3). For both subsp. *birrea* and subsp. *caffra* mean annual rainfall is usually 500-1250 mm. Mean monthly rainfall usually exceeds 50 mm in 4-7 months where subsp. *birrea* occurs and in 5-7 months where subsp. *caffra* occurs. Subsp. *caffra* is present in more humid conditions (6-9 months ≥50 mm; mean annual totals 1200-1600 mm) in the transition zone between the Guineo-Congolian and Zambezian regions, and in parts of Madagascar, and subsp. *birrea* in more arid conditions (2-3 months ≥50 mm; mean annual totals 250-500 mm) in the Sahelian region. Subsp. *multifoliolata* occurs in relatively humid conditions: mean annual rainfall 600-1400 mm and 4-8 months when mean rainfall exceeds 50 mm.

Subsp. *birrea* is typically associated with mean annual potential evapotranspiration levels of 1500-2000 mm but lower values arise in the eastern part of the range and higher values in the western part. Subspp. *caffra* and *multifoliolata*, because of the lower temperatures associated with the higher elevations common in eastern Africa and inclusion of higher latitudes in the range, are often subject to lower mean annual potential evapotranspiration values, typically 1100-1700 mm.

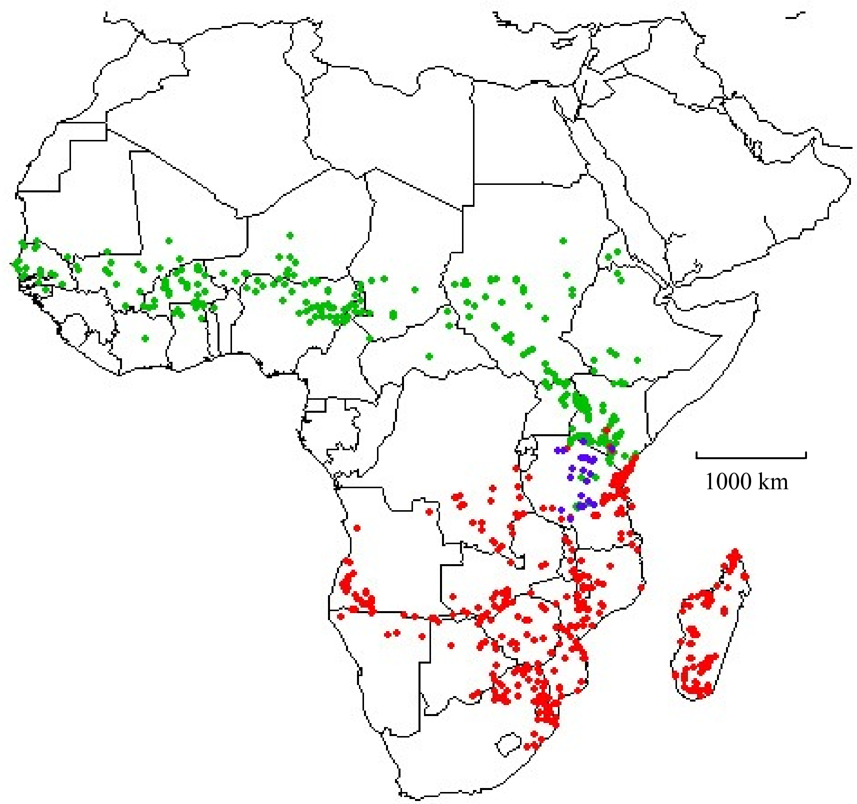


Figure 2.1 Distribution of *Sclerocarya birrea*
Green, subsp. *birrea*; red, subsp. *caffra*; blue, subsp. *multifoliolata*

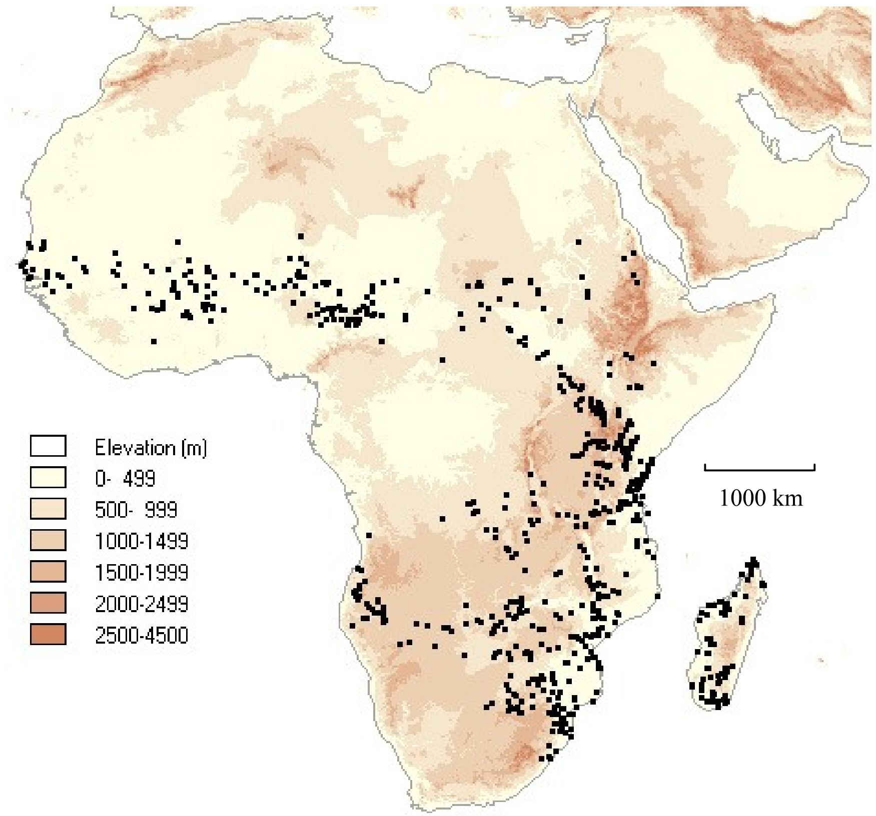
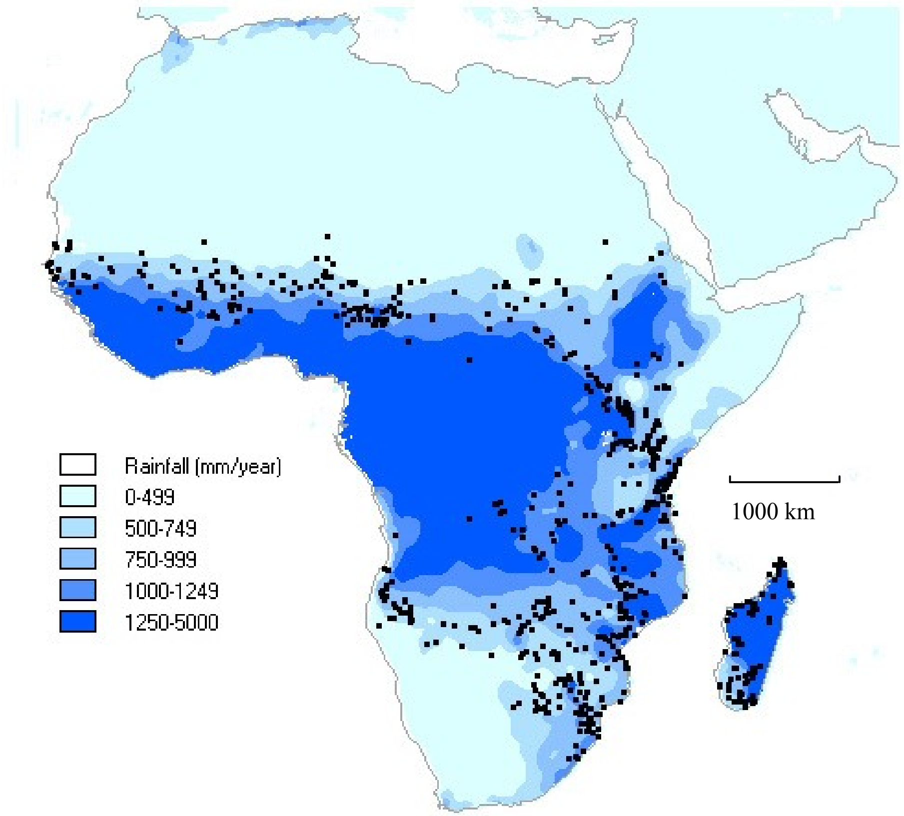


Figure 2.2 Distribution of *Sclerocarya birrea* with respect to elevation



Sources of distribution data—collection localities noted on voucher specimens held in various herbaria, supplemented with literature reports. Herbaria: Royal Botanic Garden, Kew (K); Laboratoire de Phanérogamie Muséum National d'Histoire Naturelle, Paris (P); Jardin Botanique National de Belgique, Meise (BR); Natural History Museum, London (BM); Daubeny Herbarium, Oxford (FHO); Kenya National Herbarium, Nairobi (EAH); Missouri Botanical Garden, St. Louis (MO). Elevation and climate data from Legates & Willmott (1992).

Note: Map extent is 20ºW to 60ºE, 38ºN to 35ºS. Dot width *ca* 50 km. Dot frequency reflects collecting intensity, not population density.

Figure 2.3 Distribution of *Sclerocarya birrea* in relation to rainfall

For subsp. *birrea*, Thornthwaite climatic indices calculated assuming a soil storage capacity of 100 mm available moisture fall mainly between "-20" and "-50", signifying association with the Thornthwaite categories of sub-humid, semi-arid and arid conditions. Corresponding indices for subspp. *caffra* and *multifoliolata* are mainly between "-10" and "-40", signifying association with sub-humid and semi-arid conditions. However, extension of *Sclerocarya birrea* into moister climates is not unusual. Where soil moisture storage capacity is 100 mm, active growth for 3-5 months should be possible – and for longer periods in humid or sub-humid climates. Access to sources of water supplementing direct rainfall enable populations to survive where there would otherwise be 10-12 months of soil water deficit.

2.2.2.2 Temperature regime

Populations north of the equator (subsp. *birrea*) enjoy higher temperatures (mean annual temperature generally 22-29°C) than those (subspp. *caffra* and *multifoliolata*) further south (mean annual temperature generally 19-26°C). Subsp. *birrea* experiences mean annual temperatures generally above 25°C in the lower, western, part of the range but below this in the higher eastern part.

All three subspecies are mostly associated with very similar monthly mean values for the minimum daily temperature of the coldest month – 10.0-17.5°C. However, for most populations towards the southern limit of subsp. *caffra,* minima are lower (5-10°C). Monthly mean values for the maximum daily temperature of the warmest month differ more between the two main subspecies. In much of the West African range of subsp. *birrea* values exceed 35°C. In eastern and southern Africa, in the range of subsp. *caffra*, typical values are from 27°C to 35°C. For subsp. *multifoliolata*, monthly mean values for the maximum daily temperature are consistently below 30.5°C.

The range within the tropics is almost entirely frost-free but populations in southeast Zimbabwe, and south into South Africa, experience occasional frost. This is reported (Teichman, 1983) to cause major branch loss in subsp. *caffra* when severe (-4°C). Temperatures rise above 40°C regularly during April and May in West Africa and absolute maxima above 45°C (54°C, Mali: Timbuktu) are recorded from the West African part of the range of subsp. *birrea*. Subsp. *multifoliolata* seems unlikely ever to be exposed to temperatures higher than 35°C.

2.2.3 Geology and soils

The soils where the species occurs are derived from geological formations ranging from basalts, basement complex rocks and sedimentary rocks of various ages to Quaternary deposits. Most comments about the soils associated with *Sclerocarya birrea* are restricted to the general texture. Sandy texture is specified much more than any other for all the subspecies but sandy loam and loam are also frequently mentioned. Heavy soils are regarded as unsuitable for subsp. *caffra* in Botswana (Timberlake, 1980). However, in parts of the range heavier soils also support well established populations of the species, especially subsp. *caffra* on clayey basaltic soils in southern Africa (Werger & Coetzee, 1978; Shackleton & Scholes, 2000) but also of subsp. *birrea* (*e.g.* Tuley & Alford, 1975, in Nigeria).

In the upper horizons (top 20 cm) soil reaction is weakly acid to neutral (pH 5-7 – Table 2.1) although association with more acid conditions (pH 4.8) was reported from Sudan by Morison *et al.* (1948). However, two other values given by these authors (pH 6.0 and 6.2) are consistent with those in Table 2.1. Occasionally soils are mentioned which are somewhat alkaline (*e.g.* for subsp. *caffra* in Tanzania – Vollesen, 1980) or halomorphic (*e.g.* for subsp. *birrea* in Cameroun – Letouzey, 1985). While association with such soils is only sporadic, and there are no reports that high concentrations of the species are involved, it demonstrates the wide tolerance of soil conditions.

Various views have been expressed about the fertility of the soils where *Sclerocarya birrea* grows but comments often suggest low fertility, and Ohler (1985) refers specifically to low nitrogen and phosphorus levels for subsp. *birrea* in Mali. In contrast, Trapnell (1953) regards subsp. *caffra* as an indicator of fertile soils in Zambia. The few available sets of analytical data (Spooner & Jenkin, 1966; Rains & McKay, 1968; Soumaré *et al.*, 1994; Mateke & Tshikae, 2002) of soils supporting *Sclerocarya birrea* indicate wide variation from site to site (Table 2.1). The Tanzanian samples are relatively nutrient rich, possibly indicating steady inputs through catenary processes from nearby high ground and a climatically more productive environment. The tabulated Mali data, from Niono, clearly underline the ability of subsp. *birrea*, at least, to grow successfully in soil of very low nutrient status.

Several authors refer soils at *Sclerocarya birrea* subsp. *birrea* locations in West Africa to FAO-Unesco (1977) map categories. The categories concerned vary widely – from relatively fertile cambisols in Burkina Faso (Renes, 1991) to erosion-prone regosols and leptosols in Senegal (Wolf, 1998). Acrisols, arenosols and ferralsols have also been mentioned (Giffard, 1974; Ohler, 1985).

Table 2.1. Reported characteristics* of soils sampled in the proximity of *Sclerocarya birrea*

Parameter Location	Botswana (18°15'S, 25°50'E)	Botswana ** (locality not given)	Mali (14°30'N, 5°45'W)	Tanzania (7°24'S, 37°45'E)	Tanzania (7°21'S, 37°29'E)	Tanzania (7°20'S, 37°50'E)	Tanzania (7°22'S, 37°50'E)	Tanzania (7°24'S, 37°25'E)
Subspecies	*caffra*	*caffra*	*birrea*	*caffra*	*caffra*	*caffra*	*caffra*	*caffra*
pH_{water}	6.8	-	5.2	6.0	6.3	7.0	6.3	6.6
pH_{CaCl2}	-	5-7	-	-	-	-	-	-
Loss on ignition (%)	3.3	-	-	9.5	6.2	8.4	3.9	7.9
Organic C (%)	-	0.4-0.8	0.2-0.6	-	-	-	-	-
Total N (%)	0.05	-	0.30	0.13	0.07	0.13	0.06	0.15
Exch. Ca (meq/100 g)	-	1-5	1.3	10.4	5.9	12.3	4.5	17.3
Exch. Mg (meq/100 g)	-	0.5-1.6	0.47	4.16	3.84	4.89	1.95	5.78
Exch. K (meq/100 g)	0.62	0.4-1.0	0.28	0.63	0.25	0.72	0.53	1.72
Exch. Na (meq/100 g)	0.15	0.1-0.7	0.43	0.19	0.10	0.11	0.08	0.08
Total exchangeable bases (meq/100 g)	-	-	2.48	15.38	10.09	18.02	7.06	24.88
Cation exchange capacity (meq/100 g)	-	2.0-6.5	2.65	22.78	12.57	20.82	10.62	29.70
Base saturation (%)	-	-	94	68	80	87	66	84
Total P (ppm)	-	-	90	-	-	-	-	-
Assimilable P (ppm)	-	0.5-11.0	4	28	12	93	81	34
P extracted with 0.1N sodium hydroxide (ppm)	<0.2	-	-	-	-	-	-	-

-, not reported
*Figures adjusted to represent top 20 cm of profile as far as reported information permits
Sources: Botswana – Rains & McKay (1968), Botswana** - Mateke & Tshikae (2002); Mali – Soumaré *et al.* (1994); Tanzania – Spooner & Jenkin (1966)

2.2.4 Toposequences

References to occurrences in areas subject to waterlogging are rare and where comment is explicit (*e.g.* Rattray, 1961; Timberlake *et al.*, 1993) it is clear that *Sclerocarya* is present on the better-drained parts. Many references have been made to good drainage and to the coarse soil textures (sands, sandy loams) that ensure this in most habitats. Where comments are offered, it is indicated that *Sclerocarya* is sparsely distributed in, or absent from, valley bottoms compared with the slopes above (Marchal, 1980). It is also poorly represented on well-defined ridges, although broad interfluves with extensive areas of sandy soil are a favourable habitat.

2.3 SITE

In the tropical part of its range, populations of *Sclerocarya birrea* are generally associated with frost-free conditions. Populations of subsp. *caffra* in the subtropical part of the range exhibit some tolerance of frost, frosts occurring during a period of low moisture availability when the trees are dormant. For South Africa, Poynton (1984) considers sites subject to light frosts are also suitable for growing the species. Deep soils with good drainage are generally desirable. Gentle slopes and higher undulating or level parts of the landscape provide such conditions. Positions close to drainage lines are unsuitable if there is any risk of waterlogging. Towards the southern limits of the range, valleys where cold air collects and cool, south-facing slopes are unsuitable. As long as the soil has not been degraded, the level of fertility does not appear to be critical.

2.4 *SCLEROCARYA BIRREA* AS A VEGETATION COMPONENT

2.4.1 Chorology and vegetation types

White (1983) provides a continent-wide - including Madagascar - framework useful as a context for considering the vegetation in which *Sclerocarya birrea* occurs. The principal elements in the framework are 20 phytochoria (geographic units that share floristics and historical influences). Subdivisions of these are based on vegetation structure, and sometimes predominant taxa, and distinguished in a vegetation map. In comments made on each mapping unit, White refers to major vegetation formations according to a classification refining the widely-embraced scheme conceived by Greenway (1973).

The wide range of *Sclerocarya birrea* extends to most of White's 20 phytochoria and many of his mapping units (Table 2.2). Nevertheless, in continental Africa, it is the vast Sudanian and Zambezian regional centres of endemism, and the more equatorial of the two East African coastal mosaics (Zanzibar-Inhambane) adjoining the latter, that contribute most to the range. However, the strength of the relationship with the Sudanian and Zambezian regional centres, emanates from their drier, more poleward, parts, as it is here that *Sclerocarya birrea* is concentrated. On Madagascar, the species is widespread in the West Malagasy regional centre, long-known (Aubréville, 1949) for environmental conditions comparable with those of the Zambezian and Sudanian regional centres. There is also wide occurrence in the northern half of the Tongaland-Pondoland coastal mosaic and in the southern part of the Somalia-Masai regional centre. Other occurrences represent only localized penetration into contiguous phytochoria, mostly where there are outliers of Zambezian or Sudanian vegetation or the transition to another phytochorion is gradual.

The subspecies of *Sclerocarya birrea* show fairly simple relationships with the different phytochoria – subsp. *birrea* occurs in the northern phytochoria and subsp. *caffra* in the southern phytochoria (Table 2.2). The classic central Tanzanian localities for subsp. *multifoliolata* are in the southern part of the Somalia-Masai regional centre, with subsp. *birrea* occurring further north in this centre. All three subspecies occur in the Zambezian phytochorion but subspp. *birrea* and *multifoliolata* only in the northern part, the latter mainly where exclaves of the Zambezian phytochorion are surrounded by Somalia-Masai vegetation.

Closer consideration of reported occurrences of *Sclerocarya birrea* indicates association especially with seven of White's mapping units (Table 2.2). Two of these, the Zanzibar-Inhambane and the Tongaland-Pondoland coastal mosaics, are designated "forest transitions and mosaics" as a mapping convenience for depicting intricate complexes of contrasting, but ecologically related, vegetation phases. Four of the other five (Zambezian *Colophospermum mopane* and undifferentiated woodlands and Sudanian undifferentiated woodland) are among nine woodland types contributing to the Zambezian and Sudanian regional centres. As a consequence of concentration in the drier parts of these centres, it is noteworthy that *Sclerocarya birrea* is of much less importance in the typical

Brachystegia-Julbernardia (miombo) woodlands of the Zambezian regional centre and in the typical *Isoberlinia* woodlands of the Sudanian regional centre. Occurrences of *Sclerocarya birrea* within areas mapped as miombo or *Isoberlinia* woodland are generally related to vegetation change which reflects localized disturbance or the presence of specialized conditions, often rocky terrain, rarely heavier valley soils (Rattray, 1961; Wild & Barbosa, 1967; Leeuw & Tuley, 1972; Werger & Coetzee, 1978).

The seventh mapping unit with which *Sclerocarya birrea* is associated is White's only other woodland type. This type, the transition from undifferentiated Zambezian woodland to Tongaland-Pondoland bushland, links the South Zambezian undifferentiated woodland with the Tongaland-Pondoland coastal mosaic.

All the seven mapping units include vegetation with widely varying woody plant cover as a result of agricultural activities or because they encompass gradients from moderate (600-800 mm) to low (400-600 mm) mean annual rainfall. Despite the use of "woodland" as the general mapping term, within these mapping units *Sclerocarya birrea* grows in wooded grassland, grassland and parkland (wooded farmland/"anthropic landscapes") vegetation formations at least as much as it grows in woodland, and the more open forms of the latter account for most woodland reports. It is nevertheless apparent that *Sclerocarya birrea* may also be a constituent of denser woody vegetation: forest, transition woodland, thicket, bushland and shrubland. Dry forest (Madagascar – Leandri, 1936; subsp. *caffra*) and transition woodland (Senegal – Wolf, 1998; subsp. *birrea*) formations from which *Sclerocarya birrea* has been reported are possibly relicts of a denser vegetation largely destroyed by man. Subsp. *caffra* has also been recorded as a component of riparian forest (Zimbabwe - Farrell 1968a; South Africa – Acocks, 1988) and of forest patches where there is a high water table on the coastal plain of north-eastern South Africa (Acocks, 1988). The thicket, bushland and shrubland occurrences of *Sclerocarya birrea* tend to be where the range of the species extends over the boundaries of the Zambezian and Sudanian regional centres into areas of low (<500 mm), and often bimodal, annual rainfall. Examples are occurrences of subsp. *caffra* near the Angolan coast (Gossweiler & Mendonça, 1939) and of subsp. *birrea* in the Jebel Marra area of Sudan (Wickens, 1976) and in Karamoja, Uganda (Wilson, 1962). Bushland and thicket occurrences of subsp. *caffra* are also widespread in the northern part of the Tongaland-Pondoland coastal mosaic (Werger & Coetzee, 1978). Published habitat descriptions (*e.g.* Burtt, 1942) suggest that subsp. *multifoliolata* is not uncommonly a constituent of bushland or its gradation into forest, "scrub forest" (Greenway & Vesey-Fitzgerald, 1969).

2.4.2 Community composition

There are numerous published formal and informal species listings for continental Africa which include *Sclerocarya birrea* and Tables 2.3 and 2.4, which indicate frequent woody associates, are based on these. Within the wide range of each of the two main subspecies, the information extracted is summarized on the basis of drainage areas (Tables 2.3 and 2.4). The limited available information for associates of subsp. *multifoliolata* (Table 2.5), and associates of subsp. *caffra* on Madagascar (Table 2.6), is not presented according to drainage areas.

2.4.2.1 Family prominence and floristic elements

Taking the species as a whole, frequent among associates in almost all parts of the range are species of Combretaceae, usually accompanied by mimosoid leguminous species. In more humid areas (Bight of Benin, Benue) caesalpinioid legumes are also well-represented among the associates. In the relatively humid areas of the Congo drainage and drainage into the Indian Ocean off the southern African coastal lowlands, however, neither the Combretaceae nor the caesalpinioid legumes feature strongly and the best-represented group is the mimosoid legumes. The Nile drainage is noteworthy for the number of other members of the Anacardiaceae (four) listed among the associates. The list of associates on Madagascar tends to reflect the island's distinctive flora, expressed in the presence of the endemic families Sarcolaenaceae and Sphaerosepalaceae, and several Asclepiadaceae (a family very diverse in Madagascar, and rich in endemic species). There is a paucity of Combretaceae but inclusion of several legumes (particularly caesalpinioid in this case) is a feature shared with most other parts of the range. The associates listed for subsp. *multifoliolata* indicate Somalia-Masai elements in the community (several Burseraceae) consistent with location at the interface between the Somalia-Masai and Zambezian phytochoria. More leguminous than combretaceous species are listed but it is the Caesalpinioideae (especially) and Papilionoideae, rather than the Mimosoideae that are involved.

Table 2.2. Distribution of *Sclerocarya birrea* in relation to White's (1983) major floristic units (phytochoria), mapping units and vegetation types.

Regional phytochoria	**Mapping unit**	**Vegetation type**	**Subspecies**
Guineo-Congolian regional centre of endemism	Mosaic of Guineo-Congolian lowland rain forest and secondary grassland	Guineo-Congolian secondary grassland and wooded grassland	subsp. *birrea*
Zambezian regional centre of endemism	Mosaic of Zambezian dry deciduous forest and secondary grassland	Zambezian dry deciduous forest and scrub forest	subsp. *caffra*
	Wetter Zambezian miombo woodland	Zambezian miombo woodland	subsp. *caffra*
	Drier Zambezian miombo woodland	Zambezian miombo woodland	subsp. *birrea, caffra*; *multifoliolata* in exclaves
	**Colophospermum mopane* woodland and scrub woodland	*Zambezian mopane woodland and scrub woodland	subsp. *caffra*
	*North Zambezian undifferentiated woodland	*North Zambezian undifferentiated woodland and wooded grassland	subsp. *caffra*
	*South Zambezian undifferentiated woodland	*South Zambezian undifferentiated woodland and scrub woodland	subsp. *caffra*
	not mapped	Zambezian swamp forest and riparian forest	subsp. *caffra*
Sudanian regional centre of endemism	Sudanian woodland with abundant *Isoberlinia*	Sudanian *Isoberlinia* and Related woodlands	subsp. *birrea*
	*Sudanian undifferentiated woodland	*Sudanian undifferentiated woodland	subsp. *birrea*
	Sudanian undifferentiated woodland with islands of *Isoberlinia*	Sudanian undifferentiated woodland	subsp. *birrea*
	Ethiopian undifferentiated woodland	Ethiopian undifferentiated woodland	subsp. *birrea*
Somalia-Masai regional centre of endemism	Somalia-Masai *Acacia-Commiphora* deciduous bushland and thicket	Somalia-Masai *Acacia-Commiphora* deciduous bushland and thicket	subsp. *birrea*, *multifoliolata*
	Somalia-Masai *Acacia-Commiphora* deciduous bushland and thicket	Somalia-Masai edaphic grassland	subsp. *multifoliolata*
	Somalia-Masai *Acacia-Commiphora* deciduous bushland and thicket	Somalia-Masai secondary grassland and wooded grassland	subsp. *multifoliolata*
	Somalia-Masai *Acacia-Commiphora* deciduous bushland and thicket	Somalia-Masai scrub forest	subsp. *multifoliolata*
	Mosaic of East African evergreen bushland and secondary *Acacia* wooded grassland	Somalia-Masai secondary grassland and wooded grassland	subsp. unspecified (?*multifoliolata*)
	Mosaic of East African evergreen bushland and secondary *Acacia* wooded grassland	East African evergreen and semi-evergreen bushland and thicket	subsp. *multifoliolata*

*mapping units and vegetation types in which *Sclerocarya birrea* occurs particularly frequently

Table 2.2 (continued). Distribution of *Sclerocarya birrea* in relation to White's (1983) major floristic units (phytochoria), mapping units and vegetation types.

Regional phytochoria	Mapping unit	Vegetation type	Subspecies
Karoo-Namib regional centre of endemism	Bushy Karoo-Namib shrubland	Bushy Karoo shrubland	subsp. *caffra*
Guineo-Congolia/Zambezia regional transition zone	Mosaic of Guineo-Congolian lowland rain forest and secondary grassland	Grassland and wooded grassland	subsp. *caffra*
Guineo-Congolia/Sudania regional transition zone	Mosaic of Guineo-Congolian lowland rain forest and secondary grassland	Coastal Plain of Basse Casamance	subsp. *birrea*
Lake Victoria regional mosaic	Mosaic of Guineo-Congolian lowland rain forest and secondary grassland	Grassland and wooded grassland	subsp. *birrea*
Zanzibar-Inhambane regional mosaic	Zanzibar-Inhambane East African coastal mosaic	Zanzibar-Inhambane undifferentiated forest	subsp. *caffra*
	Zanzibar-Inhambane East African coastal mosaic	Zanzibar-Inhambane woodland and scrub woodland	subsp. *caffra*
	Zanzibar-Inhambane East African coastal mosaic	Zanzibar-Inhambane evergreen and semi-evergreen bushland and thicket	subsp. *caffra*
	*Zanzibar-Inhambane East African coastal mosaic	*Zanzibar-Inhambane secondary grassland and wooded grassland	subsp. *caffra*
Kalahari-Highveld regional transitional zone	Zambezian transition from undifferentiated woodland to *Acacia* deciduous bushland and wooded grassland	Kalahari thornveld and the transition to Zambezian broad-leaved woodland	subsp. *caffra*
	Transition from *Colophospermum mopane* scrub woodland to Karoo-Namib shrubland	Zambezia/ Kaokoveld-Mossamedes transition	subsp. *caffra*
	Kalahari deciduous *Acacia* wooded grassland and bushland	Kalahari thornveld and the transition to Zambezian broad-leaved woodland	subsp. *caffra*
Tongaland-Pondoland regional mosaic	Tongaland-Pondoland East African coastal mosaic	Tonga land-Pondoland undifferentiated forest	subsp. *caffra*
	Tongaland-Pondoland East African coastal mosaic	Tongaland-Pondoland secondary grassland	subsp. *caffra*
	*Tongaland-Pondoland East African coastal mosaic	*Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket	
	*Transition from undifferentiated Zambezian woodland to Tongaland-Pondoland bushland	*Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket	subsp. *caffra*
Sahel regional transition zone	Sahel *Acacia* wooded grassland and deciduous bushland	Sahel wooded grassland	subsp. *birrea*
	Sahel *Acacia* wooded grassland and deciduous bushland	Sahel deciduous bushland	subsp. *birrea*
	Northern Sahel semi-desert grassland and shrubland	Sahel semi-desert grassland and the transition to the Sahara	subsp. *birrea*
West Malagasy regional centre of endemism	Malagasy dry deciduous forest	West Malagasy dry deciduous forest	subsp. *caffra*
	Mosaic of Malagasy dry deciduous forest and secondary grassland	West Malagasy grassland	subsp. *caffra*

*mapping units and vegetation types in which *Sclerocarya birrea* occurs particularly frequently

farmland/"anthropic landscapes") vegetation formations at least as much as it grows in woodland, and the more open forms of the latter account for most woodland reports. It is nevertheless apparent that *Sclerocarya birrea* may also be a constituent of denser woody vegetation: forest, transition woodland, thicket, bushland and shrubland. Dry forest (Madagascar – Leandri, 1936; subsp. *caffra*) and transition woodland (Senegal – Wolf, 1998; subsp. *birrea*) formations from which *Sclerocarya birrea* has been reported are possibly relicts of a denser vegetation largely destroyed by man. Subsp. *caffra* has also been recorded as a component of riparian forest (Zimbabwe - Farrell 1968a; South Africa – Acocks, 1988) and of forest patches where there is a high water table on the coastal plain of Natal, South Africa (Acocks, 1988). The thicket, bushland and shrubland occurrences of *Sclerocarya birrea* tend to be where the range of the species extends over the boundaries of the Zambezian and Sudanian regional centres into areas of low (<500 mm), and often bimodal, annual rainfall. Examples are occurrences of subsp. *caffra* near the Angolan coast (Gossweiler & Mendonça, 1939) and of subsp. *birrea* in the Jebel Marra area of Sudan (Wickens, 1976) and in Karamoja, Uganda (Wilson, 1962). Bushland and thicket occurrences of subsp. *caffra* are also widespread in the northern part of the Tongaland-Pondoland coastal mosaic (Werger & Coetzee, 1978). Published habitat descriptions (*e.g.* Burtt, 1942) suggest that subsp. *multifoliolata* is not uncommonly a constituent of bushland or its gradation into forest, "scrub forest" (Greenway & Vesey-Fitzgerald, 1969).

Most of the lists in Tables 2.3 and 2.4 consist of a mixture of Pluri-regional and Sudano-Zambezian linking species with Sudanian (north of the equator) or Zambezian (south of the equator) elements. However, at the Atlantic seaboard (Senegal, Northern Atlantic and Southern Atlantic drainage areas) there is reduced representation of linking elements while in the Congo drainage area the listing is almost exclusively of these. There are two widely listed groups of linking species. One is of those southern African species typical of White's (1983) "undifferentiated North Zambezian woodlands" which are also present north of the equator, and well-represented in the Benue drainage area. The other is a group of very resilient and widely distributed savanna species, among them several mimosoid legumes listed for the Congo drainage area. Undifferentiated North Zambezian woodland species more or less restricted to southern and eastern Africa are prominent among the associated species in the Zambezi drainage area.

In most of the drainage areas of the eastern part of the range additional phytogeographical elements are represented in the lists. Despite being north of the equator, in the Nile drainage area there are few strictly Sudanian associates, many widespread linking species and several typically eastern and southern African species. Further south, in the area draining into the Indian Ocean north of the Limpopo River, frequent associates include few Sudano-Zambezian linking species, and more species shared with miombo woodland communities (although not the characteristic miombo dominants) than typical North Zambezian undifferentiated woodland. Southern and eastern African species account for most of those listed for the Limpopo drainage area, the remainder being widespread linking species. Linking species and southern and eastern African species feature equally among the associates listed for the drainage into the Indian Ocean off the southern African coastal lowlands. Among the linking species are several that are widespread and resilient and present especially where there is an interface between open communities and forest.

2.4.2.2 Associated species

Considering the associates at species, rather than at family or ecological guild, level, subspp. *birrea* and *caffra* differ, indicating the general floristic contrast between the Sudanian and Zambezian phytochoria. For subsp. *birrea*, the watershed confining the Nile drainage basin separates this area from the drainage areas and low watersheds of West Africa. The West Africa drainage areas are all closely similar to each other while sharing fewer floristic features with the Nile drainage area. Nevertheless, frequent associates through the drainage areas from the Nile to the Atlantic coast are *Acacia seyal, Balanites aegyptiaca, Commiphora africana* and *Tamarindus indica*. Of the twelve species listed (Table 2.3) as major associates in at least four of the seven drainage areas the widespread and characteristic combretaceous associates, *Anogeissus leiocarpus, Combretum glutinosum* and *Guiera senegalensis,* do not feature as major associates in the Nile drainage area and the lower frequency there of *Sterculia setigera* is also noteworthy. Further contrasts with the associates of subsp. *birrea* further west arise from the frequency in the Nile drainage of typical eastern African taxa which are absent or rare west of the Nile/Tchad divide, such as *Albizia amara, A. anthelmintica, Lannea triphylla* and *Terminalia brownii*.

Among the West African drainage areas, the main differences are due to the higher frequencies of moist savanna associates indicated for the Benue drainage area and, to a lesser extent, the Bight of Benin drainage area – illustrated by *Bombax costatum, Parkia biglobosa, Piliostigma thonningii, Prosopis africana, Pterocarpus erinaceus, Vitellaria paradoxa* and *Ximenia americana*. In the Benue and Bight of Benin drainage areas typical wooded farmland (agroforestry parkland) species are prominent among the frequent woody associates. The Niger and Senegal drainage areas represent the drier parts of the range of subsp. *birrea*. In these, the frequency of *Commiphora africana* is noteworthy.

There is some overall similarity between subsp. *birrea* and subsp. *caffra* in the lists of frequent woody associates. Closer inspection shows this to arise primarily from the moister parts of the ranges – the Benue drainage area (subsp. *birrea*) and the Congo drainage area (subsp. *caffra*). The species involved are aggressive and resilient savanna species, such as *Annona senegalensis, Bridelia ferruginea, Hymenocardia acida* and *Piliostigma thonningii*, typically found at the savanna interface with the periphery of the equatorial forest region. Additional associates of subsp. *birrea* in the Benue drainage area are also listed for subsp. *caffra* in the Indian Ocean drainage area south of the River Limpopo estuary, another relatively moist part of the range.

Compared with the relatively uniform terrain of the Sudanian region, the part of the range of *Sclerocarya birrea* south of the equator is, as a whole, much more rugged, with extensive areas at elevations above 1000 m and numerous escarpments and deep valleys. This seems to be reflected in the lack of a well-defined set of associates extending across the region as is evident for West Africa.

The southern Atlantic coastal drainage area associates of subsp. *caffra* (Table 2.4) are species widespread in dry conditions in southern tropical Africa, apart from *Pachypodium lealii*, which is characteristic of the Karoo-Namib regional centre of endemism. The Zambezi drainage area list of associates typifies Zambezian mopane woodland communities, combining pluriregional savanna linking elements with exclusively southern and eastern elements (*Albizia harveyi, Colophospermum mopane, Lonchocarpus capassa*). Internal drainage pans associates are an attenuated expression of the most frequent associates present in the Zambezi drainage area. In the drainage area into the Indian Ocean north of the Limpopo basin, several associates are again typical of the Zambezian mopane and undifferentiated woodlands and some (including *Acacia nigrescens, Lonchocarpus capassa* and *Xeroderris stuhlmannii*) are shared with the Zambezi drainage area. *Afzelia quanzensis, Diplorhynchus condylocarpon*, *Pseudolachnostylis maprouneifolia* and *Terminalia sericea* are associates which are also common in miombo woodland. Frequent associates in the Limpopo drainage area are predominantly elements of southern and eastern African affinity (such as *Dombeya rotundifolia, Ozoroa paniculosa* and *Pappea capensis*), but of drier-area affinity than those of the more southerly drainage into the Indian Ocean. In the latter drainage area, several of the associates are characteristic of dry forests and their edges, such as *Dialium schlechteri, Garcinia livingstonei, Sideroxylon inerme* and *Xylotheca kraussiana*.

The listing of associates for subsp. *multifoliolata* (Table 2.5) is noteworthy in contrasting sharply with the other lists in the high representation of species regarded (White, 1965) as typical of miombo, the defining miombo species *Brachystegia spiciformis, Isoberlinia angolensis* and *Julbernardia globiflora* being among these. Only in the case of this subspecies can *Sclerocarya birrea* be regarded as a miombo tree.

Table 2.3. Woody species frequently associated with *Sclerocarya birrea* subsp. *birrea*, in relation to drainage areas

Associated species	Chorology/community	Drainage areas (West)						(East)
Grewia bicolor Juss. (Tiliaceae)	Plur	**A**						
Diospyros mespiliformis A.DC. (Ebenaceae)	Plur	**A**		**C**				
Lannea acida A.Rich. (Anacardiaceae)	S	**A**	**B**	**C**				
Piliostigma reticulatum (DC.) Hochst. (Leguminosae Caesalpinioideae)	S	**A**	**B**			**E**	**F**	
Sterculia setigera Delile (Sterculiaceae)	S	**A**	**B**	**C**		**E**	**F**	
Anogeissus leiocarpus (DC.) Guill. & Perr. (Combretaceae)	S	**A**	**B**	**C**	**D**	**E**	**F**	
Combretum glutinosum DC. (Combretaceae)	S	**A**	**B**	**C**	**D**	**E**	**F**	
Guiera senegalensis J.F.Gmel. (Combretaceae)	S	**A**	**B**	**C**	**D**	**E**	**F**	
Tamarindus indica L. (Leguminosae Caesalpinioideae)	Plur (Zambezian *Colophospermum* woodlands)	**A**	**B**	**C**		**E**		**G**
Commiphora africana (A.Rich.) Engl. (Burseraceae)	Plur	**A**	**B**		**D**		**F**	**G**
Balanites aegyptiaca (L.) Delile (Balanitaceae)	Plur (Zambezian *Colophospermum* woodlands)	**A**		**C**	**D**	**E**	**F**	**G**
Cordyla pinnata (A.Rich.) Milne-Redh. (Leguminosae Papilionoideae)	S		**B**					
Terminalia macroptera Guill. & Perr. (Combretaceae)	S		**B**					
Acacia macrostachya DC. (Leguminosae Mimosoideae)	S		**B**	**C**				
**Adansonia digitata* L. (Bombacaceae)	Plur (Zambezian *Colophospermum* woodlands)		**B**	**C**				
Khaya senegalensis (Desr.) A.Juss. (Meliaceae)	S		**B**	**C**				
Bombax costatum Pellegr. & Vuillet (Bombacaceae)	S		**B**	**C**		**E**		
Parkia biglobosa (Jacq.) Benth. (Leguminosae Mimosoideae)	S		**B**	**C**		**E**		
Pterocarpus erinaceus Poir. (Leguminosae Papilionoideae)	S		**B**	**C**		**E**		
Terminalia avicennioides Guill. & Perr. (Combretaceae)	S		**B**		**D**	**E**		
Ziziphus mauritiana Lam. (Rhamnaceae)	Plur (Zambezian *Colophospermum* woodlands)		**B**		**D**	**E**		
Prosopis africana (Guill. & Perr.) Taub. (Leguminosae Mimosoideae)	S		**B**	**C**		**E**		
Faidherbia albida (Delile) A.Chev. (Leguminosae Mimosoideae)	Plur (N Zambezian)		**B**	**C**			**F**	
**Annona senegalensis* Pers. (Annonaceae)	Plur (N Zambezian)		**B**	**C**		**E**	**F**	
Entada africana Guill. & Perr. (Leguminosae Mimosoideae)	S		**B**	**C**		**E**	**F**	
Acacia seyal Delile (Leguminosae Mimosoideae)	Plur		**B**		**D**	**E**	**F**	**G**
Acacia gourmaensis A.Chev. (Leguminosae Mimosoideae)	S			**C**				
Albizia chevalieri Harms (Leguminosae Mimosoideae)	S			**C**				
Bauhinia rufescens Lam. (Leguminosae Caesalpinioideae)	S			**C**				
Boscia angustifolia A.Rich. (Capparaceae)	Plur (Zambezian *Colophospermum* woodlands)			**C**				
Cassia sieberiana DC. (Leguminosae Caesalpinioideae)	S			**C**				
Maerua crassifolia Forssk. (Capparaceae)	S			**C**				

		West				East
Associated species	**Chorology/community**	**Drainage areas**				
Pteleopsis suberosa Engl. & Diels (Combretaceae)	S	**C**				
Pterocarpus lucens Guill. & Perr. (Leguminosae Papilionoideae)	S	**C**				
Combretum micranthum G.Don (Combretaceae)	S	**C**	**D**			
Lannea microcarpa Engl. & K.Krause (Anacardiaceae)	S	**C**	**D**			
**Dichrostachys cinerea* (L.) Wight & Arn. (Leguminosae Mimosoideae)	Plur	**C**	**D**	**E**	**F**	
Acacia dudgeonii Holland (Leguminosae Mimosoideae)	S	**C**		**E**		
Crossopteryx febrifuga (G.Don) Benth. (Rubiaceae)	Plur	**C**		**E**		
Daniellia oliveri (Rolfe) Hutch. & Dalz. (Leguminosae Caesalpinioideae)	S	**C**		**E**		
Detarium microcarpum Guill. & Perr. (Leguminosae Caesalpinioideae)	S	**C**		**E**		
Grewia mollis Juss. (Tiliaceae)	Sudanian-Eastern	**C**		**E**		
Isoberlinia doka Craib. & Stapf (Leguminosae Caesalpinioideae)	S	**C**		**E**		
**Piliostigma thonningii* (Schum.) Milne-Redh. (Leguminosae Caesalpinioideae)	Plur (N Zambezian)	**C**		**E**		
Securidaca longepedunculata Fresen. (Polygalaceae)	Plur	**C**		**E**		
Vitellaria paradoxa C.F.Gaertn. (Sapotaceae)	S	**C**		**E**		
Feretia apodanthera Delile (Rubiaceae)	S	**C**		**E**	**F**	
Ximenia americana L. (Olacaceae)	Plur	**C**		**E**		**G**
**Maytenus senegalensis* (Lam.) Exell (Celastraceae)	Plur	**C**		**E**		**G**
Boscia senegalensis (Pers.) Poir. (Capparaceae)	S	**C**			**F**	
Acacia senegal (L.) Willd. (Leguminosae Mimosoideae)	Plur	**C**			**F**	**G**
**Acacia nilotica* (L.) Delile (Leguminosae Mimosoideae)	Plur (Zambezian *Colophospermum* woodlands)	**C**				**G**
Combretum nigricans Guill. & Perr. (Combretaceae)	S		**D**	**E**		
Senna singueana (Delile) Lock (Leguminosae Caesalpinioideae)	Plur (N Zambezian)		**D**	**E**		
Commiphora pedunculata (Kotschy & Peyr.) Engl. (Burseraceae)	S-Z		**D**	**E**	**F**	
Afzelia africana Pers. (Leguminosae Caesalpinioideae)	S			**E**		
**Bridelia ferruginea* Benth. (Euphorbiaceae)	S-Z			**E**		
Boswellia dalzielii Hutch. (Burseraceae)	S			**E**		
**Dalbergia melanoxylon* Guill. & Perr. (Leguminosae Papilionoideae)	Plur (N Zambezian)			**E**		
**Hymenocardia acida* Tul. (Euphorbiaceae)	Plur			**E**		
Pericopsis laxiflora (Baker) Van Meeuwen (Leguminosae Papilionoideae)	S			**E**		
Pseudocedrela kotschyi (Schweinf.) Harms (Meliaceae)	S			**E**		
Steganotaenia araliacea Hochst. (Apiaceae)	Plur			**E**		
**Strychnos spinosa* Lam. (Loganiaceae)	Plur			**E**		
**Strychnos innocua* Delile (Loganiaceae)	Plur			**E**		
Terminalia laxiflora Engl. (Combretaceae)	S			**E**		
Vitex doniana Sweet (Verbenaceae)	Plur			**E**		

Associated species	Chorology/community	Drainage areas (West → East) E	F	G
**Ziziphus mucronata* Willd. (Rhamnaceae)	Plur (N Zambezian)	E		
**Acacia hockii* De Wild. (Leguminosae Mimosoideae)	Plur	E		G
Boscia salicifolia Oliv. (Capparaceae)	Plur (Zambezian *Colophospermum* woodlands)	E		G
**Combretum adenogonium* A.Rich. (Combretaceae)	Plur (N Zambezian)	E		G
Combretum collinum Fresen. (Combretaceae)	Plur (N Zambezian)	E		G
**Combretum molle* G.Don (Combretaceae)	Plur (N Zambezian)	E		G
Lannea schimperi (A.Rich.) Engl. (Anacardiaceae)	Eastern	E		G
**Stereospermum kunthianum* Cham. (Bignoniaceae)	Plur (N Zambezian)	E		G
Acacia ataxacantha DC. (Leguminosae Mimosoideae)	Plur		F	
Combretum aculeatum Vent. (Combretaceae)	Sudanian-Eastern		F	
Lannea humilis (Oliv.) Engl. (Anacardiaceae)	Plur		F	G
Albizia amara (Roxb.) Boivin (Leguminosae Mimosoideae)	Z-Eastern (N Zambezian)			G
Albizia anthelmintica Brongn. (Leguminosae Mimosoideae)	Z-Eastern (*Colophospermum* woodlands)			G
Bridelia scleroneura Muell.Arg. (Euphorbiaceae)	S			G
Lannea triphylla (A.Rich.) Engl. (Anacardiaceae)	Eastern			G
Ozoroa insignis Delile (Anacardiaceae)	Plur			G
Terminalia brownii Fresen. (Combretaceae)	Eastern			G

Chorology/community categories (entries in parentheses indicate specific major Zambezian plant communities where the species is most characteristic, according to White, 1965):

Eastern, Eastern African element; N Zambezian, in Zambezian phytochorological region characteristic of North Zambezian undifferentiated woodland; Plur, pluriregional linking element; S, Sudanian element; S-E, Sudanian-East Africa linking species; S-Z, Sudano-Zambezian linking element; Z *Colophospermum*, in Zambezian phytochorological region characteristic of Zambesian *Colophospermum* woodlands; Z-E, Zambezian-East African linking species; *, species also listed as a frequent associate of subsp. *caffra*.

Drainage areas and sources of information:

A - River Senegal: Trochain (1940), Monod (1986); B - West-facing North Atlantic coast: Trochain (1940), Lykke (1998), Wolf (1998); C - Bight of Benin: Taylor (1960), Marchal (1980), Bonkoungou & Framond (1988), Devineau (1999); D – River Niger: Aubréville (1937), Dundas (1938), Fairbairn (1943), Keay (1949), Onochie (1964), Clayton (1966), Kershaw (1968); E – River Benue: Ramsay & Leeuw (1965), Tuley (1970), Leeuw & Tuley (1972), Tuley & Alford (1975), Letouzey (1985); F – Lake Tchad: Gillet (1963), Letouzey (1968, 1985), Leeuw & Tuley (1972), Tuley & Alford (1975), Boulvert (1980), Ahmed (1983), Miehe (1988), Seghieri *et al.* (1995), Tchamba (1995); G – River Nile: Harrison & Jackson (1958), Ramsay (1958), Langdale-Brown (1959, 1960a, b), Wilson (1962), Miehe (1988).

Table 2.4. Woody species frequently associated with *Sclerocarya birrea* subsp. *caffra* on continental Africa, in relation to drainage areas

Associated species	Chorology/community	Drainage areas (West)						(East)
		A	B	C	D	E	F	G
Berchemia discolor (Klotsch) Hemsl. (Rhamnaceae)	Z-E (*Colophospermum* woodlands)	**A**						
Combretum psidioides Welw. (Combretaceae)	Z-E (miombo)	**A**						
Kirkia acuminata Oliv. (Simaroubaceae)	Z	**A**						
Pachypodium lealii Welw. (Apocynaceae)	Karoo-Namib	**A**						
Pterocarpus antunesii (Taub.) Harms (Leguminosae Papilionoideae)	Southern	**A**						
Terminalia prunioides M.A.Lawson (Combretaceae)	Z-E (*Colophospermum* woodlands)	**A**						
Adansonia digitata L. (Bombacaceae)	Plur (*Colophospermum* woodlands)	**A**			**D**			
Croton gratissimus Burch. (Euphorbiaceae)	Plur		**B**					
Albizia harveyi E.Fourn. (Leguminosae Mimosoideae)	Z-E (N Zambezian)		**B**		**D**			
Colophospermum mopane (Benth.) J.Leonard (Leguminosae Caesalpiniodeae)	Z (*Colophospermum* woodlands)		**B**		**D**			
Acacia nigrescens Oliv. (Leguminosae Mimosoideae)	Z (*Colophospermum* woodlands)		**B**		**D**	**E**		**G**
Combretum imberbe Wawra (Combretaceae)	Z (*Colophospermum* woodlands)		**B**		**D**		**F**	
Combretum apiculatum Sond. (Combretaceae)	Z-E (*Colophospermum* woodlands)		**B**				**F**	
Peltophorum africanum Sond. (Leguminosae Caesalpiniodeae)	Z (N Zambezian)		**B**				**F**	
Combretum molle G.Don (Combretaceae)	Plur (N Zambezian)		**B**					**G**
Acacia hockii De Wild. (Leguminosae Mimosoideae)	Plur			**C**				
Acacia polyacantha Willd. (Leguminosae Mimosoideae)	Plur			**C**				
Acacia sieberiana DC. (Leguminosae Mimosoideae)	Plur (N Zambezian)			**C**				
Annona senegalensis Pers. (Annonaceae)	Plur (N Zambezian)			**C**				
Antidesma venosum Tul. (Euphorbiaceae)	Plur			**C**				
Bridelia ferruginea Benth. (Euphorbiaceae)	S-Z			**C**				
Desmodium velutinum (Willd.) DC. (Leguminosae Papilionoideae)	Plur			**C**				
Dombeya quinqueseta (Delile) Exell (Sterculiaceae)	S-Z			**C**				
Entada abyssinica A.Rich. (Leguminosae Mimosoideae)	Plur (N Zambezian)			**C**				
Erythrina abyssinica Lam. (Leguminosae Papilionoideae)	Z-E			**C**				
Hymenocardia acida Tul. (Euphorbiaceae)	Plur			**C**				
Maytenus senegalensis (Lam.) Exell (Celastraceae)	Plur			**C**				
Mussaenda arcuata Poir. (Rubiaceae)	Plur			**C**				
Parinari curatellifolia Benth. (Chrysobalanaceae)	Plur (miombo)			**C**				
Psorospermum febrifugum Spach. (Clusiaceae)	Plur			**C**				
Sterculia quinqueloba (Garcke) K.Schum. (Sterculiaceae)	Z			**C**				
Stereospermum harmsianum K.Schum. (Bignoniaceae)	Z			**C**				
Stereospermum kunthianum Cham. (Bignoniaceae)	Plur (N Zambezian)			**C**				

		West				East
Associated species	**Chorology/community**	**Drainage areas**				
Terminalia mollis M.A.Lawson (Combretaceae)	Plur (N Zambezian)	**C**				
**Piliostigma thonningii* (Schumach.) Milne-Redh. (Leguminosae Caesalpiniodeae)	Plur (N Zambezian)	**C**	**D**			
Albizia versicolor Oliv. (Leguminosae Mimosoideae)	Z-E (N Zambezian)	**C**		**E**		
Albizia adianthifolia (Schumach.) W.Wight (Leguminosae Mimosoideae)	Plur	**C**				**G**
Acacia tortilis (Forssk.) Hayne (Leguminosae Mimosoideae)	Plur (*Colophospermum* woodlands)		**D**			
**Combretum adenogonium* A.Rich. (Combretaceae)	Plur (N Zambezian)		**D**			
**Dalbergia melanoxylon* Guill. & Perr. (Leguminosae Papilionoideae)	Plur (N Zambezian)		**D**			
Kigelia africana (Lam.) Benth. (Bignoniaceae)	Plur		**D**			
Lonchocarpus capassa Rolfe (Leguminosae Papilionoideae)	Z (N Zambezian)		**D**	**E**		
Xeroderris stuhlmannii (Taub.) Mendonce & E.C.Sousa (Leguminosae Papilionoideae)	Plur (N Zambezian)		**D**	**E**		
Diplorhynchus condylocarpon (Muell.Arg.) Pichon (Apocynaceae)	Z (miombo)			**E**		
Pseudolachnostylis maprouneifolia Pax (Euphorbiaceae)	Z (miombo)			**E**		
Terminalia sericea DC. (Combretaceae)	Z (miombo)			**E**	**F**	
Afzelia quanzensis Welw. (Leguminosae Caesalpiniodeae)	Z-E (miombo)			**E**		**G**
Combretum zeyheri Sond. (Combretaceae)	Z-E				**F**	
Dombeya rotundifolia (Hochst.) Planch. (Sterculiaceae)	Z-E (miombo)				**F**	
Lippia javanica (Burm.f.) Spreng. (Verbenaceae)	Z-E				**F**	
Ozoroa paniculosa (Sond.) R. & A.Fernandes (Anacardiaceae)	Southern				**F**	
Pappea capensis Eckl. & Zeyh. (Sapindaceae)	Z-E				**F**	
Rhus leptodictya Diels (Anacardiaceae)	Southern				**F**	
**Acacia nilotica* (L.) Delile (Leguminosae Mimosoideae)	Plur (*Colophospermum* woodlands)				**F**	**G**
**Dichrostachys cinerea* (L.) Wight & Arn. (Leguminosae Mimosoideae)	Plur				**F**	**G**
**Ziziphus mucronata* Willd. (Rhamnaceae)	Plur (N Zambezian)				**F**	**G**
Acacia caffra (Thunb.) Willd. (Leguminosae Mimosoideae)	Southern					**G**
Acacia robusta Burch. (Leguminosae Mimosoideae)	Z-E					**G**
Dialium schlechteri Harms (Leguminosae Caesalpiniodeae)	Southern					**G**
Garcinia livingstonei T.Anderson (Clusiaceae)	Plur					**G**
Sideroxylon inerme L. (Sapotaceae)	Z-I/T-P					**G**
**Strychnos innocua* Delile (Loganiaceae)	Plur					**G**
**Strychnos spinosa* Lam. (Loganiaceae)	Plur					**G**
Trichilia emetica Vahl (Meliaceae)	Plur (N Zambezian)					**G**
Vangueria infausta Burch. (Rubiaceae)	Plur					**G**
Xylotheca kraussiana Hochst. (Flacourtiaceae)	Southern					**G**

Chorology/community categories (entries in parentheses indicate specific major Zambezian plant communities where the species is most characteristic, according to White, 1965):

K-N, Karoo-Namib element; N Zambezian, characteristic of North Zambezian undifferentiated woodland; Plur, pluriregional linking element; Southern, southern African element; S-Z, Sudano-Zambezian linking element; Z, Zambezian element; Z *Colophospermum*, in Zambezian phytochorological region characteristic of Zambesian *Colophospermum* woodlands; Z-E, Zambezian-East African linking species; Z-I/T-P, Zanzibar-Inhambane/Tongaland-Pondoland element; *, species also listed as a frequent associate of subsp. *birrea*.

Drainage areas and sources of information:

A – South Atlantic: Gossweiler & Mendonça (1939), Barbosa (1970), Werger & Coetzee (1978); B – Inland pans: Keet (1950), Rains & McKay (1968), Barbosa (1970), Timberlake (1980), Timberlake *et al.* (1993); C – River Congo: Trapnell (1953), Mullenders (1954), White & Werger (1978); D – River Zambezi: Trapnell (1953), Pedro & Barbosa (1955), Farrell (1968b), Rains & McKay (1968), Timberlake *et al.* (1993), Toit (1993), Astle *et al.* (1997), Smith (1997); E – Indian Ocean from rivers north of River Limpopo: Pedro & Barbosa (1955), Birch (1963), Wild & Barbosa (1967), Farrell (1968a, b), Werger & Coetzee (1978), Timberlake *et al.* (1993); F – River Limpopo: Pedro & Barbosa (1955), Wild & Barbosa (1967), Meulen (1979), Rodgers (1979), Timberlake *et al.* (1993); G – Indian Ocean from rivers south of River Limpopo: Pedro & Barbosa (1955), Edwards (1967), Werger & Coetzee (1978).

Table 2.5. Woody species frequently associated with *Sclerocarya birrea* subsp. *multifoliolata* on continental Africa

Species		**1**	**2**	**3**	**4**	**5**
Lannea humilis (Oliv.) Engl. (Anacardiaceae)	Plur				**f**	**f**
Lannea schweinfurthii (Engl.) Engl. (Anacardiaceae)	Z-E (Zambezian *Colophospermum* woodlands)		**2**			**f**
Annona senegalensis Pers. (Annonaceae)	Plur (N Zambezian)	**1**		**f**		
Diplorhynchus condylocarpon (Muell.Arg.) Pichon (Apocynaceae)	Z (miombo)	**1**		**3**		
Stigmatorhynchus umbelliferus (K.Schum.) Schltr. (Asclepiadaceae)	S-M				**f**	**f**
Adansonia digitata L. (Bombacaceae)	Plur (Zambezian *Colophospermum* woodlands)				**4**	**5**
Commiphora africana (A.Rich.) Engl. (Burseraceae)	Plur				**f**	**f**
Commiphora caerulea B.D.Burtt (Burseraceae)	Z-E				**f**	**f**
Commiphora mossambicensis (Oliv.) Engl. (Burseraceae)	Z	**1**		**3**	**4**	**5**
Combretum adenogonium A.Rich. (Combretaceae)	Plur (N Zambezian)	**1**		**f**		
Combretum zeyheri Sond. (Combretaceae)	Z	**1**		**f**		
Terminalia mollis M.A.Lawson (Combretaceae)	Plur (N Zambezian)	**1**		**3**		
Diospyros kirkii Hiern (Ebenaceae)	Z (miombo)	**1**		**f**		
Euphorbia matabelensis Pax (Euphorbiaceae)	Z (miombo)				**f**	**f**
Pseudolachnostylis maprouneifolia Pax (Euphorbiaceae)	Z (miombo)	**1**		**3**		
Brachystegia x *longifolia* Benth. (Leguminosae Caesalpinioideae)	Z (miombo)	**1**		**3**		
Brachystegia spiciformis Benth. (Leguminosae Caesalpinioideae)	Z (miombo)	**1**		**3**		
Burkea africana Hook. (Leguminosae Caesalpinioideae)	Plur (miombo)	**1**		**f**		
Isoberlinia angolensis (Benth.) Hoyle & Brenan (Leguminosae Caesalpinioideae)	Z (miombo)	**1**		**3**		
Julbernardia globiflora (Benth.) Troupin (Leguminosae Caesalpinioideae)	Z (miombo)	**1**		**3**		
Ormocarpum flavum J.B.Gillett (Leguminosae Papilionoideae)	S-M			**f**	**f**	
Pericopsis angolensis (Baker) van Meeuwen (Leguminosae Papilionoideae)	Z (miombo)	**1**		**3**		
Pterocarpus angolensis DC. (Leguminosae Papilionoideae)	Z (miombo)	**1**		**3**		
Strychnos cocculoides Baker (Loganiaceae)	Z	**1**		**f**		
Ekebergia benguelensis C.DC. (Meliaceae)	Z (miombo)	**1**		**f**		
Turraea nilotica Kotschy & Peyr. (Meliaceae)	Z-E (N Zambezian)	**1**			**f**	
Cassipourea mollis (R.E.Fr.) Alston (Rhizophoraceae)	Z (miombo)	**1**		**f**		
Catunaregam spinosa (Thunb.) Tirveng. (Rubiaceae)	Plur	**1**		**f**		

Table 2.6. Woody species associated with *Sclerocarya birrea* subsp. *caffra* in Madagascar

Species	**List 1**	**List 2**	**List 3**	**List 4**
Aloe vaombe Decorse & Poisson (Aloaceae)			**3**	
Mascarenhasia lisianthiflora A.DC. (Apocynaceae)		**2**		
**Voacanga thouarsii* Roem. & Schult. (Apocynaceae)				**4**
Borassus madagascariensis Jum. & H.Perrier (Arecaceae)		**2**		
**Phoenix reclinata* Jacq. (Arecaceae)		**2**		
Cryptostegia grandiflora R.Br. (Asclepiadaceae)	**1**			**4**
Marsdenia verrucosa Decne. (Asclepiadaceae)				**4**
Pentopetia grevei (Baill.) Venter (Asclepiadaceae)	**1**		**3**	
Secamonopsis madagascariensis Jum. (Asclepiadaceae)				**4**
Dicoma incana (Baker) O.Hoffm. (Asteraceae)		**2**		
Mikania scandens Willd. (Asteraceae)				**4**
Fernandoa madagascariensis (Baker) A.H.Gentry (Bignoniaceae)	**1**			**4**
Stereospermum euphorioides DC. (Bignoniaceae)		**2**		
Brexiella sp. (Celastraceae)		**2**		
**Maytenus linearis* (L.f.) Marais (Celastraceae)	**1**	**2**	**3**	
Combretum platycladum Baker (Combretaceae)	**1**			
Dioscorea soso Jum. & H.Perrier (Dioscoreaceae)	**1**			
**Jatropha curcas* L. (Euphorbiaceae)				**4**
**Aphloia theiformis* (Vahl) Benn. & R.Br. (Flacourtiaceae)				**4**
Flacourtia ramontchi L'Her. (Flacourtiaceae)	**1**			
Colvillea racemosa Bojer (Leguminosae Caesalpinioideae)	**1**			**4**
**Parkinsonia aculeata* L. (Leguminosae Caesalpinioideae)			**3**	
**Tamarindus indicus* L. (Leguminosae Caesalpinioideae)		**2**		**4**
**Albizia gummifera* (J.F.Gmel.) C.A.Sm. (Leguminosae Mimosoideae)		**2**		
**Crotalaria incana* L. (Leguminosae Papilionoideae)				**4**
Koehneria madagascariensis (Baker) S.A.Graham, Tobe & Baas (Lythraceae)				**4**
Pandanus humbertianus Martelli (Pandanaceae)			**3**	
Cedrelopsis grevei Baill. (Ptaeroxylaceae)				**4**
Carphalea sp. (Rubiaceae)			**3**	
Leptolaena diospyroidea (Baill.) Cavaco (Sarcolaenaceae)		**2**		**4**
Rhopalocarpus lucidus Bojer (Sphaerosepalaceae)	**1**	**2**		**4**
Lasiosiphon decaryi Leandri (Thymelaeaceae)		**2**		

*, also on mainland Africa, although not necessarily represented by the same infraspecific taxa

Key: **1**, Kiliarivo; **2**, between Isahaina and Malio; **3**, Beraketa; **4**, Onilahy-Teheza (all from Basse, 1934)

2.4.3 Prominence, population levels and representation

Even when well-represented, *Sclerocarya* individuals tend to be well-separated. Nevertheless, the species is often a prominent element of the vegetation because the communities where it occurs are open and otherwise of low stature (Moll & White, 1978; White, 1983), or are parklands within which it is one of the principle trees retained (Wild & Barbosa, 1967; Seignobos, 1982). Under these circumstances it has been widely used as a descriptor species for the plant communities involved (Table 2.7).

Table 2.7. Plant communities, by country, for which *Sclerocarya birrea* has been used as a descriptor

Country – area (subspecies)	**Plant community**	**Reference**
Botswana (*caffra*)	*Acacia nigrescens-Sclerocarya caffra* savanna	Rutherford (1978)
Cameroun (*birrea*)	Boisements soudano-sahéliens à *Sclerocarya birrea*	Letouzey (1985)
Cameroun (*birrea*)	Boisements soudano-sahéliens à *Anogeissus leiocarpus* et *Sclerocarya birrea*	Letouzey (1985)
Central African Republic (*birrea*)	Secteur sahélo-soudanien à *Sclerocarya birrea*	Boulvert (1980)
Madagascar (*caffra*)	Savanes à *Sclerocarya*	Aubréville (1949)
Mali (*birrea*)	*Adansonia digitata-Sclerocarya birrea* parkland	Bonkoungou *et al.* (1998)
Mali (*birrea*)	*Sclerocarya birrea* parkland	Bonkoungou *et al.* (1998)
Mali (*birrea*)	*Sclerocarya birrea-Balanites aegyptiaca* parkland	Bonkoungou *et al.* (1998)
Mali (*birrea*)	*Sclerocarya birrea-Combretum glutinosum* parkland	Bonkoungou *et al.* (1998)
Mali (*birrea*)	*Sclerocarya birrea-Piliostigma reticulatum* parkland	Bonkoungou *et al.* (1998)
Mali (*birrea*)	*Sclerocarya birrea-Prosopis Africana* parkland	Bonkoungou *et al.* (1998)
Mali (*birrea*)	*Sclerocarya birrea-Vitellaria paradoxa* parkland	Bonkoungou *et al.* (1998)
Mozambique (*caffra*)	*Albizia-Afzelia-Sclerocarya* woodland and savanna woodland	Wild & Barbosa (1967)
Mozambique (*caffra*)	*Julbernardia globiflora-Ostryoderris-Sclerocarya* tree savanna	Wild & Barbosa (1967)
Niger (*birrea*)	*Combretum-Sclerocarya* association	Dundas (1938)
Niger (*birrea*)	*Anogeissus-Lannea-Sclerocarya* association	Dundas (1938)
Niger (*birrea*)	*Sclerocarya-Bauhinia-Guiera-Combretum* association	Dundas (1938
Nigeria (*birrea*)	*Anogeissus-Sclerocarya-Strychnos* open savanna woodland	Keay (1949)
South Africa (*caffra*)	*Acacia nigrescens-Sclerocarya* savanna	Acocks (1988)
South Africa (*caffra*)	*Sclerocarya-Burkea* veld	Acocks (1988)
South Africa (*caffra*)	Open *Sclerocarya* veld	Acocks (1988)
South Africa (*caffra*)	Knobthorn-Marula parkland	Codd (1951)
South Africa (*caffra*)	*Sclerocarya-Acacia* tree veld	Edwards (1967)
South Africa (*caffra*)	*Acacia nigrescens-Sclerocarya* tropical plains thornveld	Werger & Coetzee (1978)
South Africa (*caffra*)	Knobthorn/marula veld	Wyk (1972-1974)
South Africa (*caffra*)	Leadwood/marula/*Albizia* veld	Wyk (1972-1974)
Sudan (*birrea*)	*Terminalia-Sclerocarya-Anogeissus-Prosopis* savannah woodland	Harrison & Jackson (1958)
Zambia (*caffra*)	*Acacia macrothyrsa-Sclerocarya caffra* open chipya	King (1976)
Zambia (*caffra*)	*Combretum-Sclerocarya* type	Trapnell (1953)
Zimbabwe (*caffra*)	*Kirkia-Sclerocarya-Commiphora-Acacia nigrescens* woodland	Rattray (1957)
Zimbabwe (*caffra*)	*Colophospermum-Grewia-Sclerocarya-Kirkia-Eragrostis* type	Rattray (1961)

Considering the wide distribution of the species, use as a descriptor species and the extensive literature containing references to its presence in a range of vegetation types, little quantitative information on its abundance is available. This lack arises mainly because individuals within populations are often widely dispersed and very poorly represented in inventories of the small (<1 ha) sample plots typical of ecological studies. Differences in field procedures, particularly in size thresholds and parameters applied in data collection, are additional complications. In terms of numbers of individuals or stems, a general impression can, nevertheless, be gained from reports concerning both subsp. *birrea* and subsp. *caffra* (Table 2.8). However, with the exception of Shackleton *et al.* (2002), reported figures do not extend to the corresponding basal area or biomass values of subsp. *caffra*. Shackleton *et al.* (2002) cite figures for vegetation under three levels of mean annual rainfall (*ca* 550 mm; *ca* 670 mm; >850 mm) near Kruger National Park, South Africa, stems tallied including those <1 m tall. *Sclerocarya birrea* subsp. *caffra* was more strongly dominant in the percentage contributed to stand basal area (12.8% - 1.27 m^2 ha^{-1}; 15.6% - 1.35 m^2 ha^{-1}; 8.7% - 1.22 m^2 ha^{-1}, respectively) and biomass (20.3% - 4.67 t ha^{-1}; 30.7% - 6.22 t ha^{-1}; 12.6% - 5.22 t ha^{-1}, respectively) than the numbers of stems (0.3% - 16.8 ha^{-1}; 1.9% - 107.5 ha^{-1}; 0.2% - 37.7 ha^{-1}, respectively). *Sclerocarya* regeneration clearly was limited in the Kruger National Park study area. Even less information is available for subsp. *birrea*, although Breman & Kessler (1995) report a fresh weight of 475 kg for one individual, including 14.3 kg of foliage.

Most of the tabulated information was generated from surveys of relatively large areas (≥5 ha) furnishing at least 8 observations of *Sclerocarya birrea*. Data from small samples with at least 5 observations have been included to illustrate local concentrations of the species, which has been to shown (subsp. *caffra*) to sometimes occur on a patchy basis (Lewis, 1987; Scholes & Walker, 1993). Stocking values reach 5 ha^{-1} only where extrapolated from small samples, or if small (<9 cm dbh; <5 m tall) individuals are included in the counts. Impressions of high stocking levels seem likely to arise from the prominence of groups of large individuals which are not unusual in the parts of the range where the species is most frequently encountered, and explains occasional references to occurrence in 'pure stands' (*e.g.* Maydell, 1986 – subsp. *birrea*). Over large areas it appears that *Sclerocarya birrea* population densities of 5 ha^{-1} ≥10 cm dbh are not normal.

Calculations of the representation (percentage of the individual trees present) within sampled communities mostly indicate trivial contributions to the plant community when figures are based on low size thresholds. When attention is restricted to individuals ≥10 cm dbh, the species may account for higher proportions, as indicated by Marchal (1980), reflecting the importance among the larger plants which underlies the frequent adoption as a community descriptor. Unfortunately, only figures for *Sclerocarya birrea* individuals are given in the reports for the large areas assessed by Coetzee *et al.* (1979) and Lewis (1987) and representation cannot be calculated.

In several studies individuals of *Sclerocarya birrea* have been tallied and referred to size classes (Fig. 2.4). Areas assessed vary widely, from plots of 1 ha or less (Keay, 1949 – subsp. *birrea*; Khonje *et al.*, 1999 – subsp. *caffra*) to over 100 ha (Taylor, 1960 – subsp. *birrea*; Walker *et al.*, 1986 – subsp. *caffra*). Differences in field procedures handicap comparison of numbers on the basis of consistent size classes. Several entail conversions from imperial to metric units and/or girth to diameter and the example from Serengeti, Tanzania (Lamprey *et al.*, 1967) uses height rather diameter categories.

In diameter at breast height (dbh) terms, no extensive (≥5 ha) sample has indicated a mean value above 1 individual ha^{-1} ≥10 cm dbh, or values as high as 0.5 individual ha^{-1} ≥20 cm dbh. Information from small (≤1 ha) samples expressed on a per hectare basis generates much higher values which are not representative of the situation at the landscape scale.

Similar indications result from tallies using height as the recording parameter. However the estimates of numbers of individuals (subsp. *caffra*) ≥5.5 m tall from a series of 100 m wide transects in the Kruger National Park, South Africa (Coetzee *et al.*, 1979) confirm that this is an area with an unusually high concentration of the species.

Table 2.8. Representative estimates of stocking and representation of *Sclerocarya birrea*

Stocking (ha^{-1}) (Representation)	Value for inclusion	Location	Survey	Attribute (if specified)	Reference
5 (0.6%)	not stated	Gonse, Burkina Faso (12°22'N, 1°19'W; 300 m)	5 observations in 1 ha of Sudanian undifferentiated woodland	stems ("souches") of subsp. *birrea*	Bonkoungou & Framond (1988)
0.8 (10.3%)	not stated; mature individuals implied	Tugu, Burkina Faso (13°30'N, 2°15'W; 330 m)	70 observations on 87 ha of sahelian parkland derived from Sudanian undifferentiated woodland	individuals of subsp. *birrea*	Marchal (1980)
0.28 (0.2%)	9.7 cm dbh	Gambaga Scarp (East) Forest Reserve, Ghana (10°32'N, 0°25'W)	50 observations in 180 ha of Sudanian *Isoberlinia* and related woodlands	individuals of subsp. *birrea*	Taylor (1960)
37.5 (1.2%)	1.5 m tall	Goba, Mozambique (26°12'S, 32°08'E; 550 m)	15 observations in 0.4 ha of undifferentiated woodland and *Androstachys johnsonii* forest	individuals of subsp. *caffra*	Bandeira *et al.* (1999)
22.5 (6.8%)	≥1.6 cm dbh	Zurmi, Nigeria (12°50'N, 6°50'E)	9 observations in 0.4 ha of Sudanian undifferentiated woodland	individuals of subsp. *birrea*	Keay (1949)
12.5 (16.1%)	≥10 cm dbh	Zurmi, Nigeria (12°50'N, 6°50'E)	5 observations in 0.4 ha of Sudanian undifferentiated woodland	individuals of subsp. *birrea*	Keay (1949)
50.0 (19.4%)	≥1.6 cm dbh	Zurmi, Nigeria (12°50'N, 6°50'E)	20 observations in 0.4 ha of Sudanian undifferentiated woodland	individuals of subsp. *birrea*	Keay (1949)
7.5 (8.6%)	≥10 cm dbh	Zurmi, Nigeria (12°50'N, 6°50'E)	3 observations in 0.4 ha of Sudanian undifferentiated woodland	individuals of subsp. *birrea*	Keay (1949)
1.6 (0.3%)	1 cm dbh	Fathala Forest, Senegal (13°38'N, 16°28'W; <100 m)	9 observations on 7 ha of Sudanian savanna	individuals of subsp. *birrea*	Lykke (1998)
0.3 (1.1%)	20 cm dbh	Fathala Forest, Senegal (13°38'N, 16°28'W; <100 m)	8 observations on 24 ha of Sudanian savanna	individuals of subsp. *birrea*	Lykke (1998)
4.3 (highest of 18 estimates)	≥5.5 m tall	Kruger National Park, South Africa (24°30'S, 31°45'E)	604 observations on 142 ha of Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket	individuals of subsp. *caffra*	Coetzee *et al.* (1979)
0.5 (lowest of 18 estimates)	≥5.5 m tall	Kruger National Park, South Africa (24°30'S, 31°45'E)	101 observations on 224 ha of Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket	individuals of subsp. *caffra*	Coetzee *et al.* (1979)
16.8 (0.3%)	not specified but includes individuals <1 m tall	Transvaal, South Africa (24°45'S, 31°15'E; 550 m)	Unstated area of Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket under ±500 mm mean annual rainfall	stems of subsp. *caffra*	Shackleton *et al.* (2001)

Table 2.8 (continued). Representative estimates of stocking and representation of *Sclerocarya birrea*

Stocking (ha^{-1}) (Representation)	Value for inclusion	Location	Survey	Attribute (if specified)	Reference
107.5 (1.9%)	not specified but includes individuals <1 m tall	Transvaal, South Africa (24°45'S, 31°15'E; 550 m)	Unstated area of Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket under ±670mm mean annual rainfall	stems of subsp. *caffra*	Shackleton *et al.* (2001)
37.7 (0.2%)	not specified but includes individuals <1 m tall	Transvaal, South Africa (24°45'S, 31°15'E; 550 m)	Unstated area of Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket under >850 mm mean annual rainfall	stems of subsp. *caffra*	Shackleton *et al.* (2001)
41.9	not specified but presumably including individuals <1 m tall	Timbavati, South Africa (24°15'S, 31°40'E)	Unspecified area of communal land in Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket area	stems of subsp. *caffra*	Shackleton *et al.* (2001)
7.5	'mature' individuals	Timbavati, South Africa (24°15'S, 31°40'E)	Unspecified area of communal land in Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket area	stems of subsp. *caffra*	Shackleton *et al.* (2001)
8	individuals >2 m tall	Bushbuckridge, South Africa (24°45'S, 31°15'E)	Unspecified area of communal land in Tongaland-Pondoland evergreen and semi-evergreen bushland and thicket area	stems of subsp. *caffra*	Shackleton *et al.* (2001)
2.67 (0.9%)	not specified; presumably seedlings	Darfur, Sudan (12°30'N, 23°00'E)	Sample of 8.8 ha of Sudanian undifferentiated woodland	presumably individuals of subsp. *birrea*	Ramsay (1958)
1.82 (1.0%)	not specified; presumably seedlings	Darfur, Sudan (12°30'N, 23°00'E)	Sample of 5.5 ha of Sahel wooded grassland	presumably individuals of subsp. *birrea*	Ramsay (1958)
1.0 (0.3%)	≥0.9 m tall	Serengeti National Park, Tanzania (1°45'S, 35°00'E)	5 observations on 4.9 ha of Somalia-Masai secondary grassland and wooded grassland	individuals; subspecies not specified	Lamprey *et al.* (1967)
0.05	≥3 m tall	Luangwa Valley, Zambia (13°22'S, 31°38'E; 540 m)	42 observations on 780 ha of poorly drained soil	individuals of subsp. *caffra*	Lewis (1987)
0.40	≥3 m tall	Luangwa Valley, Zambia (13°22'S, 31°38'E; 540 m)	130 observations on 330 ha of deep, well-drained soil	individuals of subsp. *caffra*	Lewis (1987)

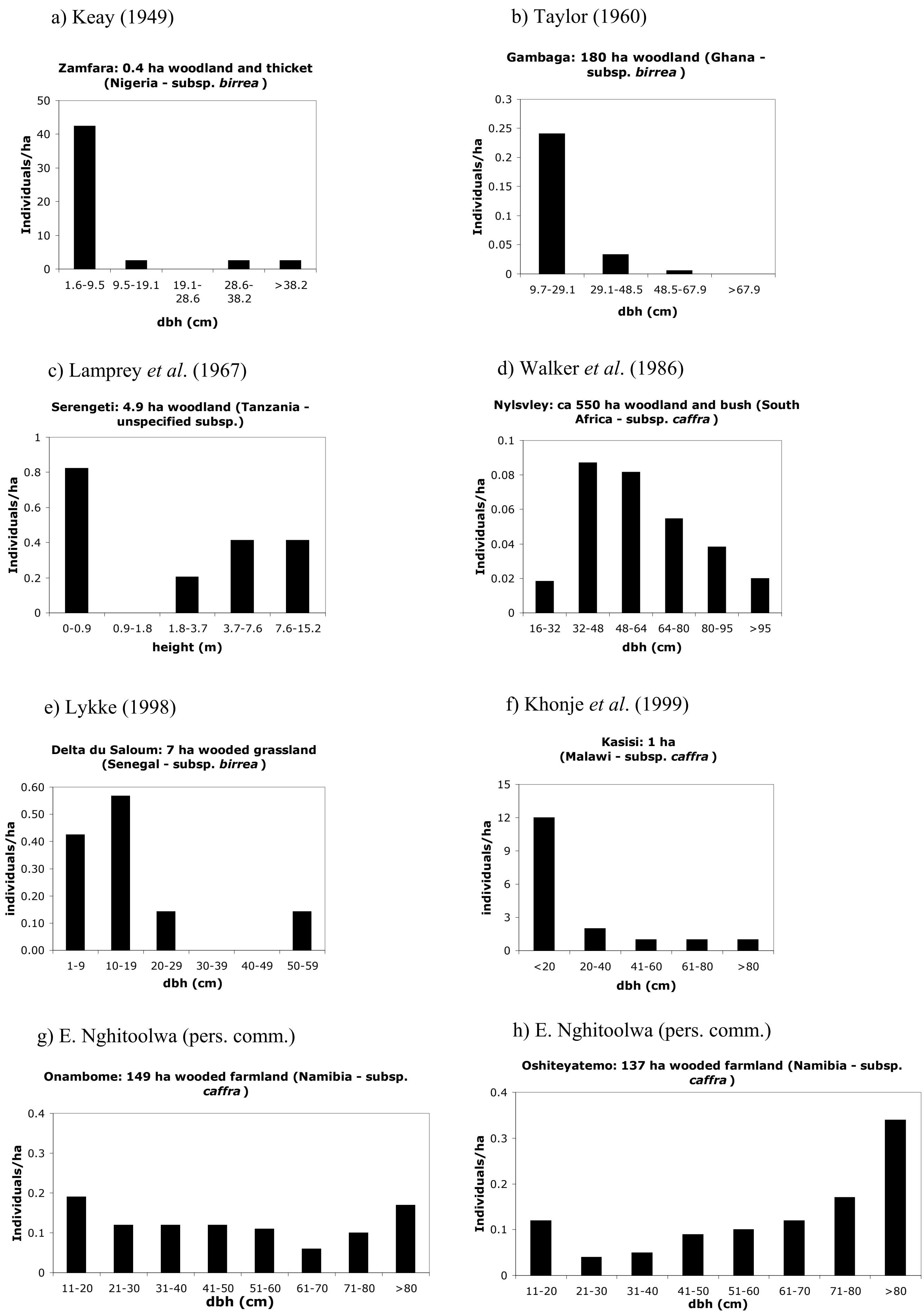


Figure 2.4. Representative size class distributions of *Sclerocarya birrea* populations.

2.4.4 Interactions involving *Sclerocarya birrea* within communities

2.4.4.1 Root system character and influence on the soil environment

Breman & Kessler (1995) have referred subsp. *birrea* to a group of woody plants in the Sudan and Sahel zones of West Africa typified by "shallow and extending roots". Nevertheless, Shone (1979), for subsp. *caffra* in Kruger National Park, South Africa, indicates that trees are sufficiently firmly anchored to commonly resist uprooting by elephants. A substantial root system is also consistent with Breman & Kessler's recognition that tree roots in dryland vegetation may be significant storage sites. This role is reflected in observations on subsp. *birrea* (Soumaré *et al.,* 1994; Groot & Soumaré, 1995) made at Niono, Mali, of a thick tap root penetrating up to 2.4 m, subtending extremely widely spreading lateral roots. Alexandre (1992), for neighbouring Burkina Faso, lists subsp. *birrea* among the dryland trees noteworthy for early development of a tuberous rootstock storing sugars and water and associates the feature with growth in difficult soils. For subsp. *caffra*, storage is also implied in one report (McGregor, 1995) that the roots have served as famine food in the past and reference in another to extraction of drinkable water from severed sections, 1-2 m long, of excavated thick superficial roots (Wyk, 1972-1974).

Ability to exploit soil to a considerable distance from the bole and store reserves may contribute to the ability of *Sclerocarya birrea* in the drier parts of the range to attain greater size than most of its associates, only *Adansonia digitata* being even taller in such demanding environments.

Soumaré *et al.* (1994) recorded several differences between soils (sands) beneath and away from the crowns of trees of subsp. *birrea*, attributing these to sequestration, in conjunction with architectural characteristics and the effects of root turnover. *Sclerocarya birrea* has a rounded crown and widely spreading branches which do not supply water to bole flow to the same extent as the main branches of species with obconical crowns, such as *Acacia seyal* Del. Less concentration of intercepted rainfall to the region of the root crown results.

Soil parameters monitored by Soumaré *et al.* (1994) which were affected by the presence of the trees were reaction (pH) and levels of organic matter. The upper soil horizons (top 0-20 cm of the profile) were more acid (pH 5.2) under the crown than away from it (pH 5.4). Organic matter content in horizons at 20-50 cm depth was lower (0.6%) away from the trees than under their crowns (0.8%). Cation exchange capacity and water holding capacity were considered enhanced under the tree crowns because of the quantity of tree roots present. In turn, the raised water holding capacity is suggested (Groot & Soumaré, 1995) to have increased phosphorus diffusion, raising the level of available phosphorus.

A natural mycorrhizal association was observed on excavated roots of subsp. *birrea* in Mali (Soumaré *et al.*, 1994) but no fungal identifications were reported. From Zimbabwe, McGregor (1995) has reported association between subsp. *caffra* and a botellid mushroom.

2.4.4.2 Loranthaceous parasites

Several loranthaceous parasites have been recorded on *Sclerocarya birrea* (Table 2.9). *Agelanthus crassifolius* has not been recorded on any other host.

The most widely publicized of these parasites is *Erianthemum dregei*, the haustorium of which is sold as the ornamental curiosity, the woodrose. Dzerefos & Witkowski (1997) have described the anatomy of the haustorial and adjacent host tissues of this species and *Pedistylis galpinii*. Dzerefos *et al.* (1998) unsuccessfully attempted to inoculate subsp. *caffra* with *Erianthemum dregei* and also monitored (over one year) the effectiveness of removing the shoots of 78 individuals of the parasite, noting that 68 appeared to recover.

Table 2.9. Loranthaceous parasites of *Sclerocarya birrea*

Species	Host	Reference
Agelanthus crassifolius (Wiens) Polh. & Wiens	subsp. *caffra*	Polhill & Wiens (1998)
Agelanthus prunifolius (Harv.) Polh. & Wiens	subsp. *caffra*	Wyk (1972-1974)
Erianthemum dregei (Eckl. & Zeyr.) Tieghem	subsp. *caffra*	Wyk (1972-1974); Dzerefos & Witkowski (1997); Dzerefos *et al.* (1998, 1999)
Helixanthera garciana (Engl.) Danser	subsp. *caffra*	Polhill & Wiens (1998)
Pedistylis galpinii (Sprague) Wiens	subsp. *caffra*	Dzerefos & Witkowski (1997); Dzerefos *et al.* (1999); Polhill & Wiens (1998)
Tapinanthus globiferus (A.Rich.) Tieghem	subsp. *birrea*	Hutchinson & Dalziel (1954-1958)

2.4.4.3 Relations with fauna

The relationship of elephants with *Sclerocarya birrea* has been the focus of more attention that any other relations with fauna, and some authors (*e.g.* Wyk, 1972-1974; Shone, 1979; Storrs, 1979) even comment at length on the "inebriation" of animals consuming fermenting fruits in excess!

For the Kruger National Park, South Africa, Coetzee *et al.* (1979) concluded that in the presence of high numbers of elephants the most vulnerable subsp. *caffra* were those along roads and at the edges of concentrations of the tree. Periods of annual rainfall above average value seemed to coincide with more widespread damage. Details of elephant impact on individual subsp. *caffra* trees were reported. Elephant impact at its most extreme involves pushing susceptible trees over, uprooting them, and then consuming all parts except the main trunk and large branch bases. Even exposed roots may be eaten (Palmer & Pitman, 1972-1974). Less severe damage is manifested by varying degrees of branch loss as the animals bend branches beyond breaking point to obtain foliage or fruits. The trunk may be snapped when the tree is firmly rooted (Coetzee *et al.,* 1979). Loss or displacement of the main stem may be followed by development of coppice shoots. Comparable resilience in subsp. *birrea* is implied in the reference (Maydell, 1986) to "gregarious root suckering", although other authors have not drawn attention to this feature.

Coetzee *et al.* (1979) describe the replacement of lost bark, highlighting colour changes and regenerative growth rates enabling the time of loss to be estimated. Within a week of the damage event, scars were bright pink, darkening through red to reddish-brown over the succeeding 10-40 weeks. Subsequently, appearance became blackish before progressively fading to grey shades. When new bark formation re-covers scars, a rate of 2.86 cm year^{-1} (*i.e.* during the single annual growing season) was estimated. A scar approximately 17 cm wide would thus be closed after about three growing seasons, when growth from each side came into contact, but only if covering an intact cambial layer. Recovery capacity was described as remarkable – supporting opinions expressed previously (Wyk, 1972-1974; Werger & Coetzee, 1978), but at variance with Shone's (1979) view that mature trees are easily killed by ringbarking.

Elephant impact on populations and the plant community overall is documented for woodland vegetation at Waza, Cameroun, by Tchamba (1995) and for wooded grassland in the Serengeti North Extension, Tanzania, by Lamprey *et al.* (1967). Tchamba distinguished three levels of damage: 'undamaged' (no evidence of browsing), 'damaged' (up to half the tree browsed) and 'seriously damaged' (more than half the tree browsed and/or the plant uprooted). *Acacia seyal*, *Combretum glutinosum* and *Piliostigma reticulatum* were the most severely affected and impact on the 14% of trees examined which were *Sclerocarya birrea* (subsp. *birrea*) in the sample was low: none of 203 trees was seriously damaged and only 29 were damaged. A selection preference ratio (percentage of subsp. *birrea* individuals browsed/percentage of trees examined contributed by subsp. *birrea*) of 1.0 was calculated. This suggested the animals neither sought nor avoided *Sclerocarya birrea*.

Lamprey *et al.* (1967) recorded 5777 trees, including nine trees of *Sclerocarya birrea* (subsp. unspecified but presumably *birrea* or *multifoliolata*) in 10 study plots, together covering 4.86 ha. Elephant impact on trees <1.6 m tall (4 of 4563 being *Sclerocarya birrea*) was described as negligible. There were 1214 larger trees, including five *Sclerocarya birrea* individuals – all >3.6 m tall. One of these had been cut (human impact) and all the other four had suffered elephant damage (3, broken branches; 1, chewed and abraded bark), although none was among 21 uprooted trees.

Many authors comment also on a wide range of other vertebrates which consume the foliage or fruits. Table 2.10 indicates the wide appeal of *Sclerocarya birrea* fruit to mammals, including those with gnawing ability or particularly powerful jaws which enable removal of the kernel from the endocarp. Most mammals seek the fruit pulp, discarding the stone. The limited appeal to birds is also apparent, the parrot listed (*Poicephalus meyeri*) benefitting from mandibles strong enough to enable nut feeding and to tear the leathery epicarp (Palmer & Pitman, 1972-1974). Some of the larger mammals are recorded as dispersal agents. Fewer species are recorded as browsing the tree than reported to eat fruits, but in areas with high numbers of large herbivores, browse lines may signify the height to which giraffe and elephant are able to feed (Wyk, 1972-1974). Smaller herbivores (impala and grey duiker) feed on fallen leaves (Palmer & Pitman, 1972-1974), as do goats (South Africa, subsp. *caffra* - Shone, 1979).

Shone (1979) notes that bird use of the tree as a nesting site is relatively rare, but has been known for the white-browed sparrow weaver (*Plocepasser mahali* Smith) although even this species usually nests in *Acacia*.

There is clearly a dearth of information on insects associated with subspecies other than subsp. *caffra* (Table 2.11). For subsp. *caffra*, however, a wide range of associated insects is known, including numerous coleopterous wood borers and lepidopterous leaf feeders (including mopane worms, *Gonimbrasia belina*), and dependent parasites. Some relationships are apparently opportunistic – as with use of the trees as breeding/nesting sites by mosquitoes and ants. Potential pollinating insects, notably bees (see Chapter 3), have been excluded from the table but aerial insect activity around inflorescences has attracted comment (Palmer & Pitman, 1972-1974; Mbuya *et al.*, 1994). Poynton (1984) and Guinko *et al.* (1987) associate *Sclerocarya birrea* with apiculture. Several other insects, which have proved to be pests of *Sclerocarya birrea* in nursery and commercial circumstances, are noted in Chapter 8 (Table 8.4).

A less direct relationship with insects arises with the presence of *Sclerocarya birrea* trees on termitaria. However, this is not a widely documented relationship, or one of especial significance, although both subsp. *birrea* (Morison *et al.*, 1948; Ramsay & Leeuw, 1964) and subsp. *caffra* (Malaisse, 1978; Meulen, 1979) are involved.

2.4.4.4 Anthropic relations – including fire

Fire, livestock, tree removal and soil disturbance have all been reported to affect the regeneration or population character of *Sclerocarya birrea* although only fire effects have been systematically evaluated. Climate and fuel load conditions make the whole range of *Sclerocarya birrea* potentially subject to wildfires. Where the mean annual rainfall is low (<400 mm), however, intervals of two or more years without extensive fire may arise. In sequences of years with below-average rainfall, only light (dry matter <1 t ha^{-1}) fuel loads develop (Houérou, 1989). Houérou (1989) suggests, however, that rangeland deterioration and associated biomass reductions have reduced the destructive action of wildfires in the drier, northern, parts of the Sudanian region, under mean annual rainfall as high as 600 mm. Fires nevertheless remain regular, and often destructive, annual events over the greater part of the area of distribution. In areas where fuel loads reach or surpass 4 t ha^{-1} fires increasingly tend to supress woody plant regeneration and eliminate many smaller established individuals. Suppression of *Sclerocarya birrea* regeneration by fire, along with that of other woody species, is inferred in the vegetation assessments of Lamprey *et al.* (1967) and Coetzee *et al.* (1979).

Table 2.10. Vertebrate use of *Sclerocarya birrea* as a food resource

	Subspecies of *Sclerocarya*	**Uses indicated**				**Countries**	**References**
Wild mammals		bk	br	fr	kn		
Baboon, *Papio cynocephalus* (L.)	*caffra*			+	+	South Africa	Shone (1979)
Black rhino, *Diceros bicornis* (L.)	*caffra*			+		South Africa	Shone (1979)
Burchell's zebra, *Hippotigris quagga* (Gmelin)	*caffra*			+		South Africa	Shone (1979)
Bushbuck, *Tragelaphus scriptus* (Pallas)	*caffra*			+		South Africa	Shone (1979)
Bush pig, *Potamochoerus porcus* (L.)	*caffra*			+		South Africa	Shone (1979)
Bush squirrel, *Paraxerus cepapi* (A.Smith)	*caffra*			+	+	South Africa	Wyk (1972-1974)
Eland, *Tragelaphus oryx* (Pallas)	*caffra*			+		South Africa	Shone (1979)
Elephant, *Loxodonta africana* Blumenbach	*birrea* *caffra* *caffra* *caffra* *multifoliolata** *caffra*	+ + +	+	 + + + + +		Cameroun Dem Rep Congo Malawi South Africa Tanzania Zambia	Tchamba (1995) Malaisse (1978) Williamson (1975) Shone (1979) Burtt (1929) Mitchell (1963)
Giraffe, *Giraffa camelopardalis* (L.)	*caffra*		+	+		South Africa	Shone (1979)
Grey duiker, *Cephalophus grimmia* (L.)	*caffra*			+		South Africa	Shone (1979)
Impala, *Aepyceros melampus* (Lichtenstein)	*caffra*			+		South Africa	Shone (1979)
Kudu, *Tragelaphus strepsiceros* (Pallas)	*caffra* *caffra*		+	+ +		South Africa Zambia	Shone (1979) Mitchell (1963)
Lemur	*caffra*			+		Madagascar	Bâthie (1944)
Monkeys	*caffra*			+		South Africa	Shone (1979)
Mouse	*caffra*			+		South Africa	Shone (1979)
Nyala, *Tragelaphus angasi* (Gray)	*caffra*			+		South Africa	Shone (1979)
Porcupine, *Hystrix africae-australis* (Peters)	*caffra*			+		South Africa	Shone (1979)
Rat	*caffra*			+		South Africa	Shone (1979)
Sable antelope, *Hippotragus niger* (Harris)	*caffra*			+		South Africa	Palmer & Pitman (1972-1974)
Squirrel	*caffra*				+	Malawi	Williamson (1975)
Steenbuck, *Raphicerus campestris* (Thunberg)	*caffra*			+		South Africa	Shone (1979)
Warthog, *Phacochoerus aethiopicus* (Pallas)	*caffra** *caffra*			+ +	 +	Madagascar; South Africa	Bâthie (1944) Shone (1979)
Waterbuck, *Kobus ellipsiprymnus* (Ogilby)	*caffra*			+		South Africa	Shone (1979)
Domestic mammals							
Camel Pigs	*caffra*				+	South Africa	Shone (1979)
Donkeys Sheep	*birrea* *caffra*			+	 +	Nigeria South Africa	

Table 2.10 (continued). Vertebrate use of *Sclerocarya birrea* as a food resource

	Subspecies of *Sclerocarya*	Uses indicated				Countries	References
Domestic mammals		bk	br	fr	kn		
Cattle	*birrea** *birrea* *caffra* *birrea* *caffra* *caffra*		 + + 	+ + + + 		Nigeria Senegal South Africa Sudan Zambia Zimbabwe	Jackson (1973) Adam (1966) Shone (1979) Wickens (1976) Storrs (1979) McGregor (1995)
Goats	*caffra* *birrea* *caffra* *birrea* *caffra*		+ + +	 + + + 		Kenya Niger South Africa Sudan Zimbabwe	Maundu *et al.* (1999) Fabregues & Lebrun (1976) Shone (1979) Wickens (1976) McGregor *et al.* (1999)
Birds							
Meyer's parrot, Poicephalus meyeri *(Cretzschmar)*	*caffra*				+	South Africa	Shone (1979)
Reptiles							
Tortoise	*caffra*			+		South Africa	Shone (1979)

*regarded as a dispersal agent; bk, bark; br, browse, including thin twigs; fr, fruit; kn, kernel

Table 2.11. Insects associated with *Sclerocarya birrea* trees

Order/family/subfamily	**Species**	**Location/Remarks**	Subspecies of *Sclerocarya*	**Reference**
COLEOPTERA				
Bostrychidae	*Sinoxylon bellicosum*	South Africa; attacking freshly felled logs	*caffra*	Shone (1979)
Brenthidae	*Usambius advena* Pasc.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Buprestidae	*Evides gambiensis* Cast & Gory	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Buprestidae	*Sphenoptera maculata* Cast & Gory	South Africa; reared from felled tree and dead branches of living tree	*caffra*	Plant Protection Research Institute (1970)
Carabidae: Lebiinae	*Lebistina peringueyi* Liebke	Namibia; parasitizing *Polyclada flexuosa*	*caffra*	Neuwinger (1994)
Cerambycidae: Cerambycinae	*Cordylomera schoenherri* Fahr.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Cerambycidae: Cerambycinae	*Plocaederus frenatus* Fahr.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Cerambycidae: Cerambycinae	*Xystrocera* sp. nr *erosa* Pasc.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Cerambycidae: Lamiinae	*Lasiopezus josephus* Duv.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Cerambycidae: Lamiinae	*Lasiopezus longimanus* Thoms.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Cerambycidae: Prioninae	*Aulacopus natalensis* White	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Chrysomelidae: Halticinae	*Polyclada flexuosa* Baly	Namibia; leaf feeder	*caffra*	Neuwinger (1994)
Curculionidae	*Mecocorynus loripes* Chev.	South Africa; stem borer	*caffra*	Plant Protection Research Institute (1970)
Lyctidae	*Lyctus* sp.	South Africa; attacking freshly felled logs	*caffra*	Shone (1979)
Nitidulidae	*Carpophilus hemipterus* (L.)	Malawi; sap feeder found in fruits	*caffra*	Lee (1971)
Platypodidae	*Doliopygus interpositus* Schedl.	South Africa	*caffra*	Plant Protection Research Institute (1970)
Scolytidae	*Xyleborus eichoffi* Schreiner	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Scolytidae	*Xyleborus mascarensis* Eich.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Scolytidae	*Xyleborus sclerocaryae* Schedl.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)
Trogositidae	*Gymnochila varia* F.	South Africa; reared from felled tree	*caffra*	Plant Protection Research Institute (1970)

Table 2.11 (continued). Insects associated with *Sclerocarya birrea* trees

Order/family/subfamily	**Species**	**Location/Remarks**	Subspecies of *Sclerocarya*	**Reference**
DIPTERA				
Culicidae	unspecified mosquitoes	South Africa; breeding in cavities in bole	*caffra*	Palmer & Pitman (1972-1974)
Tephritidae	Pardalaspis cosyra *(Walker)*	South Africa; infesting fruits	*caffra*	Toit *et al.* (1983); Lange *et al.* (2001)
HEMIPTERA				
Aphididae	*Aphis gossypii* Glover	Origin of record not specified; sap feeder	not specified	Blackman & Eastop (1994)
Coccidae	*Andaspis laurentina* De Almeida	Mozambique	*caffra*	Parker (1978)
Tingidae	uncertain	Malawi; presumed leaf feeder aggregated in large masses	*caffra*	Lee (1970)
HYMENOPTERA				
Eupelmidae	Anastatus *sp.*	South Africa; parasite of eggs of *Argema mimosae*	*caffra*	Berg (1990)
Eupelmidae	Mesocomys pulchriceps *Cam.*	South Africa; parasite of eggs of *Argema mimosae*	*caffra*	Berg (1990)
Eupelmidae	Mesocomys vuilleti *(Crawf.)*	South Africa; parasite of eggs of *Argema mimosae*	*caffra*	Berg (1990)
Formicidae: Pseudomyrmicinae	Tetraponera bifoveolata *Mayr*	southern Africa; nesting in trunks	*caffra*	Prins (1978)
LEPIDOPTERA				
Lasiocampidae	*Trichopisthia monteiroi* (Druce)	Southern Africa	*caffra*	Pinhey (1975)
Lymantriidae	*Euproctis rufopunctata* Walk.	South Africa; larval leaf feeder	*caffra*	Plant Protection Research Institute (1970)
Noctuidae	*Cortyta canescens* Walker	South Africa; infesting fruits	*caffra*	Lange *et al.* (2001)
Noctuidae	*Sphingomorpha chlorea* Cram.	South Africa; larval leaf feeder	*caffra*	Plant Protection Research Institute (1970)
Olethreutidae	*Cryptophlebia leucotreta* (Meyr.)	Malawi; in fruits (and, perhaps, seeds)	*caffra*	Lee (1970)
Psychidae	*Semimanatha fumosa* Janse	South Africa; larval leaf feeder	*caffra*	Plant Protection Research Institute (1970)
Pyralidae: Phycitinae	*Heterographis ocellea* Rag.	South Africa; larvae feed in fruit	*caffra*	Plant Protection Research Institute (1970)

Table 2.11 (continued). Insects associated with *Sclerocarya birrea* trees

Order/family/subfamily	Species	Location/Remarks	Subspecies of *Sclerocarya*	Reference
Pyralidae: Phycitinae	*Meteocis nigrivenella* Rag.	South Africa	*caffra*	Plant Protection Research Institute (1970)
Pyralidae: Pyraustinae	*Polygrammodes hirtusalis* Walk.	South Africa	*caffra*	Plant Protection Research Institute (1970)
Pyralidae: Phycitinae	*Mussidia melanoneura* Rag.	South Africa; infesting fruits	*caffra*	Lange *et al.* (2001)
Saturniidae	*Argema mimosae* (Bsd.)	South Africa; larval leaf feeder	*caffra*	Berg (1990)
Saturniidae	*Gonimbrasia belina* (Westwood)	South Africa, Zambia, Zimbabwe; larval leaf feeder	*caffra*	Palmer & Pitman (1972-1974); Storrs (1979); McGregor (1995)
Saturniidae: Saturniinae	*Nudaurelia belina* Westwood	South Africa; larval leaf feeder	*caffra*	Plant Protection Research Institute (1970)
Saturniidae: Saturniinae	*Nudaurelia cytherea capensis* Stoll.	South Africa; larval leaf feeder	*caffra*	Plant Protection Research Institute (1970)
Saturniidae	*Usta sinope* Westwood	Southern Africa; larval leaf feeder	*caffra*	Pinhey (1972)
Saturniidae	*Usta terpsichore* Maassen & Weymer	Southern Africa; larval leaf feeder	*caffra*	Pinhey (1972)
Sphingidae	*Batocnema africana* (Distant)	Southern Africa	*caffra*	Pinhey (1975)
	8 species of butterfly	South Africa; larval leaf feeders	*caffra*	Palmer & Pitman (1972-1974)

Onochie (1964) provides information on the relationship of subsp. *birrea* with the prevailing fire regime at Baketa-Tureta Forest Reserve (12°39’N, 5°42’E), Nigeria, where subsp. *birrea* is a common tree under a mean annual rainfall of *ca* 1000 mm. After *ca* 20 years, the impact of five experimental burning regimes applied under the condition, in principle, of livestock exclusion, was compared. Two regimes entailed reduced exposure to fire: complete protection; early (November) burning years separated by three-year intervals of complete protection) and two regimes entailed increased exposure: annual early burning; annual late (March) burning. The remaining regime (alternating years of early burning and complete protection) was equated to the prevailing fire regime of the area. Under the various experimental conditions the composition of the woody plant population and the dynamics of denser concentrations of woody species (clumps, thickets, climber tangles) were monitored. The subsp. *birrea* population was concluded to have increased under all but the annual late burning regime and to be, with *Anogeissus leiocarpus* and *Commiphora pedunculata*, regenerating beneath the large trees.

Onochie's (1964) observations indicate well-developed fire tolerance: apart from the population increases recorded, over the first 10 years of the experimental period an individual of subsp. *birrea*, initially (1939) 8 cm dbh, under the regime of alternating years protected and burned early (November), increased in dbh by more that 1.5 cm year^{-1}. While it became apparent that annual late (intense) burning would eliminate subsp. *birrea* at Baketa-Tureta, Onochie also pointed out that only one woody species (*Combretum nigricans* could thrive under such an intense fire regime.

Not all reports from Nigeria stress fire-tolerance, however. At Zamfara Forest Reserve, under a management regime of annual early burning, Keay (1949) specifically associated the abundance of subsp. *birrea* with fire protection. Ramsay & Leeuw (1964) excluded subsp. *birrea* from their grouping of fire-resistant trees on Bima sandstone in the Gongola valley, linking it instead with moist and termite mound situations where fire impacts are somewhat less extreme. Kershaw (1968), around Kaduna and Zaria, also found that the sites where subsp. *birrea* was most typical enjoyed fire protection - from expanses of bare rock or soil serving as fire breaks, or a humid microclimate.

The fire tolerance of established individuals of subsp. *caffra* has been indicated in various reports. Fanshawe (1969) refers to local frequency, in Zambia, in "chipya" vegetation – a mosaic vegetation with open phases characterized as having woody constituents that are highly fire-resistant (White, 1983). On Madagascar, subsp. *caffra* is among the most fire tolerant of the woody plants of the annually burned grassy lowlands of the western half of the island (Basse, 1934; Bâthie, 1944). The tolerance is attributed by Basse and Bâthie to the thick bark, strong capacity to replace small branches lost when fires are particularly severe, and depressed grass growth in the tree's shade (which reduces the fuel load and fire intensity around the bole).

Goat browsing of subsp. *caffra* is sometimes sufficiently severe to kill young trees (Shone, 1979). In the case of this subspecies, however, Shone (1979) refers also to the tendency of *Panicum maximum* Jacq., a high quality fodder grass, to occur under the crown, adding to the attraction of the tree as shade and, with fruiting individuals, as a food source.

Tree removal takes account of gender, with tradition, sometimes reinforced in law (Chapter 9), often restricting felling for fuelwood or other wood to male trees. Where the fruit is not valued, female trees are likely to be removed, if the law allows. Appeal as ornamental or shade trees may be outweighed by the seasonal inconvenience of accumulated, odorous decomposing fruit attracting unwelcome wild animals.

Soil disturbance has been suggested by Walker *et al.* (1986) to be advantageous for the germination and establishment of subsp. *caffra*, although unless a protective screen of other plants is present escape from predation is unlikely.

2.4.4.5 *Sclerocarya birrea* in succession and unmanaged vegetation change

There has been little attention to the successional relationships of *Sclerocarya birrea*. The generally low stocking and lack of dense even-aged stands mean that typical ecological research plots yield too little information to show any trends. Other relevant aspects of the species' ecology also remain poorly known, particularly growth rates (Chapter 3), the architectural development of the young plants and the dynamics of cohorts of seedlings. A general impression gained, however, is that the species, including subsp. *multifoliolata* (Phillips, 1930; Scott, 1934), is most typical of fairly long-established and relatively stable communities.

Fairbairn (1939) describes subsp. *birrea* individuals as relicts of woodland or wooded grassland formation, these individuals being retained when other species are removed to initiate the cropping phase of a shifting cultivation cycle. This "parkland" significance is underlined by Boffa (1999), who specifies subsp. *birrea* as a typical dominant tree of the northern Sudanian region parklands. Seignobos (1982) attaches particular importance to subsp. *birrea* in the north Cameroun/west Tchad area as a source of vegetable oil, explaining the reluctance to fell it when farming takes place. Other comments associate subsp. *birrea* with opportunistic spread of occasional individuals into disturbed but otherwise favourable neighbouring sites (Kershaw, 1968), or with phases towards the "climax" of postulated (but speculative and disputable) successions (Eggeling, 1938; Fairbairn, 1939). Donfack *et al.* (1995) carried out a more systematic evaluation of fields on light-textured soils in north Cameroun abandoned for different periods, finding subsp. *birrea* first appeared after 5 years and recruitment continued for another 12 years. Subsp. *birrea* was one of few trees not felled for fuelwood by the age of 6 years, supposedly because fuelwood value was too low. Seignobos' (1982) results suggest, however, that interest in subsp. *birrea* as a fruit tree might also contribute, although Donfack *et al.* do not mention this.

A broadly similar picture emerges for subsp. *caffra*, even to the extent of a relict role in parklands (Wild & Barbosa, 1967). For South Africa Edwards (1967) interprets "*Sclerocarya-Acacia* tree veld" (wooded grassland), in which subsp. *caffra* is prominent, as a climax community in the Tugela basin, while Acocks (1988) also associates subsp. *caffra* with relatively stable climax and near-climax vegetation. Mogg (1969a) offers a similar view for Inhaca Island in neighbouring Mozambique. A better-characterized instance of vegetation change involving *Sclerocarya birrea* was the shift (between about 1950 and 1970) from *Acacia nigrescens/Combretum imberbe* dominance to subsp. *caffra* dominance on the basalts of the Kruger National Park. The suggested explanation of this change was overgrazing by large wild ungulates and more intense fires and, where *Acacia nigrescens* mortality was concerned, woodborers (Wyk, 1972-1974). However, this was a process of subsp. *caffra* persisting while the previous dominants declined, rather than aggressively entering the community as a distinctive new phase of succession.

3 BIOLOGY

Moses Munjuga and John B. Hall

This chapter is concerned with the biology of *Sclerocarya birrea* and focuses particularly on reviewing the state of knowledge of the life cycle, phenology and reproductive biology. All these aspects of the understanding of the species are mentioned in past literature but, apart from the anatomical studies initiated by Irmgard von Teichman some twenty years ago, published comment has almost always been in a very restricted context. Here, we have aimed at extending the picture by collating the many scattered but brief observations reported on the life cycle and phenology, including a synthesis of herbarium information for the latter, and complementing Teichman's meticulous anatomical work with a broader view of the reproductive biology.

3.1 CHROMOSOME COMPLEMENT

The only chromosome count for *Sclerocarya birrea* that has been traced is 2n = 26, for subsp. *caffra*, based on Mozambique material (Paiva & Leitao, 1989). This value apparently has not been reported for any other species in the Anacardiaceae, although values within the family range widely (from 2n = 24 to 2n = 60), and invites verification.

3.2 LIFE CYCLE AND PHENOLOGY

3.2.1 Life cycle

No monitoring of seed germination under natural conditions appears to have been reported. However, indirect literature references to subsp. *caffra* germination (Teichman, 1982; Lewis, 1987) suggest an interval of some 6-10 months between fruit fall/seed dispersal and germination in the field. This has promoted the view that a dormant period must elapse or (Chapter 8) be broken by pre-treatment before germination takes place.

Dormancy allows viability to be retained through the season of the year when conditions are not favourable for establishment. Over this period, the hermetic seal (a band of parenchymatous tissue – Teichman & Robbertse, 1986) between the operculum closing the germination aperture and the rest of the endocarp is weakened, enabling moisture to enter and be imbibed by the seed within. Hill (1933) implied that prolonged exposure to moist conditions resulted in the necessary weakening. Teichman (1982) suggests agents involved in the weakening process include bacteria and insects.

Few references to the dimensions of individuals of known or estimated age, or to rates of growth, appear in the existing literature. Those which have been made provide only a fragmentary picture, and originate from a range of situations. Consequently, generalization about the typical life cycle of *Sclerocarya birrea* is difficult.

After germination of subsp. *caffra* takes place, the shoots lengthen rapidly and may reach 0.3-0.7 m within five months (Zambia - Lewis, 1987). It is nevertheless probable that prevailing conditions often limit the heights reached during the first season of growth – Jacobs & Biggs (2002a) follow earlier work in southern Africa in adopting a 0.25 m threshold to separate "seedlings from the last growth season" from older individuals. Potential for fast growth is reflected by observations made under nursery or similar circumstances (Table 3.1). Maghembe *et al.* (1994) and Maghembe (1995) recorded mean heights of 1.9 m and 3.9 m after 27 months and 48 months, respectively. The brief (11 weeks) nursery period, recommended in Burkina Faso to raise plants 0.3 m tall, suggests the situation with subsp. *birrea* is similar (Nikièma *et al.,* 1993).

Table 3.1. *Sclerocarya birrea*: reported tree size x age relationships

Age (years)	Height (m)	Bole diameter (cm)	Crown diameter (m)	Basis	Subspecies and country	Source
2.3	1.9	4.9 (rcd)	1.2	means of 17 individuals	*caffra*: Malawi (nursery)	Maghembe *et al.* (1994)
4	3.9	9.5 (rcd)	3.6	means of 15 individuals	*caffra*: Malawi (nursery)	Maghembe (1995)
4-5	4.1-6.2	13-19 (at 30 cm)	-	range from means of 30 trees at each of four sites	*caffra*: Israel (planted)	Nerd & Mizrahi (1993)
8	3.5	-	-	unspecified number of trees	*birrea*: Niger (planted)	Delwaulle (1979)
11-12	8.2	28 (dbh)	8.1	single tree	*birrea*: Mali (wild tree)	Soumaré *et al.* (1994)
15	11	54 (us)	-	from a truncheon 1.6 m long	*caffra*: South Africa (planted)	Shone (1979)
19-20	7.1	28 (dbh)	8.1	single tree	*birrea*: Mali (wild tree)	Soumaré *et al.* (1994)
24	-	65-70 (us)	"wide"	ambiguous report requiring verification	*caffra*: Namibia (planted)	Keet (1950)
25	8.4	26 (dbh)	9.8	single tree	*birrea*: Mali (wild tree)	Soumaré *et al.* (1994)
27	9	-	-	single tree	*caffra*: South Africa (planted)	Shone (1979)
29	8.7	33 (dbh)	8.5	single tree	*birrea*: Mali (wild tree)	Soumaré *et al.* (1994)
32	-	31 (us)	-	single tree	*caffra*: South Africa (wild tree)	Shone (1979)
32	6.9	45 (dbh)	12.5	single tree	*birrea*: Mali (wild tree)	Soumaré *et al.* (1994)

dbh, diameter at breast height; rcd, root collar diameter; us, diameter at unspecified position; - , no information given

Delwaulle (1979) considered that plants of subspecies *birrea* which had reached 3.5 m in height in 8 years had grown fast, given the local conditions (600 mm mean annual rainfall, in Mali and Niger). By the age of 10 years, trees in Mali (Table 3.1) seem to have reached approximately full height – 7-8 m for the locality (Niono).

Poynton's (1984) estimate of early height increment in subsp. *caffra* is 0.6 m year^{-1} and Shone (1979) and Nerd *et al.* (1990) report increments, also for subsp. *caffra* - in South Africa and Israel, respectively - of 1 m and 2 m height growth over one year. Experimental plants beyond the nursery stage at Makoka (Malawi) increased in height at around twice this rate – from 1.9 m to 3.9 m in 21 months – and the mean annual height increment over the first 4-5 years for the plants raised in Israel is also comparable. Although ages are uncertain, for well-established plants, bole diameter increment in Nigerian subsp. *birrea* in relation to original diameter can be inferred from records reported by Onochie (1964). Onochie's figures (which he admits are generally surprisingly high and to invite further study) indicate a possible mean annual dbh increment of 2.4 cm over four years, for an individual initially 8.1 cm dbh. For the next six years, a lower dbh increment of 1.4 cm year^{-1} is implied, and over a further 11 years (at the end of which a dbh of 27.5 cm is indicated) much less: 0.1 cm year^{-1}. Diameter increment in 44 established trees (ranging from 9 cm to 57 cm in diameter 30 cm above ground level) of subsp. *caffra* in north-eastern South Africa was monitored by C. Shackleton (2002), who relates initial bole diameter (0.3 m above ground) and diameter increment as:

annual increment in mm = -0.068 initial diameter in cm + 4.54.

From this inverse relationship, times of passage and projections of diameters reached after specific time intervals in the South African savanna biome can be estimated (Table 3.2). Mean annual diameter increment falls from around 4 mm with individuals 15 cm in diameter to around 1 mm with individuals 55 cm diameter, and presumably continues to fall thereafter.

Table 3.2. *Sclerocarya birrea* subsp. *caffra*: estimates of times of passage through diameter classes and diameters attained after intervals of 10 years and 20 years in South African savanna.

Initial bole diameter 0.3 m above ground (cm)	Time of passage for a diameter increase of 10 cm (years)	Diameter after 10 years (cm)	Diameter after 20 years (cm)
10	29	14	17
20	35	23	26
30	46	32	35
40	67	42	44

Based on C. Shackleton (2002)

No estimates for the longevity of *Sclerocarya birrea* have been traced but Shackleton's observations imply ages well over 200 years for many large individuals of subsp. *caffra* in southern Africa. Onochie's (1964) observations imply much faster growth is possible with small (<25 cm dbh) individuals of subsp. *birrea* in northern Nigeria, where mean annual rainfall is *ca* 900 mm. The much reduced later dbh increment which Onochie's figures suggest, is more consistent with Shackleton's findings for subsp. *caffra* and, like these, points to considerable age for large individuals.

Apart from simple increases in height and bole diameter, *Sclerocarya birrea* individuals undergo progressive changes in tree form as they mature (Teichman, 1982), although this aspect of development has been largely neglected in published accounts. Vigorously growing individuals characteristically have a sturdy main axis, persistent branches arising from near the ground are not prominent and lateral spread is limited. There is normally only a single leading shoot, although under suboptimal conditions in Israel (Ramat Negev – Nerd & Mizrahi, 1993) young individuals were multi-stemmed. As the juvenile phase, usually signified by leaflets with relatively strongly dentate margins, gives way to a more mature state a crown of upright branches (Shone, 1979) develops. With further increase in age, there is proliferation of branching and more outward spread resulting in a rounded crown of diameter approximating to the tree's height. Vigorous individuals which survive to the largest sizes develop a widely spreading crown, its diameter exceeding the tree's height, as strikingly illustrated by Wyk (1972-1974) and Goosen (1985). So far, *Sclerocarya birrea* has not been allocated to an architectural model in the sense of Hallé *et al.* (1978).

The onset of reproductive activity in planted subsp. *caffra* in relation to age in Malawi (Maghembe, 1995) is at 4-5 years, and in Israel (Nerd *et al.*, 1990) at 4-5 years. The Malawi plants had reached a root collar diameter of *ca* 10 cm. Shone (1979) indicates an age of seven years for the onset of fruiting in wild South African plants. The smallest of 64 individuals of subsp. *caffra* included in C. Shackleton's (2002) fruiting survey in South Africa was 9 cm diameter (at 30 cm above ground level) and estimated to be less than 18 years old. From observations made in Israel, early fruit crops are small and of individually small fruits. The better yields recorded in Israel (from five trees averaging *ca* 18 cm diameter 30 cm above ground) were 947 tree^{-1}, with mean fruit fresh weight 28.3 g (Nerd & Mizrahi, 1993). Older planted trees (14-15 years) of subsp. *caffra* in Botswana have been reported (Campbell, 1986) to bear annual crops exceeding 1000 fruits; Keet (1950) describes trees of this subspecies 24 years old in Namibia as "fruiting abundantly". The numbers and individual fruit weights reported from the young trees in Israel are comparable with more typical yields within subsp. *caffra* populations in South Africa (Todd, 2001; C. Shackleton, 2002). However, the exceptional yields often mentioned in the literature (Chapter 8) are probably restricted to larger and older individuals.

3.2.2 Phenology

3.2.2.1 Deciduousness

Bie *et al.* (1998) indicate subsp. *birrea* in Burkina Faso and Mali as displaying "early flushing, deciduous" behaviour. The leafless state persists through 7-8 months under 600 mm mean annual rainfall in northern Burkina Faso but for only 3-4 months under higher rainfall 800-900 mm year^{-1} further south and at a site in Mali. These periods largely correspond to the dry season, although soil stores of moisture may delay leaf fall for about one month after the wet season ends (Seghieri *et al.*, 1995; Devineau, 1999). Seghieri *et al.* noted, however, that on a local scale in Cameroun the onset and duration of the leafless period varied with site quality – in a favourable site leaves were retained about one month longer than on a degraded soil. In the equatorial bimodal rainfall pattern of southern Kenya, the leafless phase of subsp. *birrea* coincides with the long dry season (Munjuga, 2000). Devineau's (1999) study, in Burkina Faso, extends the picture drawn by Bie *et al.* (1998) by distinguishing periods of leaf fall (through the first half of the dry season) and leaf flush (mainly the second half of the dry season). Mean durations of different phases were estimated from observation of 10 individuals: leaf fall – 2.1 months, leafless – 2.9 months, flushing – 2.2 months. With regard to the synchrony of leaf flush within the population, Devineau recorded indices (mean flushing duration for individual trees/duration for all trees combined) of 0.7 within sites (two sites) and 0.4 between sites. For subsp. *caffra* in Malawi (Hall-Martin & Fuller, 1975), South Africa (Teichman, 1982) and Zambia (Storrs, 1979), leaf flush coincides with the transition from wet to dry season. Trees are in full leaf during the mid-late rainy season in Malawi, and here and in Zambia leaf fall is early in the dry season. Hall-Martin & Fuller (1975) found during their year of monitoring, 1971, that trees in the Lengwe National Park, Malawi, remained leafless for about four months in the dry season.

3.2.2.2 Flowering and fruiting

The flowering and fruiting phenology of the subspecies of *Sclerocarya birrea* is summarized diagrammatically in Figs 3.1-3.5 (see end of chapter), which relate flowering and fruiting months indicated on herbarium labels with the climate reported (FAO, 1984) for a meteorological station below 1800 m elevation within 50 km. Flowering is a dry season event in both subsp. *birrea* and subsp. *caffra*, although less markedly so in the bimodal equatorial rainfall regime. For subsp. *birrea*, Breitenbach (1963) and Bie *et al.* (1998) consider flowering precocious in Ethiopia and Burkina Faso, respectively; for subsp. *caffra* in South Africa, Shone (1979) records precocious behaviour but Teichman (1982) associates flowering with the flush of new foliage. It occurs later in the dry season in the case of subsp. *caffra*, which often grows where there is a distinctly cool mid-dry season prior to flowering taking place. Monthly means of daily minimum temperature fall below 10°C in the coldest months in much of the subtropical part of the range. Devineau (1999) noted a mean duration of 4 months for the flowering state in individual trees of subsp. *birrea* in Burkina Faso but other references to the duration of flowering are shorter, sometimes markedly so (Clauss, 1984 – for subsp. *caffra* in Botswana; Munjuga, 2000 – for subsp. *birrea* in Kenya), probably reflecting year-to-year fluctuation in the intensity of reproductive activity. With regard to flowering within a population of subsp. *birrea* in Burkina Faso, Devineau (1999) recorded synchrony indices (mean flowering duration for individual trees/duration for all trees combined) of 0.7-0.8 within sites (two sites) and 0.6 between sites.

The timing of fruiting appears more variable, but this partly reflects the time (2-3 months) that fruits remain on the tree and inclusion of records for fruits at various stages of maturity. In the case of subsp. *caffra*, fruiting is often well within the rainy season, as noted in Zimbabwe by McGregor (1995), since flowering has taken place as the dry season is ending, particularly in more southerly latitudes. Breman & Kessler (1995), referring to the West African Sahel zone, associate the fruiting of subsp. *birrea* with the dry season. Fig. 3.2 suggests a more variable situation, with fruiting as the dry season ends as well as within it, and in the case of the two Ethiopian records included fruiting in wetter (mean rainfall >50 mm) months. Bie *et al.* (1998) also note that the fruiting period of subsp. *birrea* extends into the wet season in Burkina Faso and Mali. Individual trees in Burkina Faso carried fruits for 4 months on average in Burkina Faso (Devineau, 1999). Devineau also recorded uniform timing for fruit dissemination within each of the two sites where he worked, and between them. Taylor & Kwerepe (1995) suggest a six-weeks fruiting period is typical for trees of subsp. *caffra* in Botswana, with the period as brief as 2 weeks in some cases and as long as 8 weeks in others. Fruit fall per tree of subsp. *caffra* in Zambia continued for periods of 1 month to 3 months (Lewis, 1987).

The information on subsp. *multifoliolata* (Fig. 3.5), while limited, is consistent with a flowering event at the end of the dry season and fruiting during the succeeding wetter period.

3.2.3 Year-to-year variation in flowering and fruiting

Flower and fruit production vary more than foliage production from year-to-year and among individuals. There is wide inter-annual variation in fruit production in subsp. *caffra* (Todd, 2001; Shackleton, in press) and subsp. *birrea* (Munjuga, 2000), even to the extent of many individuals being reproductively inactive in a season following a normal fruiting season. This presumably accounts for the widely held view that trees that bear a good fruit crop in a certain year tend to develop poor fruit crops in the subsequent year. No reports of this relating to subsp. *multifoliolata* have been seen, but successive years of contrasting fruit yields are known for numerous tree species and may be presumed to apply. Occasional anomalous reports of flowering, as in May with subsp. *caffra* in Madagascar (Fig. 3.3), may arise from a second flowering period within the year.

3.3 REPRODUCTIVE BIOLOGY

3.3.1 Pollen

Pollen grains of *Sclerocarya birrea* subsp. *birrea* from Tchad and Uganda, respectively, have been described by P. Assemien in Lobreau *et al.* (1969), with illustrative photomicrographs, and by Sowunmi (1973).

The tricolporate grain is isopolar and radially symmetrical. Sowunmi (1973) found most grains to be lobate-subprolate (30 µm between poles, 25.5 µm in diameter) but also many (27%) that were prolate

(34 µm between poles, 24 µm in diameter), and similar dimensions (32 µm between poles, 22 µm in diameter) are given by Assemien. Smaller grains (29.8 µm between poles, 17.2 µm in diameter) have been noted for Kenya subsp. *birrea* (Munjuga, 2000).

The colpi are 26.9 µm long (Uganda material) and about 2.0-3.0 µm wide, with distinct margins, and sometimes constricted medially or tapering towards the ends. Assemien notes that the colpi may meet over one or both poles. The rather obscure endoapertures are 2-3 µm wide and subcircular or somewhat elongated (3.4 µm – Sowunmi, 1973) along the polar axis.

The exine is 1 µm (Sowunmi, 1973) to 2 µm (Lobreau *et al.*, 1969) thick, with its outer surface showing fine striate to striato-reticulate sculpturing, the striae 0.4 µm wide. The endexine is thinner than the ectexine (Lobreau *et al.*, 1969) but the two are not sharply separated (Sowunmi, 1973). The endexine structure is finely baculate, with bacula 0.2-0.3 µm in length (Lobreau *et al.*, 1969).

3.3.2 Sexuality

Sclerocarya birrea is usually dioecious but careful examination of trees of subsp. *caffra* in a number of studies in South Africa has revealed cases of monoecy (Palmer & Pitman, 1972-1974; Teichman, 1982; Todd, 2001). These departures from the normal pattern are primarily of occasional female flowers in one or two of the most proximal inflorescences of shoots on predominantly male trees. Teichman (1982) reports a survey where the anomaly applied to 15 of 119 trees, and Todd (2001) found 2 and 6 monoecious individuals in samples of 120 and 73 trees, respectively. A second anomaly is the rare occurrence of bisexual flowers but Palmer & Pitman (1972-1974) and Todd (2001) have noted these. Munjuga (2002) noted for subsp. *birrea* in southern Kenya, that on predominantly female trees a few flowers have some pollen-bearing anthers and are not merely staminodes.

3.3.3 Anthesis

Observations on anthesis in subsp. *birrea* in Kenya have been made by Munjuga (2000). The stigmas are receptive when the female flowers begin to open. Individual female flowers are in a fully open state from 8 h to 12 h, local time. Stigmas of newly opened flowers (<24 h old) are white to cream in colour, and the lobes are less reflexed (and drier) than in flowers that have been open for longer. Stigmas remain receptive for up to 72 h but turn brown after 5–6 days, and petals start to wither and also turn brown. After fertilization., secretion of nectar stops. Most female flowers borne were aborted, or dried up before opening, or were predated by birds. The petals, androecium, pistil and sepals wilt in succession after fertilization. The maturation and opening of male flowers follow an acropetal sequence, with most opening between dawn and midday and the peak opening period from 7 h to 9 h, local time. Anthers dehisce sequentially within the male flowers, starting on the day the flowers open. On average, all anthers had dehisced 32 h after flower-opening. After dehiscence, pollen viability (initially *ca* 90%) remains high for at least 12 h. After 48 h 50% of grains tested germinated (Munjuga, 2000). Viability is lost completely after 120 h. The whole process of anthesis lasted 6-14 days.

3.3.4 Pollination and potential pollinators

The stigmatic surface is minutely papillose and while receptive secretes mucilage which readily retains pollen grains. *Sclerocarya birrea* is recognized as an entomophilous species, producing sticky pollen grains and secreting nectar. Nectar is secreted at 4-12 sites on the disc at the base of the ovary and nectar-foragers effect pollination, with honey bees (Apidae: *Apis mellifera*) usually cited as a major pollinator of subspp. *birrea* and *caffra*. Nevertheless, although having little fragrance, *Sclerocarya birrea* flowers are very attractive to a range of other flying insects (Taylor, 1942; Breitenbach, 1963; Palmer & Pitman, 1972-1974; Storrs, 1979; Clauss, 1984). Apart from bees (Apidae and Megachilidae), flies (Muscidae: *Musca* spp.), hoverflies (Syrphidae). Wasps (Scoliidae) are secondary pollen vectors (Munjuga, 2000). Insect visits to flowers usually take place in the area studied (Kibwezi, Kenya) in cool weather, especially in the morning and in the afternoon, with maximum visitation mid-morning (Munjuga, 2000). Munjuga (2000) found that bagged racemes did not set fruits, unless pollen was manually applied. In the experiment carried out, open pollination (56% success) was more effective than assisted pollination (35% success) in promoting seed set – possibly a consequence of the early timing of pollen application (06.00 h, local time). Not all the flowers pollinated produced mature fruits, as there was an early fruit fall due to physiological causes. There was no evidence of agamospermy.

3.3.5 Fruit development and seed set

The development of the seeds and fruit structures of *Sclerocarya birrea* subsp. *caffra* in South Africa have received detailed attention from Teichman & Robbertse (1986) and Teichman (1988). Munjuga (2000), following the development of fruits in Kenya, found a situation comparable with that described below for subsp. *caffra* and noted also fruit drop through abortion at every stage. Reference has been made in Chapter 2 to agents of seed dispersal.

3.3.5.1 Ovule development

Changes within the female flower buds of subsp. *caffra* begin before anthesis as the ovule, with the inner and outer integument primordia bend towards an anatropous condition. At anthesis, the ovary is usually bicarpellate, each locule containing a pendulous ovule with a dorsal raphe and a massive funicle, with a distinctive protuberance (Teichman, 1988). Features of the ovule at this stage are a short inner integument of about four layers of cells, with tanniniferous deposits in the inner epidermis, the well-developed (proximally about six cell layers thick) outer integument, a complex hypostase *sensu lato*, also with tanniniferous deposits, in the chalazal-nucellar region and an extensive raphe. Next to the inner face of the operculum, by the time the ovule is fully developed, a "ponticular outgrowth" (Teichman & Robbertse, 1986) has developed from it. After fertilization, the embryo initially shows only limited growth and the character of the ovule is retained; later there is extensive development of the hypostase complex and chalaza. The ovule and funicle fill most of the ovary locule in fruits measured at 9.4 mm x 7.5 mm.

During maturation of the seed coat, subepidermal cells in the outer integument undergo lignification and some secondary thickening, and cell walls in the hypostase complex are impregnated with lipidic substances (probably suberin and lignin). Mature seeds measure about 15-20 mm x 4-8 mm. The mature seed coat is formed by the raphe, the hypostase complex and chalaza and the remnants of the inner and outer integuments and a cuticular layer (Teichman, 1988). Reserve materials in the cotyledons of the mature seed are proteins and lipids. There is no starch, there is no endosperm, and the seed is exalbuminous (Teichman, 1988). When fruit size reaches *ca* 20 mm x 15 mm, growth in the ovary wall has increased the size of the locule, now less than half-filled by the seed and the much bulkier funiculus. Even when the fruits are 30 mm x 20 mm (three-quarters of full size), the seed is little developed (being only one-third final size), but the embryo may be as large as 2 mm x 1.5 mm, in which case the cotyledons can be recognized.

3.3.5.2 Ovary wall development

In the young ovary of subsp. *caffra*, the ovary wall consists, from exterior to interior, of six layers:

- an outer epidermis which enlarges by anticlinal cell division
- a subepidermal layer of cells, many tanniniferous
- a parenchymatous layer in which secretory cavities are forming
- a zone of parenchyma containing procambial strands differentiating into xylem vessels
- an inner parenchymatous zone containing a proportion of tanniniferous cells
- an inner epidermis enlarging mainly by anticlinal cell division.

In slightly older ovaries, the innermost parenchymatous zone demarcates the operculum, this being represented by a mass of parenchyma. The ovary wall at this stage contains secretory structures (canals and cavities) lined with epithelial cells, anastomoses between procambial strands have developed and bundles of fibre initials have been derived from other procambial cells.

When fully developed ovules are present, tanniniferous cells are prominent in the parenchyma lining the ovary locule and delimiting the operculum, this structure having been developed from the inner tissues of the young ovary wall. Behind the lining, the ovary wall tissue now contains abundant fibre initials, often tanniniferous, in a ground matrix of isodiametric parenchymatic cells. Within the developing operculum, also, there are bundles of fibre initials, associated with sclereid initials, the latter often tanniniferous. At this stage, when the fruit dimensions are *ca* 20 mm x 15 mm, the exocarp (the outer epidermis, its cells elongating radially and increasingly tanniniferous, with the subepidermal parenchyma and the outer part of the zone with secretory cavities and canals) can be distinguished from the endocarp (the inner epidermis and adjacent subepidermal parenchyma, and the inner parenchymatic zones with abundant fibre and sclereid initials). The endocarp has grown rapidly, particularly through thickening of the zone initially distinguished by procambial strands, which is now of numerous interwoven bundles of fibre initials among which are scattered groups of sclereid initials. The operculum tissue similarly has abundant interwoven fibre initials and groups of sclereid initials.

Teichman (1986) concluded that mesocarp development followed the differentiation and lignification of the endocarp, a process completed well before the seed within reaches full size. Wannan & Quinn (1990) question this view, however, arguing that the outermost part of the pericarp zone, treated by Teichman as endocarp tissue, should be referred to the mesocarp. When the fruits are 30 mm x 20 mm, the mesocarp is readily recognizable as several layers of radially elongated mesocarp initials.

By the time of normal abscission, the epidermal cells of the exocarp have lengthened and most epidermal cell walls have been heavily cutinized, and the subepidermal cells have become collenchymatous. The mesocarp parenchyma has elongated further, as have the radial secretory cavities. At the interface of this parenchyma with the endocarp is a zone of isodiametric sclereids. In total, the time of development after fertilization to maturity of fruit is 2-5 months, depending on moisture and temperature.

3.4 ECOPHYSIOLOGY

In view of the wide range and significance as a useful plant, remarkably little attention has been given to the physiology of *Sclerocarya birrea*. Even assessment of characteristics allowing allocation to functional species groups on anything more than an informal basis has been neglected. Nevertheless, the ability of *Sclerocarya birrea* to thrive under seasonally and periodically intensely dry conditions has drawn the attention of various researchers.

An attempt to quantify assimilation rate and leaf conductance for young nursery-grown seedlings of subsp. *caffra* was made at Chiredzi, Zimbabwe, for the purpose of comparison with the primary target species, *Ziziphus mauritiana*, using conventional leaf chambers (Clifford *et al.*, 1997). Under demanding high irradiance conditions (photosynthetically active radiation >1500 μmol m^{-2} s^{-1}), and at temperatures around 40°C and at vapour pressure deficit of around 5.3 kPa, leaf assimilation was 10.9 μmol CO_2 m^{-2} s^{-1} and leaf conductance 0.26 mol m^{-2} s^{-1}.

Jackson (1973) devised a scheme for determining a moisture index applying to subsp. *birrea* in Nigeria, based on a score reflecting the range of climatic zones where the tree grows and a score reflecting the habitats occupied. The two scores were summed to produce an overall moisture index. The index value determined was 8.2 (climatic score, 3.5; habitat score 4.7) which, being <8.5 identifies subsp. *birrea* as a dry savanna species – this equates to being a characteristic floristic element of the Sudanian centre of endemism (Chapter 2). The climatic score underlines association (in the Nigeria context) with dry climates; the habitat score indicates occupation of mesic, rather than edaphically dry, sites in the landscape.

Species that typify the drier north of Senegal, under mean annual rainfall <600 mm, are compared by Poupon (1980) in terms of foliage characteristics: development of surface area, degree of sclerophylly and degree of succulence. For subsp. *birrea*, development of surface area (0.69 cm^2 of foliage surface area per cg of foliage weight at saturation) signified a marginally xerophytic character. The degree of sclerophylly (0.41 cg of dry matter per cm^2 of foliage surface area) conforms to subsp. *birrea* being semi-sclerophyllous although other work in the area has suggested a lesser tendency towards sclerophylly, with a value of only 0.20 (Houérou, 1989). The degree of succulence (1.06 cg of water held per cm^2 of foliage surface area, when leaf is saturated) is relatively low and insufficient for subsp. *birrea* to be rated as even semi-succulent.

Sclerocarya birrea subsp. *birrea* appears well able to survive and form populations in dry conditions. Seghieri *et al.* (1995) identify the tree as "arido-active", adopting an expression coined by desert researchers to signify the ability of plant populations to remain metabolically active in the dry season. In the case of subsp. *birrea*, referral to this category was made because flowering was observed (Diamaré Plain, Cameroun, 1986-1987) to be a strictly dry season process. Seghieri's earlier work (Breman & Kessler, 1995) had already indicated leaf flushing in subsp. *birrea* as an indication of rising air humidity heralding the onset of the rainy season of north Cameroun. Rising air humidity, rather than rainfall, was concluded to trigger the flushing event.

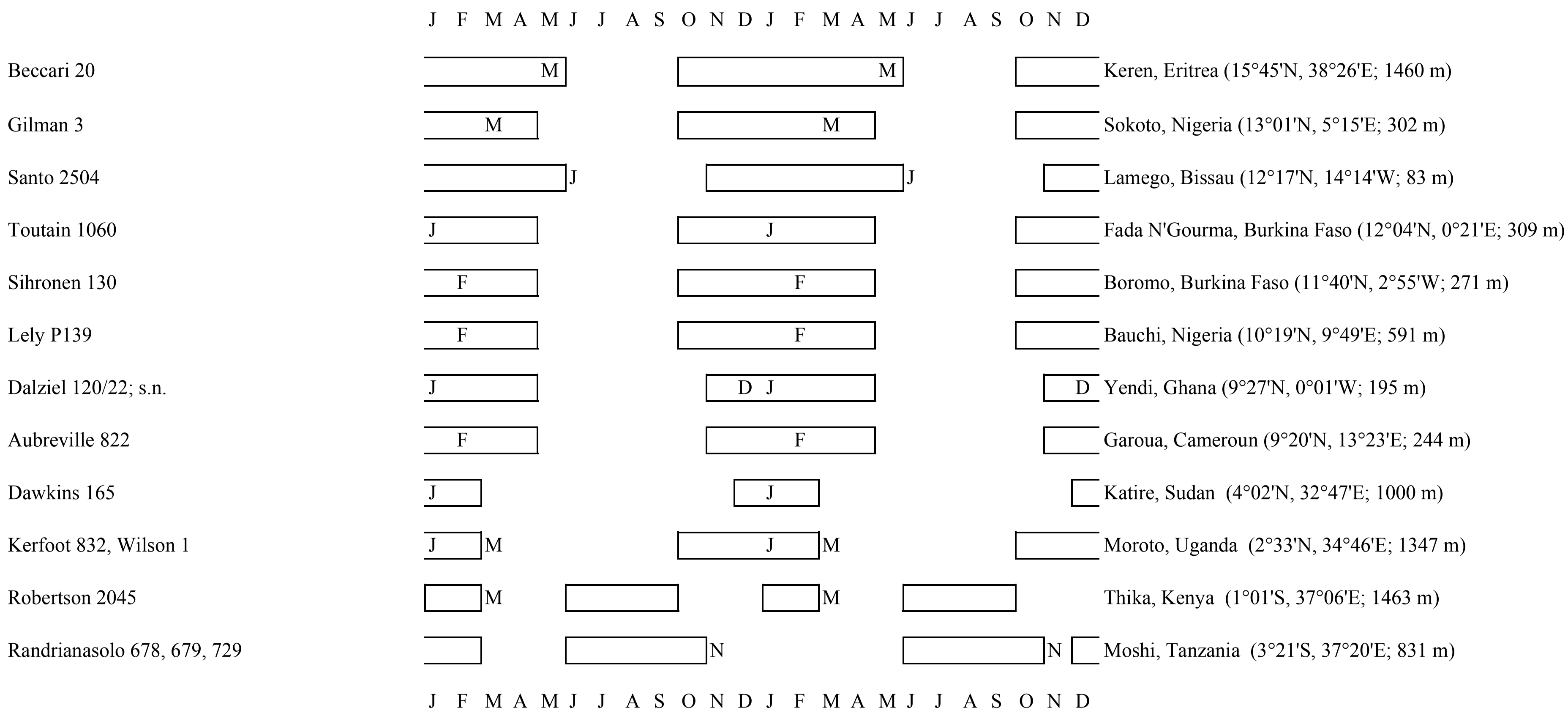


Figure 3.1. Flowering of *Sclerocarya birrea* subsp. *birrea* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when flowering was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence.

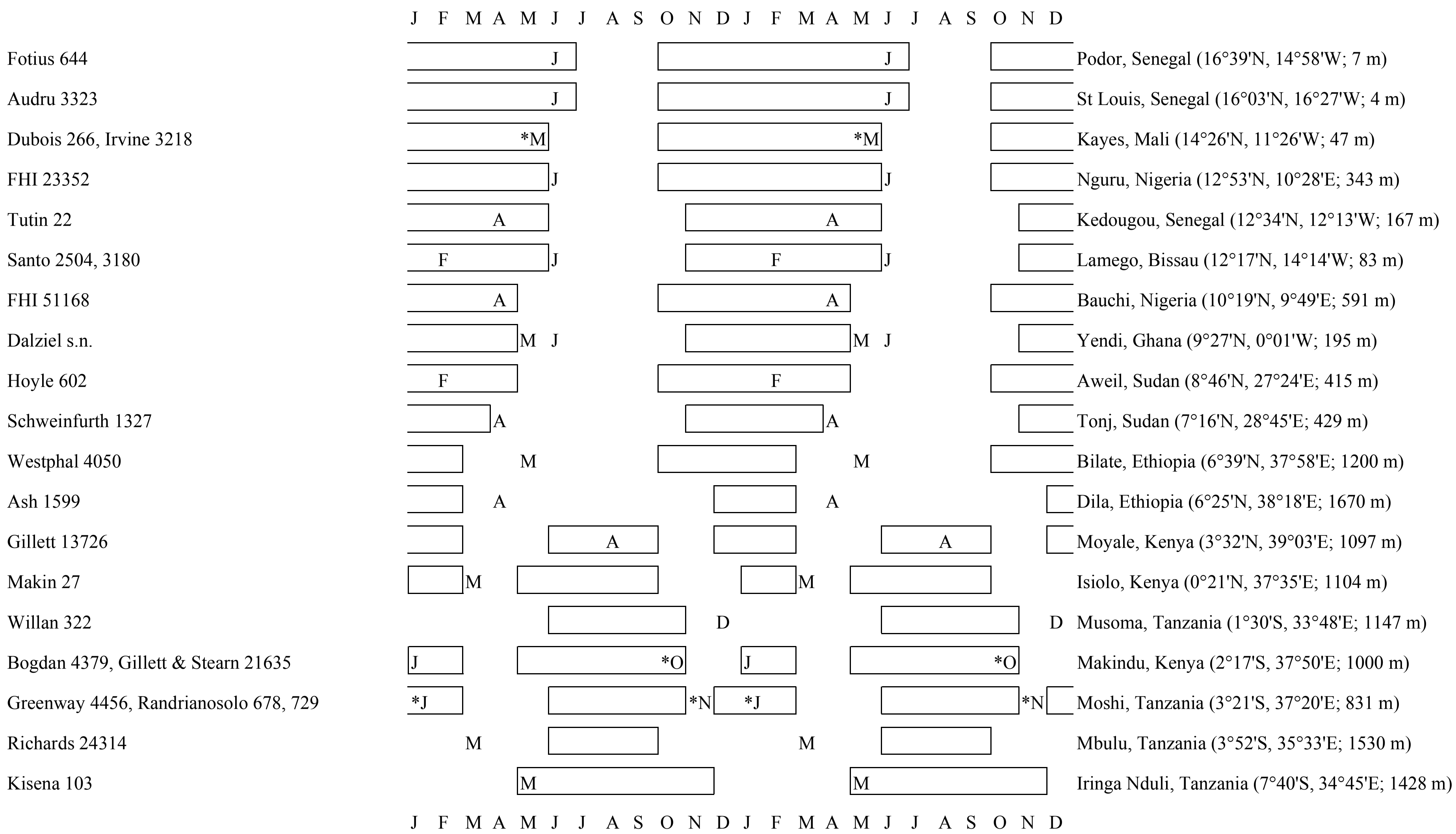


Figure 3.2. Fruiting of *Sclerocarya birrea* subsp. *birrea* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when fruiting was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence. *Recorded as young or developing fruits.

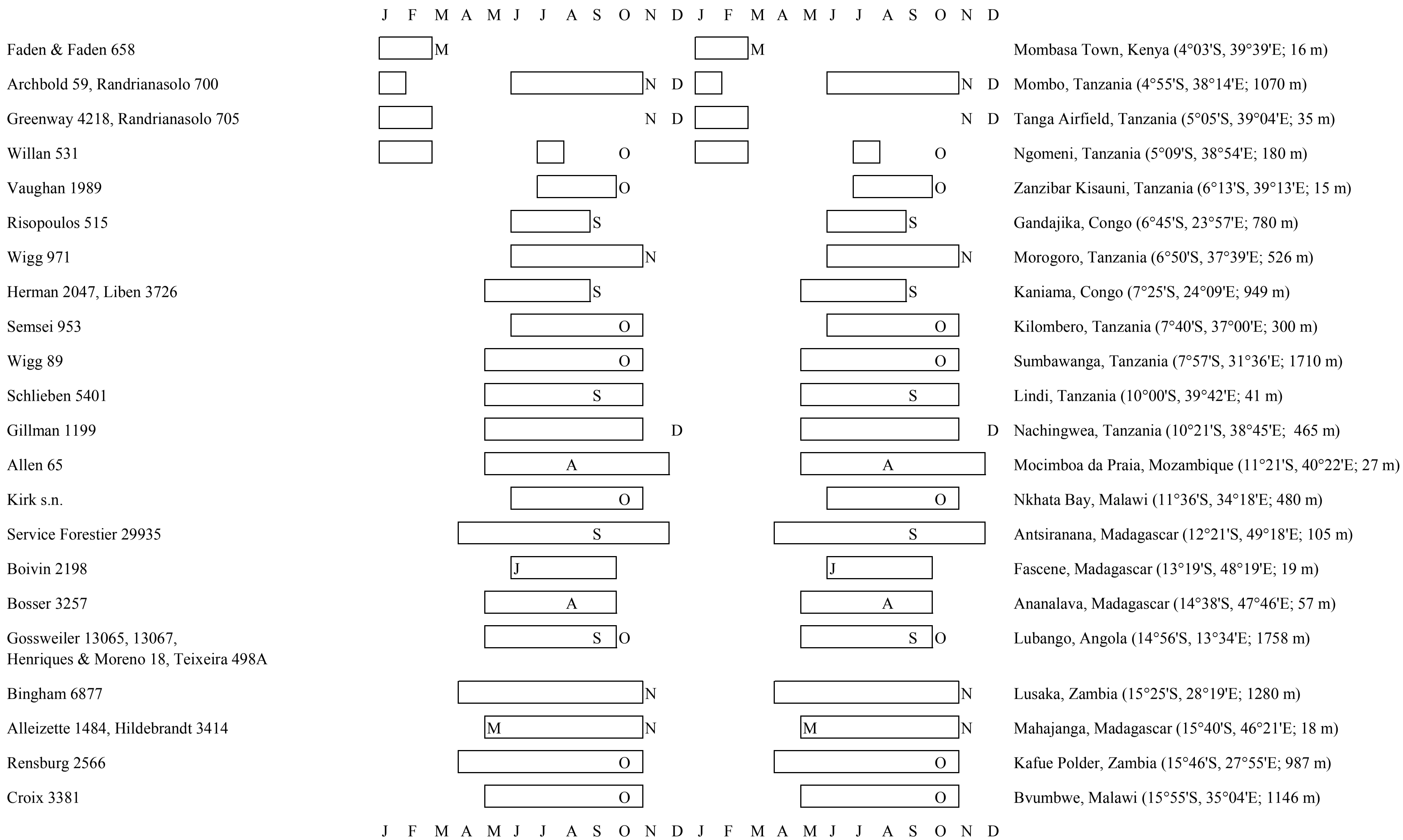


Figure 3.3. Flowering of *Sclerocarya birrea* subsp. *caffra* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when flowering was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence.

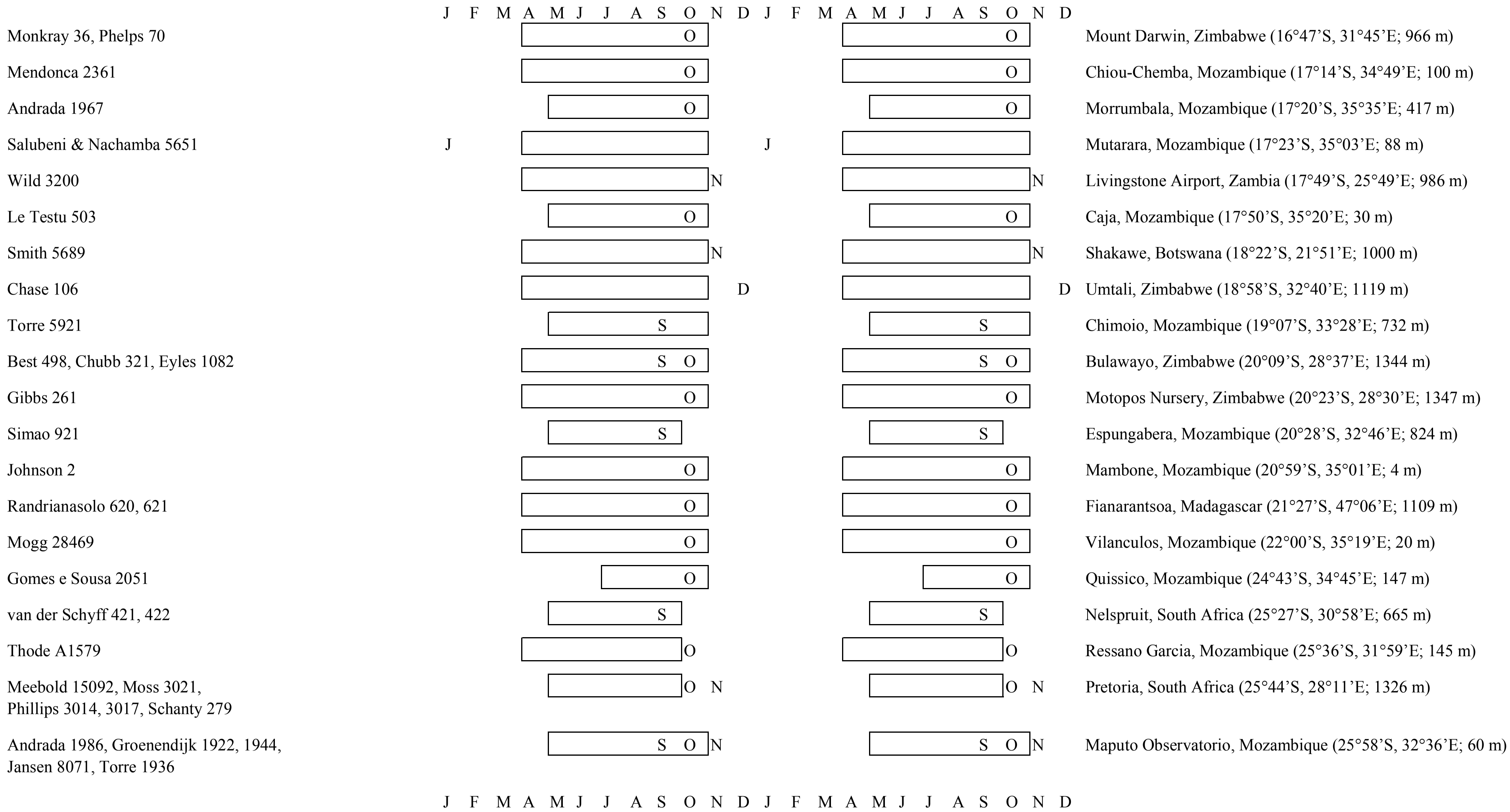


Figure 3.3 (continued). Flowering of *Sclerocarya birrea* subsp. *caffra* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when flowering was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence.

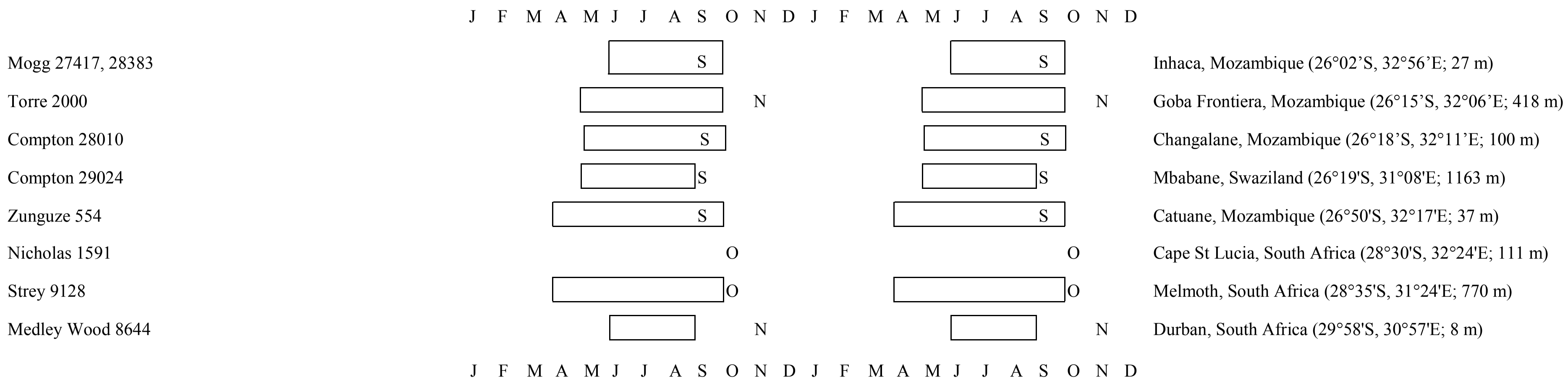


Figure 3.3 (continued). Flowering of *Sclerocarya birrea* subsp. *caffra* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when flowering was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence.

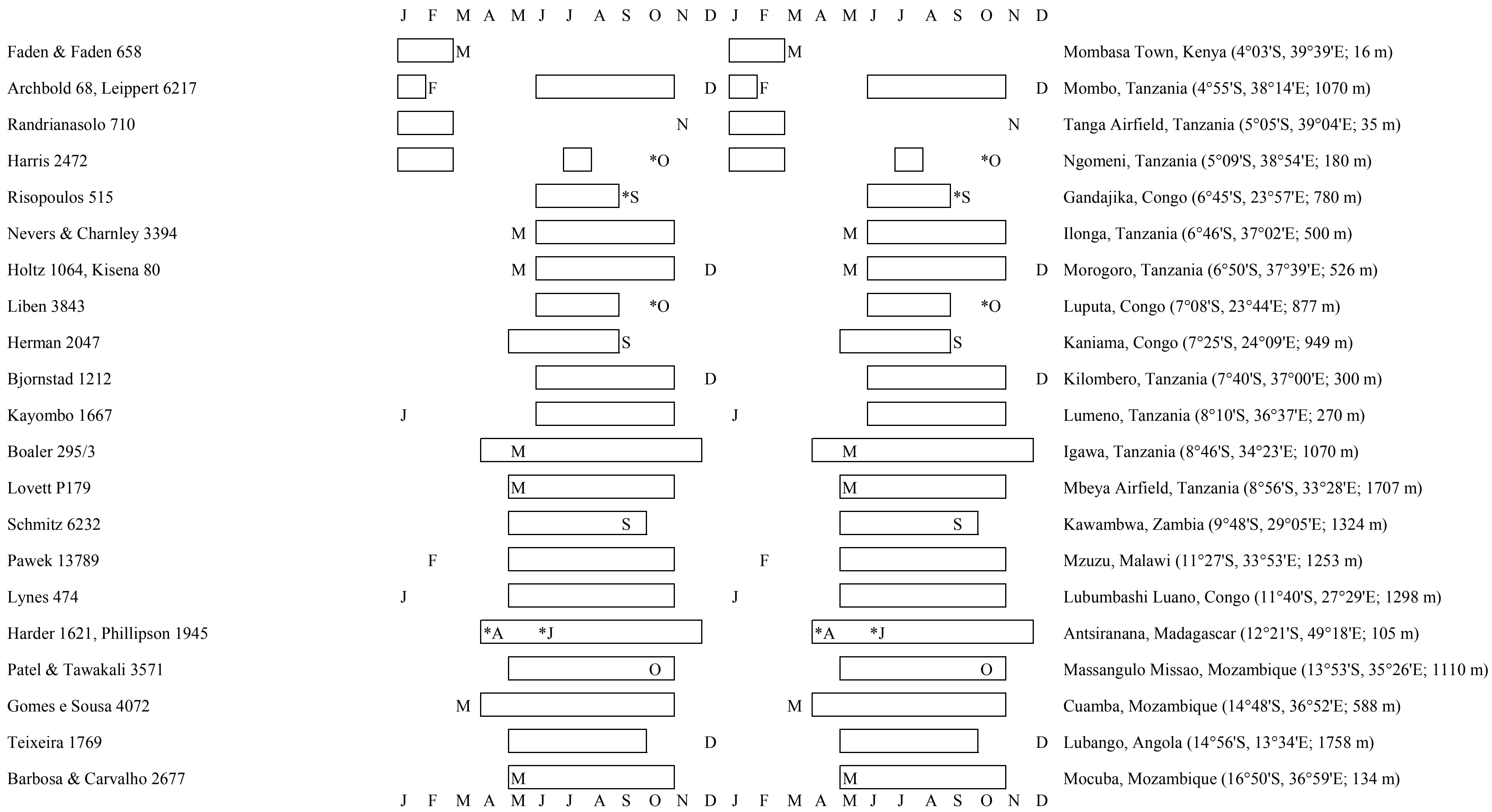


Figure 3.4. Fruiting of *Sclerocarya birrea* subsp. *caffra* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when fruiting was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence. *Recorded as young or developing fruits.

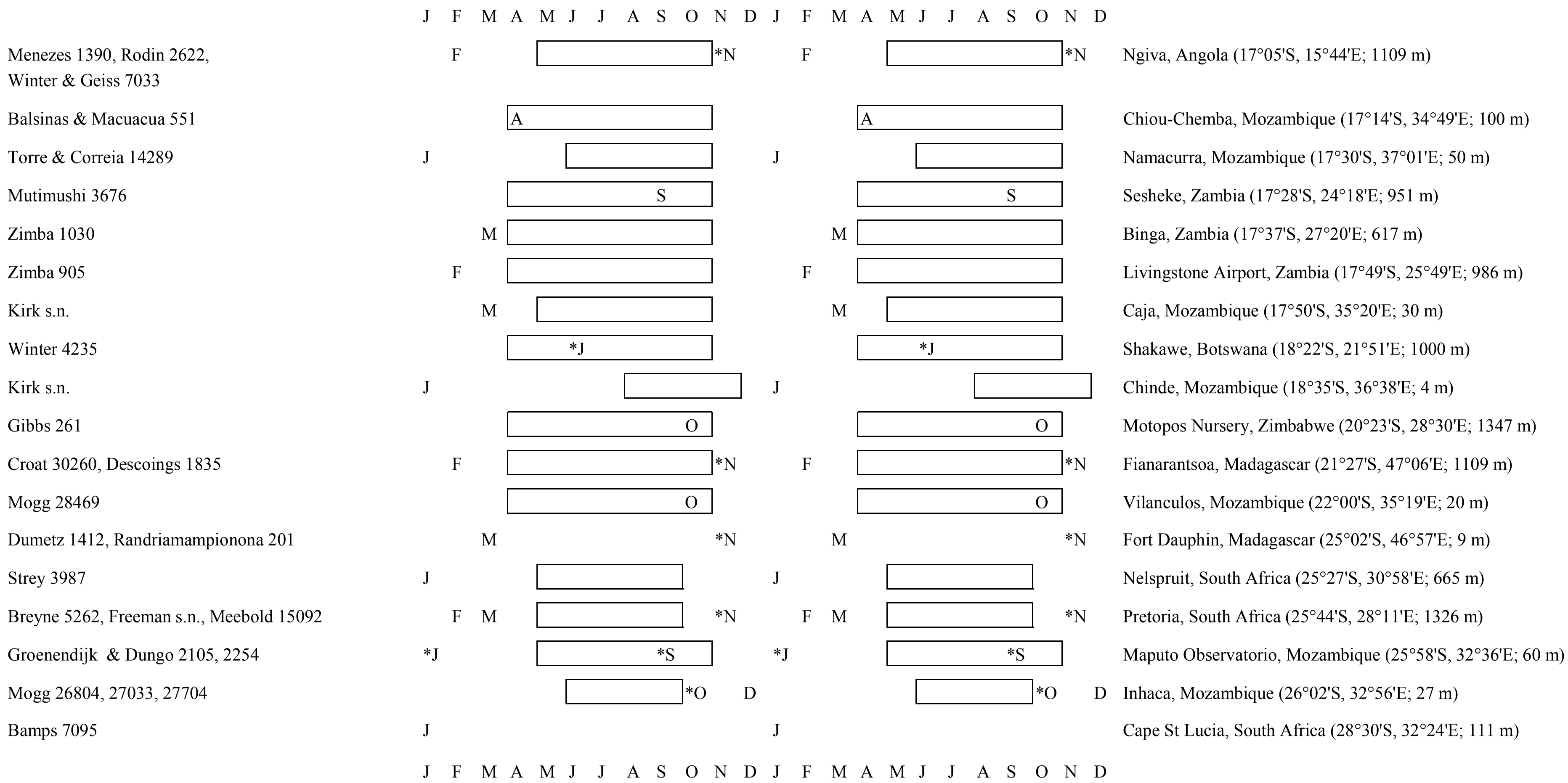


Figure 3.4 (continued). Fruiting of *Sclerocarya birrea* subsp. *caffra* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when fruiting was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence. *Recorded as young or developing fruits.

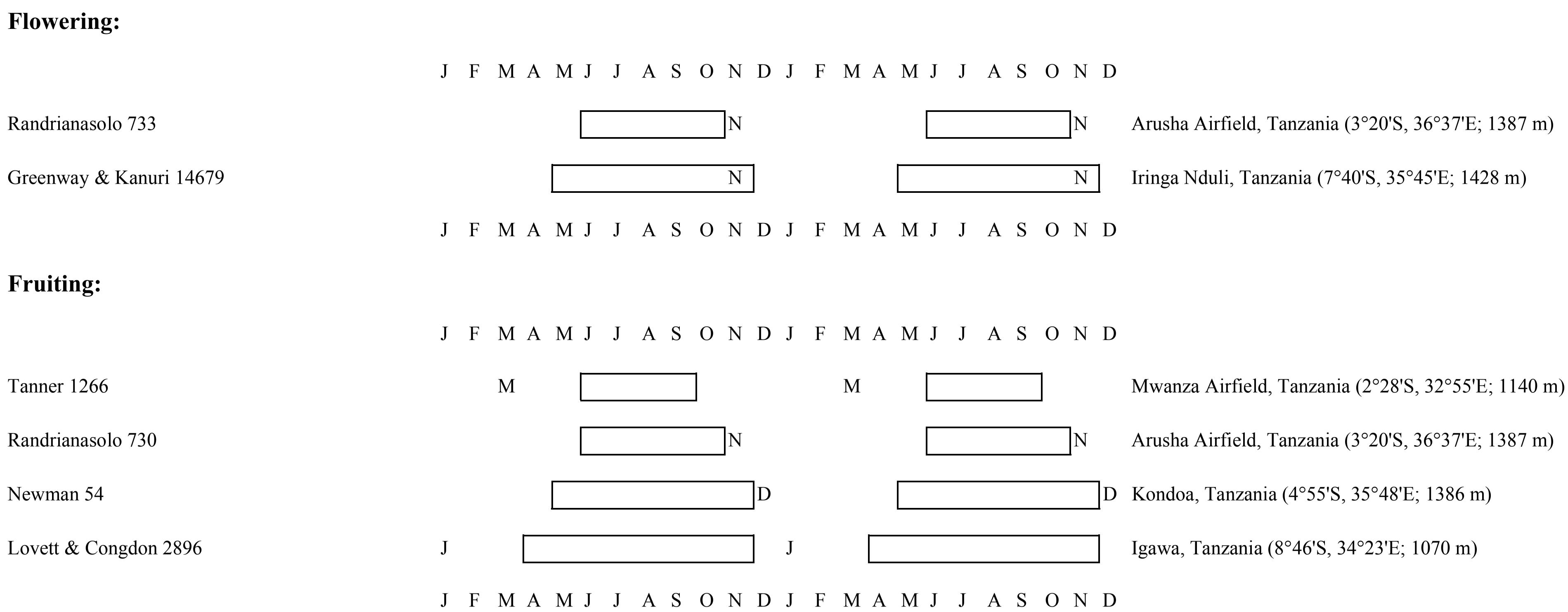


Figure 3.5. Flowering and fruiting of *Sclerocarya birrea* subsp. *multifoliolata* in relation to dry months (mean rainfall <50 mm). Records are associated with a meteorological station within 50 km and the sequences of dry months are enclosed by frames. Entries of initial letters of the month indicate when activity was recorded in each case. A 24-month cycle is adopted to emphasize climatic seasonality. Meteorological stations are presented in a north-south sequence.

4 FOOD SECURITY AND NUTRITION

Margaret K. Thiong'o and O.T. Edje

Sclerocarya birrea plays a very significant role in the diet and culture of people in many countries, especially in southern Africa. It is one of the four most important indigenous food plants in Swaziland (Dlamini, 1998; Anon., 2000).

4.1 FOOD SECURITY

Both the pulp and nut-like seed kernel of *Sclerocarya birrea* fruit are nutritious and commonly exploited wild food resources throughout large portions of Africa. Secondary food resources include edible caterpillars ('mopane worms') and wild, as well as domesticated, animals that feed on its leaves, and honey from bees nesting in its bark.

4.1.1 Fruit

Sclerocarya birrea is a prolific fruit producer, a single prolific tree providing in a heavy fruiting season between 21 000 and 91 000 fruits (Quin, 1959). The fruit is an egg-shaped or plum-like fleshy drupe 3 to 5 cm in diameter with a relatively tough, bitter-tasting, skin. Fruits drop off the tree when they are still green and ripen on the ground, making harvesting relatively easy. Ripe fruit can be eaten fresh, typically by biting or cutting through the thick skin and sucking the juice out or chewing the mucilaginous flesh after the skin is removed. The white juicy pulp is fleshy and fibrous and clings tightly to a single hard creamy-brown stone, making it difficult to separate them. The hard shell encasing the nut is usually cracked between two stones, anvil-and-hammer style, and the nuts picked from the debris and shell (Weinert *et al.*, 1990). A small piece of bone tool, fashioned to a special pattern, is sometimes used for extracting the nut from the opened shell (Shone, 1979).

Domestic animals such as cattle, goats and sheep are known to relish the fruit, especially during drought periods and because of this farmers construct fences around the tree to prevent cattle and goats from devouring the fruits (Shone, 1979). There is similar appeal to wild animals, especially elephants, monkeys and baboons.

4.1.1.1 Fruit pulp

The juice of ripe fruits is pleasantly acidic, slightly sour-tasting and refreshing. According to Wehmeyer (1976), its characteristically turpentine-mango-like flavour consists of about 150 flavour compounds and is known to vary from tree to tree, fruits from some being sweet, from some being dry, and from others being aromatic (Williamson, 1975; Arnold *et al.*, 1985).

The pulp is variable in its texture, ranging from fleshy and juicy to thick and grainy. It is eaten raw or boiled to a thick, black consistency and used for sweetening porridge. It makes an excellent conserve or jam and a delicious amber-coloured jelly. It is also used for making beer or wine, as well as a non-alcoholic juice.

Ripe sweet fruits are used to brew beer. In Swaziland, this is called marula, manganu, baganu, or emaganu, and is so popular that there is an Annual Marula Festival celebrated at the Royal Residence of the King at Ebuhieni in Hhohho Region of Swaziland between February and March. Both the King and the Queen Mother are presented with marula beer from each household, in keeping with it being a 'fruit fit for kings' (Nhleko, 1996). Only afterwards can Swazis drink the beer. The Tonga people pour offerings of fresh beer over the tombs of their dead chiefs (Vilakati, 2001). The traditional local brewing of marula beer in Swaziland is usually done by the women. *Sclerocarya birrea* fruits, still green, that have fallen to the ground, are collected and kept in a cool place covered with dry grass or a sack, until they turn yellow with soft brown spots to facilitate piercing. The fruits are then washed in tap water. The fruits are pierced with a sharp object like a thorn, stone or teaspoon, then the skin is removed from the fruit and the pulp is put into a container of clean water. To about three parts of fruit pulp one part of water is added. Sugar, 1 kg per 25 litres of water, may be added. The skins are thrown away or fed to goats. A sack is placed over the mixture in the container and allowed to ferment for four to seven days, when it is considered mature. The majority of the women keep it for seven days. The average amount of fruit processed per day varies mainly from 30-50 kg but about a third of the women process more than 50 kg per day. After fermentation, a large wooden spoon or a special wooden device with four prongs at the end is used to stir the mixture to remove the kernels from the pulp. The resulting juice is allowed to ferment further. Fresh fruits may be added, pounded and this fresh unfermented juice mixed with fermented juice. The mixture is allowed to ferment for a day or so, then the floating materials are removed leaving beer of a light brown colour (Edje, 1996; Shongwe, 1996; Tiisekwa *et al.*, 1996; Mhlongo, 1997; Chengeta, 1998). It can be consumed shortly after brewing or can be stored underground in containers for about eight months. The brew can be highly intoxicating, being called 'Seven days' or 'Kick like horse' in Swaziland. If sugar is added periodically, a potent 'whiskey' develops.

Trees from drier environments have sweeter fruits than those from wetter areas (Leakey, 1999). Sour fruits are particularly good for juice making. The juice ferments naturally because of yeasts that occur naturally in the fruit. Even with fermentation, the level of vitamin C in the juice remains fairly constant as N. Ngwenya-Dlamini & L. Ndlovu (pers. comm.) report. Sweet fruits are also fermented and distilled commercially to make 'Amarula Cream®', a liqueur similar to 'Bailey's Irish Cream' that is commercially produced in South Africa and distributed internationally. Numerous small enterprises produce 'marula' jam and jelly. Pasteurised juice has been marketed in Botswana (Taylor & Kwerepe, 1995).

4.1.1.2 Kernels

Two or three kernels 1 to 1.5 cm in length are encased in each hard, light brown, smooth oval-shaped stone. These kernels ('nuts') can be eaten raw or roasted, have a delicious taste, and are regarded by many indigenous people as a delicacy, a 'Food of Kings' (Wehmeyer, 1976). They are commonly used to supplement the diet during winter or drought periods, being pounded and mixed with vegetables or meat (Shone, 1979). In the extreme north-east of South Africa, in the past, the Venda have used them to prepare meat for storage, but this practice has possibly been discontinued (C. Shackleton, pers. comm.). After mixing pounded nuts with the meat, it is shaped into cakes. Dried and stored in a cool place, such meat is said to keep for up to a year (Shone, 1979; Peters, 1988). Wild animals such as baboons and squirrels are fond of the nuts. Baboons are said to break the hard stones with their jaws to access the nuts. The bush squirrel uses its sharp teeth to gnaw through the stone (Shone, 1979).

Kernels contain about 60% of a non-drying oil, which is rich in protein. This oil is used for cooking, as flavouring in porridge, and as a skin moisturiser, medicine and insecticide (Desert Research Foundation of Namibia, 1994). It is especially valued by the cosmetics industry due to its slow oxidizing properties. In Madagascar, the nuts are boiled until an oily residue, rich in protein and iodine, forms on the surface. This oil is used as moisturizer and is marketed commercially as 'Sokoa Oil'. It is being researched as a possible sunscreen for commercial marketing (Roodt, 1988).

4.1.2 Leaves and flowers

The tree provides important secondary food resources. Its many flowers provide nectar and honey bees build nests in the rotted out portions of the trunk. In spring, its leaves host edible caterpillars, such as the 'ombembo' (Luo) eaten in parts of western Kenya, and the 'Mopane worm' eaten in parts of southern Africa (Arum, 1990). Branches are lopped for animal fodder in times of drought, although the leaves are said to be slightly poisonous (Maydell, 1986). Otherwise, leaves are browsed as high as animals can reach, particularly by giraffe and kudu. Elephants are also fond of the bark and it is not unusual to find debarked trees in a park (Shone, 1979). Another contribution to fodder is the fact that buffalo grass, *Panicum maximum,* one of the most valuable fodder grasses, grows well under *Sclerocarya birrea*.

4.2 NUTRITIONAL STATUS

4.2.1 Flesh

The flesh has a high moisture content of 83-91.7%. It has an especially high vitamin C content, up to 400 mg/100 g fresh matter (Eromosele *et al.,* 1991; Jaenicke & Thiong'o, 2000), which is several times that of citrus. This makes the fruits an important nutritional component in the local diet (Table 4.1). Indeed, in 1937, an outbreak of scurvy due to a severe drought in the Letaba district in South Africa was relieved as soon as the affected population could again obtain fruit and produce marula beer (Shone, 1979). Poor people also consume the fresh fruits to prevent common colds (Arnold *et al.,* 1985; Erkkila & Siskonen, 1992). Sugar levels range between 7% and 16% sucrose (Taylor & Kwerepe, 1995; Jaenicke & Thiong'o, 2000). Carbohydrate in the flesh consists mainly of sucrose, with smaller quantities of glucose and fructose. Excluding ascorbic acid, citric acid is the most abundant of the organic acids (Weinert *et al*., 1990).

4.2.2 Kernel

4.2.2.1 Proximate fractions and vitamin and mineral content

The kernels have a low moisture content, and high fat, protein and mineral contents (Table 4.1). They are highly nutritious with 27-32% protein, 2.02% citric acid, malic acid, sugar, phosphorus, magnesium, copper, zinc, thiamine and nicotinic acid. Protein levels of 54-70% have been reported for de-fatted nuts (Burger *et al.,* 1987).

4.2.2.2 Amino acids

The essential amino acid content of the marula nut (Table 4.2), with the exception of lysine, which is deficient, has been likened to human milk and whole hen's eggs (Weinert *et al.*, 1990). Due to the small amounts of lysine (in comparison to other nuts), the marula nut would not be suitable to supplement cereal diets which normally lack lysine. Levels are also low for alanine, aspartic acid, leucine, phenylalanine, praline and tyrosine but it is rich in glutamic acid, at about 24 g/100 g protein, and arginine (Busson, 1965; Burger *et al.,* 1987).

4.2.3 Kernel oil

4.2.3.1 Physicochemical characteristics

Marula oil has been successfully refined at both bench and commercial scales. The extracted unrefined oil has a clear, light yellow colour and is suitable for soap manufacture and edible use (Shone, 1979; Ogbobe, 1992). The specific gravity and the saponification value (Table 4.3) are comparable to those of olive oil. The iodine value is also near to that of olive oil but is, nevertheless, relatively low compared to sunflower oil (Weinert *et al.,* 1990). The oxidative stability of marula oil is thought to explain its successful utilization in traditional meat preservation processes (Shackleton *et al*., 2002). However, as a source of vitamin E, the oil is of poor quality, containing only some 23 mg/100 g of tocopherols, little of this being α-tocopherol (Burger *et al.*, 1987).

Table 4.1. Nutritional composition of pulp and kernel

Plant part	energy (kJ/100 g dry weight)	water (%)	protein (%)	fibre (%)	fat (%)	total CHO (%)	ash (%)	Vit C (mg/100 g fresh flesh)	Thiamin (mg/100 g)	Riboflavin (mg/100 g)	Niacin/Nicotinic Acid (mg/100 g)	Ca (mg/100 g)	Co (mg/100 g)	Cu (mg/100 g)	Fe (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	Mn (mg/100 g)	Na (mg/100 g)	P (mg/100 g)	Si (mg/100 g)	Zn (mg/100 g)		Reference
flesh	225*	85	3.3	8	2.7	80	6	194	0.03	0.02	0.27	20.1	-	0.07	0.5	317	25.3	-	2.24	11.5	-	0.1	*caffra*	Arnold *et al.* (1985) : Botswana/Namibia
kernel	2703	4	29.5	3	59.7	3.9	4	-	0.42	0.12	0.72	118	-	2.81	4.87	601	462	-	3.81	808	-	5.19	*caffra*	Arnold *et al.* (1985): Botswana/Namibia
kernel	-	3.7	30.6	3.8	61.5	1.3	6.1	-	-	-	-	170	-	-	-	-	-	-	-	1040	-	-	*birrea*	Busson (1986): Côte d'Ivoire
flesh	-	86-87	-	-	-	-	-	53-179	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*caffra*	Carr (1957): Zimbabwe
flesh	-	-	-	-	-	-	-	403	-	-	-	36.2	0.13	0.1	1.12	-	31.9	0.11	-	18	-	0.34	*birrea*	Eromosele *et al.* (1991): Nigeria
kernel	-	3.9	28.7	4.7	58.5	3.9	4.3	-	-	-	-	161	-	-	-	-	-	-	-	1907	-	-	*caffra*	Ferrão & Xabregas (1960): Angola
flesh	-	-	-	-	-	-	-	-	-	-	-	481	-	-	2.49	-	310	-	15.2	264	-	-	*birrea*	Glew et al. (1997): Burkina Faso
kernel	-	-	-	-	-	-	-	-	-	-	-	156	-	-	2.78	-	193	-	11.9	212	-	2.65	*birrea*	Glew *et al.* (1997): Burkina Faso
flesh			6.9	9.2	6.6	68.5	8.8					800	-			2700	400			200	400		*birrea*	Houérou (1980): Senegal
kernel	-	4.6	30.4	-	57	-	-	-	-	-	-	150	-	1.97	5.23	555	355	0.5	-	761	-	5.72		Jaenicke & Thiong'o (2000): Kenya
flesh	1461*	83	4.2	9.1	10.1	70	6.6	-	-	-	-	250	-	-	40	-	-	-	-	225	-	-	*caffra*	Malaisse & Parent (1985): Democratic Republic of Congo
flesh	-	-	-	-	-	-	-	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*caffra*	Maghembe et al. (1994) : Zambia
kernel	-	-	23-31	-	56-61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*caffra*	Maghembe et al. (1994): Zambia
kernel	2447	0	31.2	4	53.1	8.2	3.5	-	-	-	-	80	-	-	60	-	-	-	-	1600	-	-	*caffra*	Malaisse & Parent (1985): Democratic Republic of Congo
kernel	2700	3.9	27	3.6	58.9	5.9	3.6	-	0.43	0.12	0.72	130	3.6	-	9.3	525	457	-	4.2	779	-	4.9	*caffra*	National Food Research Institute (1972): South Africa
kernel	-	9	30.3	3.1	59.7	5.8	4.1	-		0.2	0.74	93	8.1	-	4.4	675	329	-	81	774	-	2.9	*caffra*	Oliveira (1974): Mozambique

Table 4.1 (continued). Nutritional composition of pulp and kernel

Plant part	energy (kJ/100 g dry weight)	water (%)	protein (%)	fibre (%)	fat (%)	total CHO (%)	ash (%)	Vit C (mg/100 g fresh flesh)	Thiamin (mg/100 g)	Riboflavin (mg/100 g)	Niacin/Nicotinic Acid (mg/100 g)	Ca (mg/100 g)	Co (mg/100 g)	Cu (mg/100 g)	Fe (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	Mn (mg/100 g)	Na (mg/100 g)	P (mg/100 g)	Si (mg/100 g)	Zn (mg/100 g)		Reference
flesh	-	-	-	-	-	-	-	-	-	-	-	-	tr	-	0.06	-	1.4	tr	-	-	-	0.1	*birrea*	Smith *et al.* (1996) : Burkina Faso/Niger
kernel	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	0.02	-	1.2	0.01	-	-	-	0.1	*birrea*	Smith *et al.* (1996) : Burkina Faso/Niger
flesh	130*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*caffra*	Teichman (1983) : South Africa
flesh	-	91.7	6	6	1.2	84.3	2.4	67.9	0.03	0.05	0.25	6.2	-	0.04	0.1	54.8	10.5	-	tr	8.7	-	-	*caffra*	Wehmeyer (1966): Botswana
kernel	-	4	32.2	2.5	59.4	1.6	4.4	-	0.04	0.12	0.71	106	-	1.99	0.42	677	467	-	338	836	-	-	*caffra*	Wehmeyer (1966): Botswana

*, the two low values are assumed to be for 100 g fresh pulp and the high value for 100 g pulp on a dry weight basis; tr, trace quantity; -, no value reported

Table 4.2. Amino acid composition of *Sclerocarya birrea* kernel meal, kernels and, for comparison, fruit flesh (g/100 g protein)

	Kernel meal (Southern Africa) Burger *et al.* (1987)*	Kernel (Angola) Ferrão & Xabregas (1960)	Kernel (Mozambique) Oliveira (1974)	Kernel (Ivory Coast) Busson (1965)	Kernel (Burkina Faso) Glew *et al.* (1997)	Fruit flesh (Burkina Faso) Glew *et al.* (1997)
Alanine	2.7±0.38			3.2		
Arginine	14.2±2.03	14.15		15.8		
Aspartic acid	6.4±0.75			7.9		
Cystine			2.30		3.48	2.69
Cystine (half)	1.6±0.34					
Glutamic acid	23.2±3.46			25.8		
Glycine	4.2±0.57			5.0		
Histidine	2.5±0.23	2.28		2.4		
Isoleucine	3.2±0.37	5.47	5.03	4.0	4.52	5.08
Leucine	5.0±0.54	4.74	5.58	5.9	6.75	7.61
Lysine	1.6±0.09	1.81	2.43	1.9	2.30	4.36
Methionine	1.5±0.26	2.28	1.89	1.6	1.21	1.42
Phenylalanine	3.5±0.37	3.37	4.72	4.8	4.23	4.44
Proline	2.1±0.35			3.3		
Serine	3.8±0.38			4.4		
Threonine	1.8±0.19	1.38	2.09	2.3		
Tryptophan		2.64	1.31		1.48	1.44
Tyrosine	2.6±0.30		2.30	3.5	2.63	3.67
Valine	3.9±0.43	12.42	6.52	4.8	5.41	6.03

*, mean ± standard deviation

Table 4.3. Physicochemical characteristics of *Sclerocarya birrea* kernel oil

Assay	Shone (1979) South Africa	Ligthelm *et al.* (1951) Southern Africa	Shackleton *et al.* (2001) Southern Africa	Weinert *et al.* (1990) Sudan	Ogbobe (1992) Nigeria
Melting point (°C)	25				26-28
Refractive index	1.46	1.46		1.46	1.46
Specific gravity (15°C)	0.92	0.91			0.88
Acid value	3.7	14.8		1.3	33.7
Peroxide value			0		4.58
Saponification value	193.5	190.0	191	199.8	162.7
Hydroxyl value				2.6	
Iodine value	76.6	74.4	70-80	65.7	100.25
Unsaponifiable matter (%)	0.6	2.4		0.82	3.06
Sterols (mg/100 g)		900		410	

4.2.3.2 Fatty acids

The oil content (53-61% of the kernel by weight) has (Table 4.4) a very good dietetic ratio of saturated (palmitic and stearic) to unsaturated (linoleic and oleic) fatty acids (Weinert *et al.*, 1990; M.K. Thiong'o, pers. comm.). The fatty acid profile is similar to that of olive oil, but with a stability that is ten times greater. It has a high mono-unsaturated content (C 18:1 – 66-74%) suggesting a good oxidative stability. Its exceptional stability has been attributed to its fatty acid composition (high oleic acid content) as it has a relatively low total tocopherol content, an average of 22 mg to 27 mg per 100 g oil, and low β-tocopherol in particular – 0.04-0.06 mg per 100 g oil (Burger *et al.*, 1987; Weinert *et al.,* 1990). Recently, however, this explanation has been challenged (Shackleton *et al.*, 2001) and the action of some minor oil components suggested as an alternative.

Table 4.4. Principal fatty acids of *Sclerocarya birrea* fruit flesh, kernel, kernel oil, and olive oil

	Flesh	**Kernel**		**Kernel oil** (g/100g fatty acid)				**Olive oil**
	Glew *et al.* (1997)*	Glew *et al.* (1997)**	Busson (1965)	Ligthelm *et al.* (1951)	Shone (1979)	Burger *et al.* (1987)	Thiong'o *et al.* (unpublished)	
C16:0 (palmitic)	43.0	19.7	17.4	16.1	12.0	11.2-15.3	12.7-14.7	9.4
C18:0 (stearic)	4.8	0.4	8.7	5.1	9.2	5.9-6.9	trace-3.0	2.8
C18:1 (oleic)	4.0	60.0	63.9	66.7	69.9	70.4-74.3	64.3-71.2	76.3
C18:2 (linoleic)	15.6	4.4	3.9	7.3	7.8	4.7-9.2	12.1-13.9	8.0
C18:3 (linolenic)	20.9	0.3	1.7	trace	-	0.1	trace-0.2	0.6

*, total lipid content 13.5% dry weight; **, total lipid content 19.5% dry weight; -, no value given

4.2.4 Beer from the fruit pulp

Investigation into the quality of traditional beer brewed in Swaziland, including marula beer was undertaken by Shongwe (1996). He reported that the quality of marula beer was comparable to that of some commercial beer. Marula beer was nutritious and not as intoxicating as other beers (Table 4.5) but methanol, a poisonous alcohol, is found in some locally brewed marula beer (Tiisekwa *et al.,* 1996).

Table 4.5. Composition of marula beer

Parameter	**Values**
pH	3.6
Total titrable acidity (g/100 g)	1.1
Fixed acidity (g/100 g)	0.1
Volatile acidity (g/100 g)	0.9
Total soluble solids (%)	9.0
Total solids (%)	7.6
Ash (%)	0.4
Alcohol content (% v/v)	5.8
Carbohydrate (%)	10.0
Crude protein (% per litre)	2.6
Presence of bacteria	Formed

Source: Shongwe (1996)

Tiisekwa *et al.* (1996), using experienced brewers, simulated traditional marula wine production under "controlled" laboratory conditions. They found ethanol to be the main fermentable product (Table 4.6). The ethanol concentration of 6% is lower than that in commercial wine (11-12%), but comparable with ciders and slightly higher than in beers (*ca* 4.4%). The concentration varies depending on the brewing technique. Tiisekwa (1996) reported a slightly lower value (5.8% v/v alcohol) for one sample.

Table 4.6. Concentrations of mineral elements and fermentation products of home-made marula wine

Element/product	**Concentration**
Methanol	Below detection
Ethanol (% v/v)	6.0 ± 1
Ethyl acetate	Below detection
N-propanol	Below detection
Acetaldehyde	Below detection
Cadmium	Below detection
Zinc (ppm)	27 ± 2
Manganese (ppm)	16 ± 2
Iron (ppm)	50 ± 3
Lead (ppm)	140 ± 10

Source: Tiisekwa *et al.* (1996)

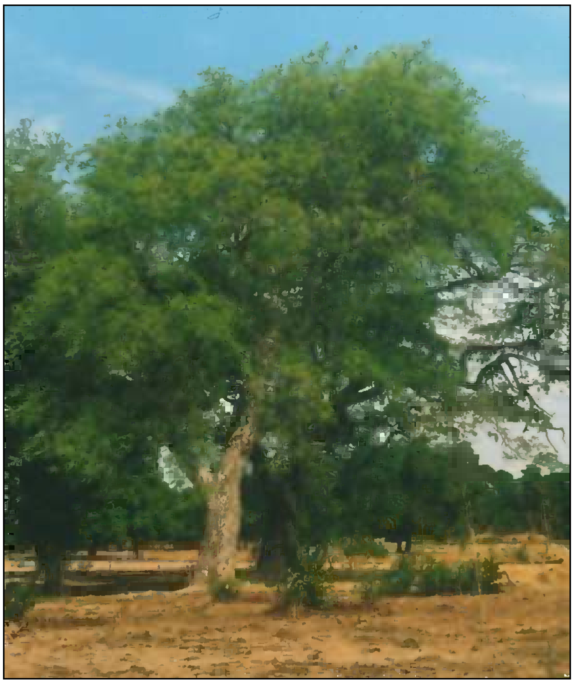


Plate 1 Plate 2

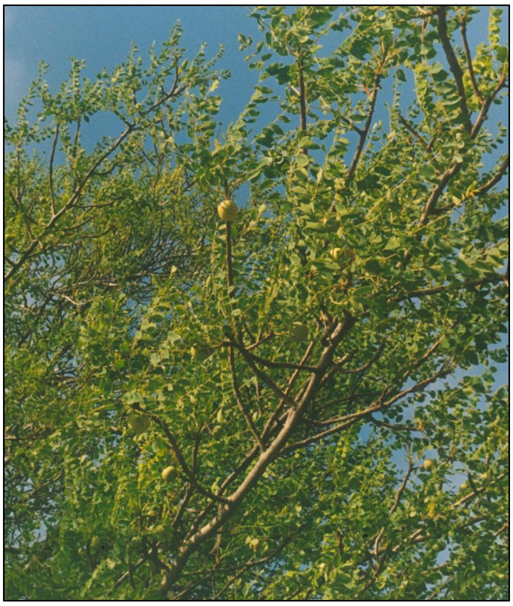


Plate 3 Plate 4

Plate 1. *Sclerocarya birrea* subsp. *birrea*: mature female tree in full leaf retained in farmland at Saponé, Burkina Faso in June (J B Hall)

Plate 2. *Sclerocarya birrea* subsp. *caffra*: leafless protected area tree during dormant season – Kruger National Park, South Africa in May (F L Sinclair)

Plate 3. *Sclerocarya birrea* subsp. *caffra*: bole – Nylsvley, South Africa (F L Sinclair)

Plate 4. *Sclerocarya birrea* subsp. *birrea*: fruiting branch - Saponé, Burkina Faso in June (J B Hall)

Plate 5

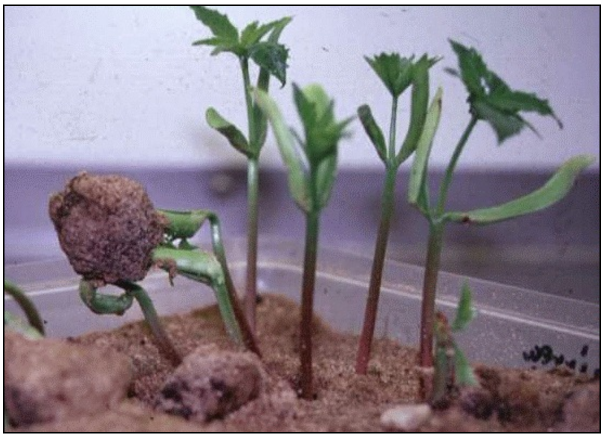


Plate 6

Plate 7

Plate 8

Plate 5 . *Sclerocarya birrea* subsp. *caffra*: two endocarps, the one on the left shows an operculum; the one on the right is covered by adherent mesocarp remnants – source Kitulanghalo Forest Reserve, Tanzania. The diameter of the coin is 22 mm (J B Hall)

Plate 6. *Sclerocarya birrea* subsp. *birrea*: recently germinated plants - Kenya. Two seeds in the endocarp on the left have germinated, their cotyledons remaining partly within it; the extending hypocotyls have lifted the endocarp shell off the substrate. Seedlings to the right show the elongated cotyledons after separation from the endocarp (M Munjuga)

Plate 7. *Sclerocarya birrea* subsp. *caffra*: young sapling – Kitulanghalo Forest Reserve, Tanzania (J B Hall)

Plate 8. *Sclerocarya birrea* subsp. *caffra*: juvenile foliage with leaflets having serrate margins – Kitulanghalo Forest Reserve, Tanzania (J B Hall)

Plate 9

Plate 10

Plate 11

Plate 12

Plate 9. *Sclerocarya birrea* subsp. *caffra*: amassed freshly fallen greenish fruits – South Africa (C Geldenhuys)

Plate 10. *Sclerocarya birrea* subsp. *birrea*: fallen fruits which have turned from green to yellow on the ground – farmland tree near Nobéré, Burkina Faso in June. The diameter of the coin is 26 mm (J B Hall)

Plate 11. *Sclerocarya birrea* subsp. *caffra*: separation of fruit skins from pulp and endocarp (M Mujunga)

Plate 12. *Sclerocarya birrea* subsp. *caffra*: use of a fork to peel fruits - South Africa (C Geldenhuys)

Plate 13

Plate 14

Plate 15

Plate 16

Plate 13. *Sclerocarya birrea* subsp. *caffra*: extraction of kernels - Thulamahashe, South Africa (F L Sinclair)

Plate 14. *Sclerocarya birrea* subsp. *caffra*: extracted kernels, broken, intended for pressing for oil extraction – Mhala Development Centre, Thulamahashe, South Africa (F L Sinclair)

Plate 15. Press for extracting oil from kernel material – Mhala Development Centre, Thulamahashe, South Africa (F L Sinclair)

Plate 16. Body Shop make-up range containing marula oil - Body Shop, Llandudno, UK (F L Sinclair)

5 EMERGING PRODUCTS, POTENTIAL MARKETS

Kago Phofuetsile and E. M. O'Brien

Knowledge of or interest in *Sclerocarya* products is poor outside rural areas, and the infra-structure between growing and/or harvesting the raw produce and selling a finished product to a customer still needs to be developed. However, compared with other potential 'cash crops', converting farmers to *Sclerocarya* production should be relatively easy since it is always a source of food, increasing rather than reducing food security during famines and droughts. Given the demand, and regardless of marketing chain, harvesting of required raw resources from 'domesticated' farm-, compound- or plantation-grown *Sclerocarya* would be economically beneficial to the owners. Moreover, harvesting of wild resources opens up potential 'cash crop' niches for children, hunter-gatherers, pastoralists and semi-horticulturalists.

There is, understandably, limited information in the public domain concerning the commercial initiatives with *Sclerocarya* that are currently being explored. Nevertheless, enough information is available to confirm that there is extensive active interest in the species, much of which arises from its proven dietary significance and long-standing traditional role in southern Africa. A noteworthy and positive aspect of several recent initiatives is application of 'fair trade' principles to business arrangements with communities supplying raw materials, the traditional custodians of the resource.

5.1 THE OVERALL PICTURE

Traditional uses for *Sclerocarya birrea* belong primarily to the household, not the marketplace. They are evaluated herein in terms of emerging or potential products and markets (Table 5.1). Given the ubiquity of *Sclerocarya*, the 'local' market is probably a poor one to pursue. Exceptions include products linked to local tourist spots, such as national parks, and mass religious or festive activities (*e.g.* marula beer) or to traditional products not produced within the household but by a specialist (*e.g.* medicinals, honey). For the most part, all potential markets exist, but without a developed niche for *Sclerocarya* products.

5.2 FLAVOUR IN *SCLEROCARYA BIRREA* SUBSP. *CAFFRA*

Commercial interest in food and beverage products with *Sclerocarya birrea* as an ingredient is largely based on exploiting the distinctive flavour. This may be associated with bulk *Sclerocarya birrea* material (as in puree or jam) ar with an added flavouring concentrate – as with biscuits. Publications by Ballschmeiter & Torline (1973), Pretorius *et al.* (1985) and Schäfer & McGill (1986) are concerned with the characteristic flavour of *Sclerocarya birrea* subsp. *caffra* fruit. Weinert *et al.* (1990) summarizes the findings of the first two of these studies. No studies on this topic relating to subsp. *birrea* have been seen.

Many volatile components have been detected through analysis of aqueous condensates or carbon absorption after vacuum stripping of fruit skins (Ballschmeiter & Torline, 1973) or liquid (juice of subsp. *caffra*) to liquid (trichlorofluoromethane/dichloromethane) extraction (Pretorius *et al.*, 1985). Ballschmeiter & Torline (1973), apparently from a single test sample, draw attention to 12 sesquiterpene hydrocarbons (including caryophyllene, α-humulene and copaene) as the dominant volatiles when fruit skins were vacuum stripped. After carbon absorption, these workers detected over 100 volatile components, in all, including the 39 listed in Table 5.2.

Sesquiterpene hydrocarbons (33 of 153 components) were also the most abundant compounds extracted from the juice by Pretorius *et al.* (1985), β-caryophyllene consistently (all four samples) being the main one. Quantitatively, almost all (95%) of the extracted volatiles were attributable to the

Table 5.1. Potential and emerging products and markets

Products	Markets Village/rural (traditional)	Urban	Tourist (FX)	Pan African	International (FX)
Fresh produce		P (including relief from malnutrition)	P	(famine relief)	
Juice/nectar (including flavour extract)		EM (including relief from malnutrition)	EM		M (juice drinks, candy)
Fruit		EM (including relief from malnutrition)	EM	(famine relief)	
Kernels	EM	EM (including relief from malnutrition)	EM	(famine relief)	EM
Liqueur		M	M		M
Wine	M	EM	EM (including prevention of food poisoning)	P	
Beer	M	EM	EM (including prevention of food poisoning)	P	
Wood items			M		

EM=developing product/market; FX=foreign exchange; M=existing product/market; P=potential product/market; $=indirect revenue through maintenance of ecosystem; secondary food resource/product

36 items listed (Table 5.3, column order), from α-ylangene to benzenemethanol. Pretorius *et al.* concluded that sesquiterpene hydrocarbons and benzyl alcohol were major contributors to the aroma. Samples differed, notably in the relative importance of the various sesquiterpene hydrocarbon compounds.

Schäfer & McGill's (1986) study reports a panel-screening of samples from five different populations of subsp. *caffra* – four from South Africa and one from Namibia. Evaluation was according to perceptions of juice odour, flavour, mouthfeel and aftertaste. There were indications of variation among samples. While there was little variation in perceived odour or aftertaste, the Namibia sample was sweeter in flavour – the authors suggested that growing conditions (sandy soil; low rainfall) contributed. A South African sample from near Pretoria had a distinctly more grainy, and thus less smooth, mouthfeel than any other.

Table 5.2. Volatile aroma compounds identified in fruit skins of *Sclerocarya birrea* subsp. *caffra*

n-pentane	3-methoxy-2-butanol	n-pentanal	ethylformate	oxalic acid
n-hexane	2-methyl-1-pentanol	3-methylbutanal	ethylpropanoate	2-methylpropanoic acid
benzene	2-ethoxypropanol	2-hexenal	ethylisobutyrate	2-methylbutanoic acid
2-octene	2-ethyl-3-hexen-1-ol	n-hexanal	ethylvalerate	ethyl-2-propenelether
1,5-hexadiene	acetone	n-heptanal	ethylbutanoate	ethylisopropenylether
diethylbenzene	acetaldehyde	n-heptanal	ethylisovalerate	methylamine
methanol	glycolaldehyde	n-octanal	ethylcaproate	acetamide
n-pentanol	crotonaldehyde	2-ethylbutanal	benzylacetateglycolic acid	

Source: Weinert *et al.* (1990), from Ballschmieter & Torline (1973)

Table 5.3. Volatile aroma compounds identified in fruit juice from *Sclerocarya birrea* subsp. *caffra*

ethyl acetate	furfural	a sesquiterpene hydrocarbon	a sesquiterpene hydrocarbon	benzenemethanol
ethyl-3-methylbutanoate	an alkylbenzene	tetrahydro-2-H-pyran-2-one	α-muurolene	benzeneethanol
3-methyl-1-butanol	α-cubebene	aromadendrene	(Z,Z)-α-farnesene	calacorene
pentan-1-ol	δ-elemene	γ-elemene	an (α)-farnesene isomer	2,5-furandialdehyde
styrene	α-ylangene	(Z)-β-farnesene	a sesquiterpene hydrocarbon	a sesquiterpene hydrocarbon
3-hydroxybutan-2-one	α-copaene	α-humulene	a sesquiterpene hydrocarbon (+ unknown)	dodecan-1-ol
3-methylbutyl-3-methylbutanoate	β-bourbonene	a sesquiterpene hydrocarbon	(E,E)-α-farnesene	pentadecan-2-one
hexan-1-ol	an ethyl-ester	(E)-β-farnesene	δ-cadinene	heptadecan-2-one
(E)-3-hexen-1-ol	β-cubebene	γ-amorphene	γ-cadinene	nonadecan-2-one
(Z)-3-hexen-1-ol	benzaldehyde	a sesquiterpene hydrocarbon	a sesquiterpene hydrocarbon	5-(hydroxymethyl)-2-furancarboxaldehyde
an ethyl-ester	linalool	γ-muurolene	ethyl nicotinate	3-methyl-butanoic acid
trans-linalool oxide, furanoid	α-bergamotene	a sesquiterpene hydrocarbon	geraniol	
cys-linanool oxide, furanoid	β-caryophyllene	a sesquiterpene hydrocarbon	a sesquiterpene hydrocarbon	

Source: Pretorius *et al.* (1985).

5.3 FOOD ITEMS BASED ON PULP, SKIN AND JUICE

5.3.1 Fresh fruit

All parts of the fruit are edible raw (Palmer & Pitman, 1972-1974; Shone, 1979; Teichman, 1983), making it a potential 'fresh produce' item. However, because the plant is relatively common within its distributional range, prospects for developing a 'local' market for 'fresh' marula are lower than those for developing an urban or international market - within or outside Africa. Given transport and storage considerations, the urban and tourist markets are the ones most likely to develop.

5.3.2 Marula-based jam and jelly

Potential products based on the pulp, of nutritional value particularly on account of reported vitamin C levels as high as 200 mg per 100 g fresh flesh (Arnold *et al.*, 1991) and 400 mg per 100 g fresh flesh (Eremosele *et al.*, 1991), include sun-dried fruit, cooked jams and preserves. It has long been recognized that richness in vitamin C is preserved in suitably prepared jam and jelly (Carr, 1957). Attempts to commercialize marula jelly production have been made in South Africa but have enjoyed mixed success (Shackleton *et al.*, 2001). The parastatal organization, Lisbon Estates, operating in an area rich in *Sclerocarya birrea* subsp. *caffra* close to the Kruger National Park, began to produce and market marula jelly in 1983 but, as demand did not rise, ceased this activity in 2001. In contrast, an initiative to market marula jam produced at household level not far away, at Thulamahashe, was swamped with the demand and the producer was unable to cope (S. Barton, pers. comm.). Another South African enterprise, Ina Lessing Jams, still continues production of jam and jelly, having started marketing these commodities within South Africa during the 1990s. To make jam, fruits are collected after they have fallen from the tree but are still 'green' (before they have begun to ferment). Fruits are incised with a cross and then boiled for 20 minutes in enough water to cover the fruits. The heat is then withdrawn, the liquid drained off and the stones separated from the pulp. This liquid and sugar are then recombined with pulp, at a ratio of 1cup of sugar to 3 cups of liquid. This mixture is then boiled for 40 to 50 minutes, until it turns brown. It is then bottled. Commercial prospects for jam production are being explored by Veld Products Research and Development in Botswana, with superior supermarkets and tourists viewed as potential customers.

5.3.3 Confectionary

'Marula chunks' are a new confectionary item being made from the skin of ripe ('soft-skinned') fruit. After fruit contents (pulp and stone) have been removed, the skin is crushed or sliced up and sugar-coated. This is a product included in the current pilot initiative of Veld Products Research and Development, in Botswana.

5.3.4 Juice, nectar, puree and flavoured products

The juice of the fruit, noteworthy for the high vitamin C content of around 200 mg per 100 g juice (Fox & Stone, 1938), can be used directly as a refreshing drink (Weinert *et al.*, 1990; Leakey, 1999), or reduced to make a flavouring extract for ice cream, yoghurt, soft drinks, cookies and cakes, and a marula-flavoured candy is available - 'Marula Cream Praline' (Nestle; //www.safpp.co.za/marula/). A product now being introduced into the urban marketplace is a marula-flavoured shortbread. Almost 20 years ago it was estimated that some 600 t juice were processed annually in South Africa and that demand appeared to be increasing (Weinert *et al.*, 1990). Within a few years, pasteurized juice was tested in Botswana as a market commodity (Taylor & Kwerepe, 1995) but the initiative encountered problems of product stability and cost-effectiveness and is now in abeyance (Shackleton *et al.*, 2001). Despite promising indications (Shackleton *et al.*, 2001), production of a marula-based puree through the same Botswana programme was also halted as insufficiently commercially rewarding. Discussions involving South Africa's Mineworkers Development Agency, based at the Mhala Development

Centre at Thulamahashe, as the supplier of raw material, and an enterprise contemplating production have led to the imminent (2002) launch on the market of a nectar, with 50% marula pulp (S. Barton, pers. comm.). Internationally, a vitamin-enhanced juice drink (15% juice) with rich mouthfeel, promoted as *Sclerocarya* (marula) flavoured (based on a supply from Mozambique), was released in the United States market in 2000.

5.3.5 Alcoholic beverages

Liqueur and cider (usually termed 'beer') are today well established marula-based alcoholic beverages, the latter with a traditional pedigree suspected to date back hundreds of years (Palmer & Pitman, 1972-1974). The South African 'Amarula' cream liqueur is internationally the most familiar marula product. Its production, by Cape Distell, is the largest and longest-standing (20 years) commercial marula enterprise, and currently the liqueur enjoys an expanding status in the global market (Shackleton *et al.*, 2001). According to Leakey (1999), trees from drier environments have sweeter fruits than those from wetter areas and it is the sweeter fruits, from the relatively high rainfall area (around 600 mm $year^{-1}$) of Phalaborwa, that are used for liqueur production (Shackleton *et al.*, 2001). However, Schäfer & McGill (1986) link a sweeter flavour with the lower rainfall of Namibia. A second enterprise in South Africa independently produces another liqueur from marula on a limited scale and the multinational Bulmer Cider company has expressed interest in working with a South African partner to do the same (S. Barton, pers. comm.). In Israel, too, liqueur is being produced, reputedly with a higher content of marula material (Shackleton *et al.*, 2001; S. Barton, pers. comm.). Wine, under the name 'Marulam', has been produced and marketed in Zambia (Leakey, 1999).

The importance of marula beer extends beyond a simple role as another alcoholic beverage. Much ceremony associated with its consumption persists and is credited with contributing to social cohesion and maintenance of societal standards. Nutritionally, it is noteworthy for the high vitamin C content (50-140 mg per 100 g) that remains after fermentation (Weinert *et al.*, 1990). The distinctive and unique flavour means there is no substitute. The breakdown of the ancient taboo on selling marula beer as a product, in the face of continuing appeal to consumers, has prompted investigations into the feasibility of commercial marula beer production, and under the name 'Afreeka' was subjected to market trials, in UK, in 1997 (Leakey, 1999). The Mineworkers Development Agency's Marula Project made an initial attempt to bring a microbrewery into operation to serve local tourist demand (Shackleton *et al.*, 2001). This activity, relying exclusively on Mineworkers Development Agency personnel, had little impact in terms of job creation, however. Collaboration with large commercial enterprises having more relevant business experience is now being considered instead. Discussions are underway with Bulmer Cider and with a French concern (S. Barton, pers. comm.).

5.4 ITEMS BASED ON KERNELS

5.4.1 Extracted kernels

Attractive nutritional qualities which make the kernels of *Sclerocarya birrea* potentially marketable are the high energy, protein, fat, magnesium, phosphorus and potassium contents (Chapter 4). The endocarps (nuts) can be cracked, and the kernels (which taste like cashew nuts) removed, to be eaten fresh and raw. They can be packaged at household level and marketed by street vendors, as in West Africa (J.B. Hall, pers. comm. – subsp. *birrea*). There is also (C. Shackleton, pers. comm.) a growing, if small, local rural market for extracted kernels of subsp. *caffra* in South Africa. However, the shelf life of extracted kernels is limited. There are instances (S. Barton, pers. comm.) of bacterial activity making them unfit for human consumption, possibly through carcinogenic qualities. Rural communities counter this risk by consuming kernels soon after extraction. Bacterial deterioration apparently does not occur while kernels remain within the endocarp making this a safe, if bulky, storage option under household circumstances.

5.4.2 Oil

Marula oil has often been described as fairly similar to olive oil (*e.g.* Burger *et al.*, 1987), but with the positive feature of a more oxidatively stable fatty acid composition. Another nutritionally attractive characteristic is the favourable saturated-to-unsaturated fatty acid ratio. On the negative side, the free fatty acid content is associated with high hydrolytic rancidity which must be countered with appropriate and specialized steps in the refining process (S. Barton, pers. comm.). Exploratory attempts to extract and refine oil from marula kernels within South Africa have been made but difficulties were encountered at various stages in the process – acquisition of kernels, oil extraction, the refinement process and selling (S. Barton, pers. comm.). However, a potential market for marula oil is still perceived. The Mineworkers Development Agency's Marula Project is supplied with kernels by people (almost all women) in the local area and extracts the oil using a hydraulic press. About half the oil present in the kernels is recovered. The oil is sold to concerns in both South Africa and the United Kingdom which refine it, currently mainly for pilot initiatives. A recent outcome of one of these initiatives has been the launch of a range of marula kernel oil based cosmetics by The Body Shop, using oil from the Mineworkers Development Agency in South Africa, and from Namibia (S. Barton, pers. comm.). Additional end products in which marula oil is a component have been suggested or are being marketed. Burger *et al.* (1987) note food industry potential for coating dried fruit, as a frying oil and in baby foods. Use in Zimbabwe in soap, and in South Africa as an aromatherapy carrier oil is taking place (S. Barton, pers. comm.). The potential value of oil by-products as a sunscreen has attracted interest (Roodt, 1988), and oil extracted from kernels in Madagascar, and processed in-country, is sold as a moisturizer under the name 'Sokoa' oil.

5.5 WOOD CARVINGS AND CURIOS

Ornamental wood carvings are marketed to tourists at roadsides around Kruger National Park, South Africa. *Sclerocarya birrea* subsp. *caffra* currently accounts for more of the wood used than any other species, doubtless reflecting the large sizes the species attains (enabling carvings as large as a 2 m giraffe to be made) and their relative abundance (Shackleton *et al.*, 2002). The development of this market is cause for concern, given that claims to utilize only male trees are disputed (Shackleton *et al.*, 2002), and the need to maintain sufficient pollen sources to keep female members of the *Sclerocarya* population fully productive (Chapter 9). Household utensils made from *Sclerocarya birrea* subsp. *caffra* are a very minor element of the carved wood marketed at the roadside in southern Zimbabwe (Braedt & Standa-Gunda, 2000). Braedt & Standa-Gunda regard carvings using *Sclerocarya* as a new development reflecting the disappearance of better quality carving woods from the area, bringing the sustainability of this trade into question.

A more acceptable *Sclerocarya*-based trade in South Africa, again around the Kruger National Park, at least from the point of view of the host tree population, is the sale at roadside and dedicated craftwork outlets of 'woodroses' as curios (Dzerefos *et al.*, 1999). 'Woodroses' are the distinctive woody structures formed on the branches of *Sclerocarya* hosts where individuals of hemi-parasitic loranthaceous shrubs, characteristically *Erianthemum dregei* and *Pedistylis galpinii*, become established.

6 MEDICINAL AND TRADITIONAL NON-WOOD USES

E. M. O'Brien

Sclerocarya birrea provides 'food for all seasons' and is one of those rare plant species that provides a cornucopia of benefits to local communities - virtually every part of the plant is either used as a medicinal or for some other purpose. Emphasis here is on medicinal use and non-wood uses. Information about the wood properties and uses, about the gum and about the foliage and its fodder potential is reported in Chapter 7.

6.1 MEDICINAL USES

Sclerocarya birrea is used as a medicinal plant throughout its distributional range. Almost all parts of the plant, but especially the bark and leaves, are exploited for medicinal uses, as described by Watt & Breyer-Brandwijk (1962) for eastern and southern Africa, Burkill (1985) and Irvine (1961) for western Africa, and Andriamihaja (1988) for Madagascar.

6.1.1 Bark

Traditionally, the bark provides medicinals for treating malaria, venereal diseases, diabetes and dysentery/diarrhoea (Oliver, 1960; Irvine, 1961; Watt & Breyer-Brandwijk, 1962; Adjanohoun *et al.*, 1979; Burkill, 1985; Andriamihaja, 1988). It is also used to treat haemorrhoids (Adam *et al.*, 1972), snakebites (Oliver, 1960; Sindiga *et al.*, 1995), liver diseases (Maundu *et al.*, 1999), inflammations of the spleen (Maundu *et al.*, 1999), stomach ulcers and pain (Goosen, 1985), gangrenous rectitis, blepharitis, skin inflammation and eruptions (Ayensu, 1978), leprosy (Oliver, 1960); and to ease labour pains (Wickens, 1980), haemorrhagic menstruation (Oliver, 1960; Adam *et al.*, 1972), headache, fevers (Oliver, 1960), sore throat/mouth and toothache (Watt & Breyer-Brandwijk, 1962; Burkill, 1985; Andriamihaja, 1988).

Details on how the bark is used have not been systematically studied nor reported, and are mostly apocryphal. Irvine (1961) reports Hausa use of a cold infusion of the bark, with mineral sodium carbonate for dysentery and applying a bark decoction to cure skin eruptions. For malaria, a brandy tincture of the bark is drunk as a prophylactic while a teaspoonful of dried powder is taken as a cure in South Africa. However, laboratory efforts to detect antimalarial activity in extracts of the bark of subsp. *caffra* failed (Spencer *et al.*, 1947). For gangrenous rectitis, the bark decoction is drunk and used to bathe the body. A half-pint of the decoction is drunk for dysentery. For use as an analgesic for toothache, the bark (and leaves, in Madagascar: Andriamihaja, 1988) is chewed and compacted into carious tooth cavities. The paste of the bark, alone or mixed with other plants, is diluted in a drink used to treat syphilis, gonorrhoea or leprosy, in Nigeria (Adam *et al.*, 1972) and elsewhere in Africa (Burkill, 1985). For snakebite, bark, from the trunk but especially the root, is pounded to a paste, rubbed on the bite until skin surface swells, then a bark decoction is drunk and applied as a dressing to the wound. It is used as a general anti-inflammatory for external use. According to Burkill (1985), it is mixed with butter and applied to the forehead to relieve headache and to the eye for blepharitis. In addition, it can be used as a purgative (Burkill, 1985), and in Kenya (Pokot, Maasai) a decoction of the bark or root is added to milk to make a health drink for children (Maundu *et al.*, 1999). It is used as an anal suppository (powder) for treating haemorrhoids (Adam *et al.*, 1972). Powdered bark, mixed in a drink of milk or millet water, is used to reduce fevers. A similar drink, mixed with dried onion leaves and other ingredients, is used to treat haemorrhagic menstruation (Adam *et al.*, 1972).

In Madagascar (Andriamihaja, 1988), internal (oral) use of the bark is usually as a tisane, a tea that is made from the leaves and bark and is commonly used as a sedative and antiseptic. For anal use, it is in a powder form. As a paste, powder or ointment, it is used externally as an astringent, antibiotic, antiseptic and emollient. In addition to the medical treatments mentioned above, it is used in Madagascar to treat neuralgia, rheumatism, gout and gastrointestinal disorders. In traditional dental medicine, it acts as a disinfectant, antiseptic, anti-inflammatory and analgesic; and can be used as a gargle or mouthwash.

The bark of *Sclerocarya birrea* is also used in traditional veterinary medicine (Kela *et al*., 1989). A decoction of the bark is used to increase the appetite of stock (Burkill, 1985), and to treat intestinal problems of horses (Adam *et al*., 1972). Shackleton *et al.* (2001) report that anti-bacterial activity of extracts of dry bark has been demonstrated.

Modern analyses of the therapeutic and pharmacological properties of *Sclerocarya* bark have only recently begun. Little is known about the active ingredients and compounds of the bark. According to Trovato *et al*. (1995), the bark decoction is non-toxic to rats and mice (LD_{50} value in mice >4 g kg^{-1}) and exhibits hypoglycaemic effects in normoglycaemic rats (Trovato *et al*., 1995). It is also active against diet-induced hypercholesterolaemia (Trovato *et al*., 1995). Kubo & Kinst (1999) have identified a tyrosinase inhibitor in the bark. It inhibits oxidation of L-3,4-dihydroxyphenylalanine (L-DOPA) by mushroom tyrosinase with an ID_{50} of 4.3 µg ml^{-1} (0.03 mmol). The anti-diarrhoeal properties appear to be due to a procyanidin (tannin) which inhibits intestinal motility and interferes with muscarinic stimulation (Galvez *et al*., 1991, 1993). Oral administration (to rats) of a procyanidin isolated from the bark resulted in marked anti-diarrhoeal activity at 150 mg kg^{-1}; and inhibited phasic contractions in a dose-dependent fashion (2.5 µg ml^{-1} to 0.64 mg ml^{-1}).

In terms of its chemistry, trunk bark, in addition to containing tannins, shows traces of ('cynahydrique') cyanide, and also contains flavones, lantanines, quinones, saponines, and traces of alkaloids (Andriamihaja, 1988). The root bark contains lantanines. According to Watt & Breyer-Brandwijk (1962), the bark varies in tannin content, from as little as 3.5% to more than 20.5%. The latter was from bark harvested just prior to the leaves appearing, suggesting time of year is a factor. Geographic variability in tannin content is also a possibility. In Kenya, bark from Nyanza is considered more potent than bark from Kisumu (Sindiga *et al.*, 1995).

It is traditionally assumed that the mature bark on the trunk is the most potent medicinally; and more potent than other parts of the plant (Sindiga *et al*., 1995). *Sclerocarya birrea* bark is so commonly exploited in parts of Kenya that it is found on homesteads partially, and some times completely, ring-barked. In the latter case, it dies within 1-2 seasons (Sindiga *et al*., 1995). However, with reference to subsp. *caffra* in the southern part of the species' range, Werger & Coetzee (1978) note that trees can survive ring-barking if the tissues removed are external to the cambium.

6.1.2 Leaves

The leaves are rich in flavonosides (Boiteau, 1986). As noted above, the leaves are mixed with bark in a variety of medical treatments. Alone, they are used to treat fever (Bossard, 1996) and diarrhoea, with a boiled water extract recommended for children (Ghazali *et al*., 1987). In Madagascar, they are macerated, alone or with bark, and used to treat any skin irritations or insect bites, and as compresses against all forms of pain. They are also used (with bark) to make a tea for treating venereal diseases, including syphilis (Andriamihaja, 1988) and a tea for treating weak veins/capillaries (Boiteau, 1986).

6.1.3 Roots

According to Burkill (1985), roots are pounded up with water and drunk for schistosomiasis and for washing scabies in Tanzania.

6.1.4 Stems/twigs

A cold infusion of bark, stems and twigs is mixed with mineral sodium carbonate and used against dysentery (Ayensu, 1978).

6.1.5 Fruit

Fermented fruit is highly intoxicating but is also antiscorbutic and a natural antimicrobial agent that prevents food poisoning. It acts against staphylococci (Andriamihaja, 1988) and has been shown to kill bacilli of *Salmonella* group B, *Salmonella enteritidis*, *Shigella sonnei* and *Shigella flexneri* (Mugochi *et al*., 1999).

6.2 NON-WOOD USAGE

6.2.1 Bark

The bark of *Sclerocarya birrea* has a strong fibre that is plaited into rope (Irvine, 1961; Sahni, 1968; Goosen, 1985) and woven into mats (Katende *et al.*, 1995). It is also used for preparing dyes and for dyeing clothes a 'khaki' colour (Adam *et al*., 1972; Andriamihaja, 1988). An extract of the bark is used to make commercial dyes - a 'khaki' shade - for dying textiles or colouring foodstuffs and confectionery. A process for extracting the dye was patented by Robert Harbottle, Durban, South Africa on 12 June 1919 (GB126742). 'The dyes are obtained either by boiling the [plant] materials in water, or by steeping in water and then expressing the juice by passage through roller mills; the juice is filtered and evaporated down. The material exhausted of dye may be used in the manufacture of paper, linoleum, etc.'

6.2.2 Fruit as fodder

The fruit of *Sclerocarya* is relished by many game animals and is commonly gathered and fed to domestic animals as fodder, especially during famines. The pulp is always consumed. Because it is difficult to mechanically or manually de-pulp *Sclerocarya* stones, use as fodder provides an efficient and ecologically beneficial 'first step' for nut-product development, as well as additional income.

6.2.3 Flowers and other fruit uses

The inflorescences are a source of nectar for bees. People are known to recover the intact stones from the faecal matter (of domestic and wild animals) for the edible kernel to be extracted for human consumption. The fruit is used as a sweetener of local foods and as a curdling agent for milk (Eromosele *et al*., 1991 – subsp. *birrea*). It is also a potent insecticide, traditionally used to kill ticks on humans and livestock (Watt & Breyer-Brandwijk, 1962). After kernel extraction, endocarp debris is valued as kindling material or as the heat source in charcoal irons (Shackleton *et al.*, 2002 – subsp. *caffra*).

6.2.4 Associated fauna

A deadly arrow poison is obtained from the larvae of *Polyclada flexuosa*, a chrysomelid beetle which lives on the tree (Goosen, 1985; Neuwinger, 1994). The leaves are a food source for the edible larvae of the saturnid moth *Gonimbrasia belina*, a species of 'mopane worm' and a nutritious and potentially important dietary resource rich in protein (Palmer & Pitman, 1972-1974; Eicker, 1988). The larvae of a wood-boring cerambycid beetle, vernacular name *izi mpunge* (Zulu), are commonly extracted from beneath the bark of subsp. *caffra*, cooked and eaten (Shackleton *et al*., 2002).

6.3 MAGIC/RITUAL SIGNIFICANCE

6.3.1 Bark

In Niger, for protection against snakebite, bark powder is added to baths (Adam *et al*., 1972). To protect hunters against the spirits of the prey, the bark powder is mixed with other ingredients and used in ablutions or in a preparation cooked with millet flour and butter and eaten - from the morning before going out on a hunt until a beast is killed (Adam *et al*., 1972).

The powdered bark of the root can reputedly be used to lift curses and help catch sorcerers. It is taken in a drink or added to ablutions - either of which must be done three times for men, four times for women.

6.3.2 Whole tree

A fine shade tree (pers. obs.), under which kraal craftsman and labourers gather and work, and which often serves as the spiritual centre for ritual activity in kraals and villages (Goosen, 1985).

7 WOOD, GUM AND LEAF FODDER

John B. Hall

Emphasis in this chapter is on qualities of the wood, gum and foliage of *Sclerocarya birrea*. Equivalent work on the fruits and kernels (Chapter 4) generally has emerged as an aspect of recognized commercial interest in the species. In contrast, the characteristics highlighted here are the result of long-term work concerned with documenting the properties of large numbers of species on a standardized basis. Consideration is in the context of the usage of the products.

7.1 WOOD

Current interest in the wood of *Sclerocarya birrea* is negligible. However, in the past subsp. *caffra* attracted sufficient attention for inclusion among timbers routinely assessed for physical properties and serviceability. Limited complementary investigation of lens and microscopic features was also carried out, revealing key features making samples and fragments of the wood identifiable. The details of wood structure thereby documented have subsequently been invaluable for application in historical and palaeontological studies. Most information relates to subsp. *caffra*. There is rather less information for subsp. *birrea* and for subsp. *multifoliolata* no comments on the wood have been traced.

7.1.1 Description

Numerous brief, general descriptions of the wood of subspp. *birrea* and *caffra* have been published. There are no striking characteristics that are consistently highlighted and, for both subspecies, the impression gained is of a rather featureless soft, diffuse-porous, low to medium density, and medium-textured wood. The colour is mainly greyish but there are reddish bands and streaks, and brown patches, pale when freshly cut but darkening to a pale reddish-brown on exposure (Scott, 1950; Bryce, 1967). Descriptions of the wood of subsp. *caffra* give more emphasis to a reddish hue, particularly in the heartwood. The sapwood has been described as very wide by Scott (1950) but more often as narrow (Goldsmith & Carter, 1981; Maydell, 1986), this variation perhaps emerging because it is not sharply differentiated from the heartwood (Scott, 1950; Maydell, 1986). There is little pattern visible to the naked eye. On transverse surfaces growth rings are variously described as poorly defined (Scott, 1950; Goldsmith & Carter, 1981) or distinct (Cardoso, 1960). On tangential surfaces well-defined lines of coarse vessels are the main feature. In contrast to the consistently straight grain of tangential surfaces, that of radial surfaces may be interlocked, with ray parenchyma and well-defined vessel lines providing more figure (Goldsmith & Carter, 1981).

7.1.2 Structure

Published information on the gross and the microscopic structure of the wood of both subspecies mostly takes the form of brief remarks. More attention has been devoted to the wood of subsp. *caffra* than to that of subsp. *birrea*, enabling the former to be described in rather more detail. Information on the two subspecies is therefore summarized separately here. It is apparent, however, that there is close similarity between the two. Such small differences as are noted below could arise as easily from contrasts in the conditions where the sampled trees grew as from their subspecific identity.

Photomicrographs of the wood structure of subsp. *caffra* have been published, with a fairly comprehensive description by Cardoso (1960), and with briefer comments by Shone (1979) and Prior & Gasson (1990, 1993). For this subspecies, Scott (1950) and Goldsmith & Carter (1981) offer further brief comments. Prior & Gasson (1993) draw attention to diagnostic anatomical features preserved when the wood is charred and transformed to charcoal. Brief comments on the wood structure of subsp. *birrea* are given by Bryce (1967), Biondi (1981) and, with reference to charcoal deduced to be that of the species and supported by photomicrographs, by Neumann *et al.* (1998).

Subsp. *caffra*

Vessels in subsp. *caffra* are sparse (Prior & Gasson, 1993) to moderately numerous (Cardoso, 1960). Scott (1950) notes zoning, with zones of tissue in which vessels are few grading into zones where there are more, to produce ill-defined growth rings. Latewood vessels are smaller. From 2-20 (mean = 7) individual vessels, or radial groups of 2-4 vessels together (Fig. 7.1), are present mm^{-2} of the transverse surface (Cardoso, 1960), and an oblique configuration has been noted (Goldsmith & Carter, 1981; Prior & Gasson, 1993). Mean tangential and radial diameters are 87 µm and 82 µm, respectively, according to Prior & Gasson (1993). Vessel elements are 71-672 µm long (mean 357 µm) and 111 µm in tangential diameter, with a wall thickness of 1.2-8.4 µm (mean 3.7 µm), according to Cardoso (1960). Perforation plates are simple (Fig. 7.2) and intervessel pits are alternate (Prior & Gasson, 1993). Vessels often contain tyloses.

Fibres are thin-walled, with more pronounced lignification in the latewood, and septate (Prior & Gasson, 1993). Cardoso (1960) reports a mean length of 912 µm and a mean diameter of 29 µm and a wall thickness of 2.1-6.3 µm (mean = 4.4 µm).

Parenchyma is paratracheal but scanty (Cardoso, 1960). Prismatic calcium oxalate crystals are present in chambered parenchyma cells (Prior & Gasson, 1990). Scott (1950) refers to fine terminal bands of parenchyma.

Cardoso (1960) recorded 3-9 rays mm^{-1} (mean = 5 mm^{-1}), 1-7 cells (mean = 3 cells) thick and 2-22 cells (mean = 9 cells) in height. Ray thickness was estimated at 52 µm and ray height at 336 µm. Rays are heterogeneous, with procumbent body cells and a single row of upright marginal cells (Fig. 7.3), and may contain horizontal secretory gum canals (Fig. 7.4). Some cells (both procumbent and marginal) contain prismatic crystals.

Subsp. *birrea*

In this subspecies, also, zoning of tissue in which vessels are few grading into zones where there are more, to produce ill-defined growth rings, has been noted (Bryce, 1967). Bryce reports 3-4 individual vessels, or radial groups of 2-4 vessels together, being present mm^{-2} of the transverse surface. Vessel diameters slightly larger (>100 µm) than those recorded for subsp. *caffra* are indicated by Bryce (1967) and Neumann *et al.* (1998), although as Neumann *et al.* were examining charcoal this may, at least in part, arise from loss of cell wall material during charring (Prior & Gasson, 1993). As in subsp. *caffra*, perforation plates are simple and intervessel pits are alternate (Neumann *et al.*, 1998). Biondi (1981) describes these pits as polygonal in outline and 8-10.5 µm in diameter. Vessel-ray pits are described by Neumann *et al*. (1998) as enlarged and simple, and comparable to the intervessel pits. Tyloses are reported to be abundant in the vessels (Bryce, 1967). Subsp. *birrea* shares with subsp. *caffra* the fibre characteristics of thin walls and septa (Neumann *et al.,* 1998). Parenchyma is paratracheal but sparse, at least some of the cells having chambers containing prismatic calcium oxalate crystals (Neumann *et al.*, 1998). Bryce (1967) draws attention to parenchyma in the form of narrow terminal lines, as a growth ring feature.

Bryce (1967) records 5-8 rays mm^{-1}, individual rays being <50 µm thick. Biondi (1981) suggests that in the sample he examined (from Senegal), rays were typically 1-3 rows of cells wide, occasionally 4 rows wide and only rarely wider. Neumann *et al.* (1998), however, noted rays 4-10 cells wide were not unusual in the charcoal (from Burkina Faso) they referred to *Sclerocarya*. Rays are heterogeneous, with procumbent body cells and a single row of square marginal cells (Bryce, 1967), or up to three rows of upright marginal cells (Neumann *et al.*, 1998). Biondi (1981) notes that the rays may contain (normally only one, rarely two, per ray) horizontal secretory gum canals, each on average 35 µm in diameter. In the ray cells, prismatic crystals of calcium oxalate are abundant (Biondi, 1981). Neumann *et al.* (1998) suggest druses occur in the procumbent ray cells. There are simple pits on the longitudinal walls of the ray cells (Biondi, 1981).

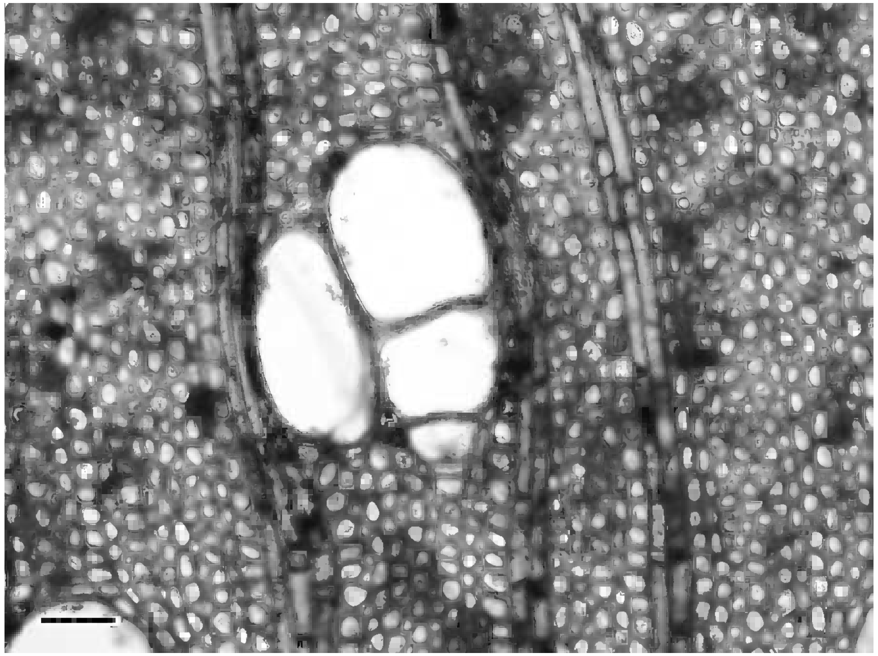


Figure 7.1. *Sclerocarya birrea* subsp. *caffra*: transverse section of wood from an unspecified locality in southern Africa (wood sample collection, School of Agricultural and Forest Sciences, University of Wales, Bangor). Note a group of vessels, rays and fairly thick-walled fibres. The scale bar is 100 µm [Jon Tuson and M.D. Hale]

Figure 7.2. *Sclerocarya birrea* subsp. *caffra*: radial longitudinal section of wood from an unspecified locality in southern Africa (wood sample collection, School of Agricultural and Forest Sciences, University of Wales, Bangor). Note the simple perforation plate and the septate fibres. The scale bar is 100 µm [Jon Tuson and M.D. Hale]

Figure 7.3. *Sclerocarya birrea* subsp. *caffra*: radial longitudinal section of wood from an unspecified locality in southern Africa (wood sample collection, School of Agricultural and Forest Sciences, University of Wales, Bangor). Note the procumbent body ray cells and the marginal row of upright cells. The scale bar is 100 µm [Jon Tuson and M.D. Hale]

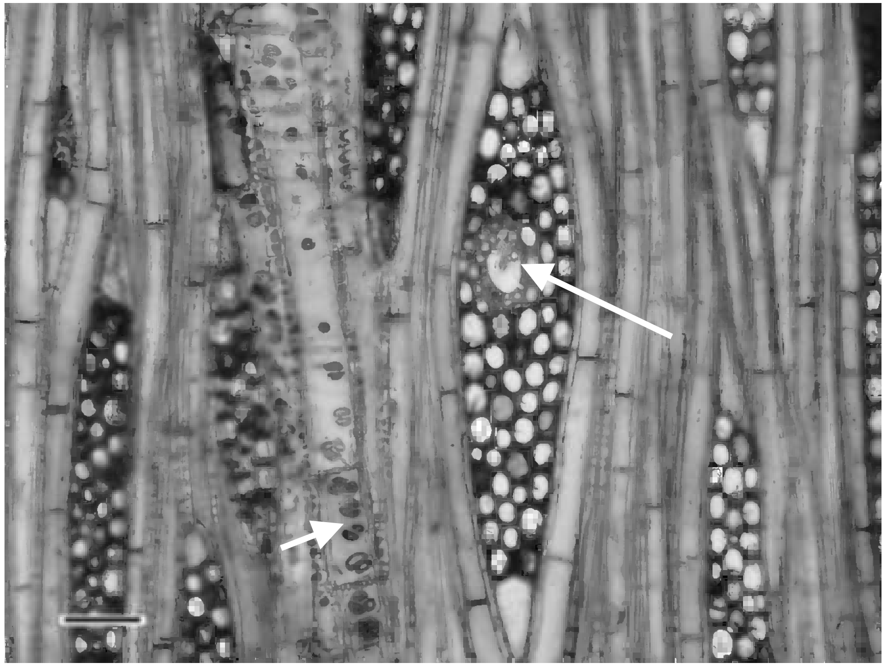


Figure 7.4. *Sclerocarya birrea* subsp. *caffra*: tangential longitudinal section of wood from an unspecified locality in southern Africa (wood sample collection, School of Agricultural and Forest Sciences, University of Wales, Bangor). Note the radial secretory canal (long arrow), septate fibres and prismatic crystals in some parenchyma cells (short arrow). The scale bar is 100 µm [Jon Tuson and M.D. Hale]

7.1.3 Working properties, seasoning and preservation

Scott (1950) describes the wood of subsp. *caffra* as pleasant wood to work, but sometimes inclined to be tough. It can be worked without difficulty with sharp hand and machine tools, despite interlocked grain (Goldsmith & Carter, 1981). When dry, it saws cleanly and easily although prone to woolliness in sawing which may cause saw teeth to clog in large logs, particularly when green logs are sawn (Scott, 1950; Shone, 1979). The wood planes to a fairly smooth surface, holds nails reasonably well, glues satisfactorily and will take a clear varnish finish (Scott, 1950; Goldsmith & Carter, 1981). Unlike many other woods of similar grain it does not rough up in working and turns well. The working properties of the wood of subsp. *birrea* are evidently closely comparable (Bryce, 1967; Maydell, 1986).

Both subspecies are subject to the same seasoning complications, although there is conflicting guidance on whether wood should be dried as rapidly as possible, to counter discoloration (Scott, 1950), or slowly - to minimize a tendency to distort severely and collapse (Goldsmith & Carter, 1981). The marked degree of shrinkage during moisture loss to the air-dried state (Scott, 1950; Goldsmith & Carter, 1981) presumably contributes to this. Maydell (1986), referring to subsp. *birrea*, also associates splitting with rapid drying. Scott (1950) notes that thin boards need careful stacking, and that the wood of subsp. *caffra* from near the centre of stems corrugates in drying. Shone (1979) emphasizes the need for the stickers separating boards undergoing drying to be closely spaced. Attributing the recommendations to Scott, Shone (1979) specifies kiln conditions for better control of the drying process (Table 7.1).

Table 7.1. Kiln conditions recommended for drying the wood of *Sclerocarya birrea* subsp. *caffra*

Moisture content of the wood (%):	>40	>30≤40	>20≤30	>15≤20	≤15
Temperature in kiln (°C):	54	57	60	66	68
Approximate saturation deficit in kiln (kPa):	3.0	4.2	6.0	12.3	16.3

Source: South Africa – M.H. Scott, cited by Shone (1979)

The wood of subsp. *caffra* has been described as not durable (Scott, 1950) but moderately permeable (Goldsmith & Carter, 1981) and treatable with preservatives. Freshly sawn boards require insecticide treatment during both seasoning and subsequent storage. For subsp. *birrea*, however, Dalziel (1937) refers to the wood as durable when well-seasoned and Maydell (1986) indicates that it is not easily impregnated. Untreated wood, which is rich in starch (Shone, 1979), of both subspecies is very susceptible to attacks by insects (including powder post beetles – *Lyctus* – and termites) and fungi (including sapstain fungi). Scott (1950) notes the frequent occurrence in subsp. *caffra* of a blue discoloration, and brown patches signifying the early stages of decay. Prompt debarking and treatment of logs minimise the problems of pre-seasoning attacks from insects and fungi.

7.1.4 Physical and strength characteristics

The wood is light and soft, and has low strength properties (Table 7.2). There are indications that the wood of subsp. *caffra* may reach higher density values than the wood of subsp. *birrea*. In addition to the values in Table 7.2, in the air dry state (moisture content 10%) a range of 530-670 kg m^{-3}, with a mean of 600 kg m^{-3}, is given by Shone (1979) for subsp. *caffra*. In contrast, no value reported for subsp. *birrea* (Dale & Greenway, 1961; Bryce, 1967) reaches 600 kg m^{-3}. However, a wider range of values for the air dry state is reported for subsp. *caffra*, including a minimum value of 450 kg m^{-3} given by Gomes e Sousa (1966-1967), than for subsp. *birrea* (minimum 481 kg m^{-3} - Bryce, 1967). Density in the green state (*ca* 80% moisture content) has been determined at 1073 kg m^{-3} (subsp. *caffra* - Scott, 1950) and 1121 kg m^{-3} (subsp. *birrea* – Bryce, 1967).

Table 7.2. Strength properties of *Sclerocarya birrea* wood

Source: / Subsp.	Scott (1950) Southern Africa* *caffra*	Shone (1979) South Africa** *caffra*	Goldsmith & Carter (1981) Zimbabwe* *caffra*	Bryce (1967) Tanzania* *birrea*	Bryce (1967) Tanzania* *birrea*
Moisture content (%)	12	12	12	12	50
Density (kg m^3)	513-657	550±76	540	561	657
Nominal specific gravity	0.55	-	-	0.50	0.44
Modulus of rupture (N mm^{-2})	51.3	50.8±10.5	57.8	53.0	28.0
Modulus of elasticity (kN mm^{-2})	5.6	5.0±1.6	7.2	3.9	2.4
Energy consumed in bending to maximum load (mm N mm^{-3})	-	-	-	-	0.132
Energy consumed in bending to total fracture (mm N mm^{-3})	-	-	-	-	0.201
Maximum compression strength parallel to grain (N mm^{-2})	29.2	28.1±5.5	31.2	35.1	12.4
Maximum shear parallel to grain (N mm^{-2})	10.0	9.4±1.9	10.0	12.9	6.0
Hardness on side grain (kN)	3.7	3.7±1.0	-	4.2	2.7
Hardness on end grain (kN)	4.9	4.8±1.1	-	-	-
Resistance to splitting – radial plane (N mm^{-1} width)	-	-	-	20.0	9.1
Resistance to splitting – tangential plane (N mm^{-1} width)	-	-	-	22.1	11.0
Radial shrinkage (from green to stated moisture content) (%)	4 (to 12%)	2.2 (to 8%)	3.6 (to 12%)	-	-
Tangential shrinkage (green to stated moisture content) (%)	-	4.1 (to 8%)	6.3 (to 12%)	-	-

*Tabulated values represent 2 cm x 2 cm standard samples after adjustment of figures reported for 2 inch x 2 inch samples, using the conversion factors given by Lavers (1983).

**Values in this column are mean ± standard deviation; -, no value reported.

7.1.5 Uses

Despite the low strength, light weight and soft texture, the wood of both subsp. *caffra* and subsp. *birrea* is widely and diversely used (Table 7.3). Table 7.3 also reflects the greater past emphasis on timber uses for subsp. *caffra*. In the past this subspecies has enjoyed popularity as a timber on account of the form, large sizes and the ease with which it can be worked. The form of the tree can allow timber industries a recovery percentage in conversion of as much as 33%, very high for a dryland tree (Shone, 1979). The demise of the best established *Sclerocarya birrea* timber market – for subsp. *caffra* in South Africa – did not arise from any dissatisfaction with product quality but from resource conservation concerns. Natural populations of the subspecies were being exploited without provision for restoration, and legislation was enacted to safeguard the non-wood roles served.

In respects other than timber, Table 7.3 reveals that local usage is comparable for the two subspecies. As for timber, where legislation and tradition permit, the size and workability make the species a very attractive wood resource. In many areas no other species offers wood combining desirable quality and sufficient size for large, single-piece, wooden items such as cattle troughs, meat trays and mortars. Serviceable and durable domestic products of diverse shape and size are easily made. Among such items are the remarkable wooden chains of as many as 20 or 30 links, each 20 cm long, carved from single pieces of subsp. *caffra* wood up to 4.5 m long (Shone, 1979).

Table 7.3. Principal uses of *Sclerocarya birrea* wood.

Use category	Subspecies *caffra*	Subspecies *birrea*
Domestic utensils	Forks, plates, spoons (Shone, 1979), kitchen utensils (Braedt & Standa-Gunda, 2000), meat trays (Shone, 1979), mortars (Shone, 1979; Rodin, 1985)	Bowls (Dalziel, 1937; Irvine, 1961; Maydell, 1986), kitchen utensils (Giffard, 1974; Bille, 1978), mortars (Dalziel, 1937; Irvine, 1961; Giffard, 1974; Maydell, 1986), pestles (Maydell, 1986)
Crafts	Carvings (Scott, 1950; Shone, 1979; Goldsmith & Carter, 1981), drums, ornaments (Shone, 1979), pattern making, toys (Goldsmith & Carter, 1981)	Boxes, carvings (Bryce, 1967), craftwork (Maydell, 1986)
Furniture	Cabinets, kitchen furniture, turnery (Goldsmith & Carter, 1981), general furniture (Scott, 1950), interior fittings, interior trim, joinery (Gomes e Sousa, 1966-1967; Goldsmith & Carter, 1981), pillows, stools (Shone, 1979)	General furniture (Maydell, 1986)
Construction	Carts, core filler, heavy crating, light structural carpentry (Goldsmith & Carter, 1981), flooring (Scott, 1950; Goldsmith & Carter, 1981)	Fencing (Maydell, 1986)
Other	Agricultural implements (Goldsmith & Carter, 1981), box shooks (Gomes e Sousa, 1966-1967; Goldsmith & Carter, 1981), cattle troughs (Shone, 1979), saddle trees (Scott, 1950)	Axe handles (Irvine, 1961), beehives (Katende *et al.*, 1995), saddles (Maydell, 1986)

Plywood prepared from subsp. *birrea* and veneer from subsp. *caffra* are mentioned by Bryce (1967) and Shone (1979), respectively. The processing of subsp. *caffra* wood into pulp is implied by Goldsmith & Carter (1981) but potential for this use is likely to be limited by the short length, 912±206 µm (mean ± standard deviation) of the fibres (Cardoso, 1960).

Considering the volume of literature on the species, and its wide distribution, comments on its use for fuel are few, this paucity a reflection of the poor energy value of the soft, light wood. Subsp. *birrea* features among woods used as domestic fuel, and even processed into charcoal (Adam *et al.*, 1972; Katende *et al.*, 1995). Possibly such use follows elimination of better alternatives. Disinclination to use subsp. *birrea* as fuel because of the availability of better quality *Acacia* spp. and *Combretum* spp. quality was detected by Donfack *et al*. (1995). Subsp. *caffra* has also been dismissed (Jumelle, 1916) as a fuelwood of poor quality but is reported to be selectively used for firing bricks in Zimbabwe (Shackleton *et al.*, 2002), and for the same purpose in the green state in Swaziland (Prior & Gasson, 1993). Shackleton *et al.* (2002) report also that almost all households assessed in a community in Kwazulu-Natal, South Africa, used subsp. *caffra* as fuel, despite protection under customary law. However, neither the proportion of fuelwood contributed by subsp. *caffra* nor whether exploitation is limited to male trees is indicated, and there is no information about whether alternative fuelwoods were readily available. Arnborg & Singh (1984) list subsp. *birrea* as a fuelwood in northern Nigeria. Even a specific traditional use of the wood ash (of subsp. *birrea*) has been recorded – applied to goatskins alone (Harris, 1950) or in mixture with ashes from other woods, including that of *Anogeissus leiocarpus*, to remove the hair in preparation for tanning (Dalziel, 1937).

7.2 GUM

7.2.1 Characteristics

When the bark of both subsp. *caffra* (Jumelle, 1916) and subsp. *birrea* (Dalziel, 1937) is damaged, gum is exuded. This gum is friable and dissolves easily in cold water (Anderson *et al.*, 1986; Anderson & Weiping, 1990). It is clear, and light-brown coloured, and is not sticky when it dries.

The analytical and compositional characteristics of subsp. *caffra* and subsp. *birrea* gums have been reported by Anderson *et al.* (1986) and Anderson & Weiping (1990), respectively. For subsp. *birrea*, Anderson & Weiping (1990) have also indicated the cationic composition of ashed gum.

The two gums are similar (Tables 7.4 and 7.5) in sugar and amino acid composition. The contributions of arabinose, glucuronic acid and galacturonic acid to the sugar composition are relatively low. Anderson *et al.* (1986) draw attention to the absence of rhamnose from their sample (from Zimbabwe) of subsp. *caffra* gum; a small quantity was detected, however, in a sample of subsp. *birrea* gum from Nigeria (Anderson & Weiping, 1990). In the amino acid composition (both subspecies) the high hydroxyproline and serine contents are noteworthy. Aspartic acid and valine contents are low.

Table 7.4. Basic analytical parameters, and sugar composition after hydrolysis, of the gum of *Sclerocarya birrea*

	subsp. *birrea*	subsp. *caffra*
Analytical parameters:		
Ash (%)	7.1	5.1
Nitrogen (%)	0.16	0.06
Methoxyl (%)	0.75	2.1
Tannin (%)	0.4	-
Specific rotation (°)	+42	+12
Intrinsic viscosity (cm^3 g^{-1})	20	4.3
Molecular weight	-	56 000
Uronic acid (%)	21	23.5
Sugar composition after hydrolysis:		
4-*O*-methylglucuronic acid (%)	4.5	12.5
Glucuronic acid (%)	16.5	8
Galacturonic acid (%)	-	3
Galactose (%)	56	63
Arabinose (%)	21	14
Rhamnose (%)	2	0

-, not specified

Sources: subsp. *birrea*: Anderson & Weiping (1990); subsp. *caffra*: Anderson *et al.* (1986).

Both subspecies yield acidic gum with a positive optical rotation. Nitrogen content is low, particularly in subsp. *caffra*, and proteinaceous (Anderson *et al.*, 1986). Differences between the subspecies which should be noted are in intrinsic viscosity (subsp. *birrea*, moderate; subsp. *caffra*, low) and in methoxyl content (subsp. *birrea*, moderate; subsp. *caffra*, high). Whether these differences reflect growing conditions at source, or are subspecifically characteristic, remains uncertain. Tannin content in subsp. *birrea* gum is high. Anderson *et al.* (1986) present no tannin value for subsp. *caffra* gum but according to Shone (1979) this is also high. Subsp. *caffra* gum is of low molecular weight.

Table 7.5. Amino acid composition (residues per 1000 residues) for gum of *Sclerocarya birrea*

	subsp. *birrea*	subsp. *caffra*
Alanine	41	65
Arginine	12	4
Aspartic acid	56	69
Cystine	0	0
Glutamic acid	37	48
Glycine	37	39
Histidine	36	29
Hydroxyproline	348	282
Isoleucine	17	19
Leucine	56	66
Lysine	25	20
Methionine	4	0
Phenylalanine	27	17
Proline	68	61
Serine	136	126
Threonine	45	76
Tyrosine	15	18
Valine	40	61

Sources: subsp. *birrea*: Anderson & Weiping (1990); subsp. *caffra*: Anderson *et al.* (1986).

For subsp. *birrea*, the cationic composition of ashed gum (Table 7.6) indicates that the dominant cations are calcium and potassium. Iron and lead contents are rather high. Copper, manganese and zinc contents are rather low.

Table 7.6. Cationic composition of ash from samples of the gum of *Sclerocarya birrea* subsp. *birrea* (ppm)

Calcium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Nickel	Potassium	Sodium	Zinc
139 000	11	25	4	9	3120	76	17 000	40	1	18 500	980	13

Source: Anderson & Weiping (1990)

7.2.2 Uses

The gum properties make it suitable for technological applications but, as it contains tannin, it is not suitable as an ingredient of foodstuffs. Recorded traditional local use for subsp. *caffra* in Botswana and Namibia is as a carrier for hunting poison (from crushed *Polyclada* beetle larvae) to tip arrows (Shackleton *et al.*, 2002). In West Africa, the gum of subsp. *birrea* has been used for making ink - as a solution in water mixed with soot (Dalziel, 1937).

7.3 LEAF FODDER

Literature references to *Sclerocarya birrea* as a source of animal fodder are numerous but in most cases consideration centres on consumption of fruits, commonly off the ground (*e.g.* Shone, 1979).

Foliage is also consumed after it falls (subsp. *caffra* – Shone, 1979; subsp. *birrea* – Bille, 1978). Comments on the foliage as livestock browse have been made for both subsp. *caffra* and subsp. *birrea* but neither is a major source of browse and use is intermittent, except at times of general feed shortage when herdsmen lop branches to make foliage accessible. The statements made about subsp. *caffra* which suggest high leaf fodder appeal, significance and quality (*e.g.* Goosen, 1985) are, however, not accompanied by factual data. Comments on the leaf fodder value of subsp. *birrea* are less effusive (International Board of Plant Genetic Resources, 1984). For this subspecies, in West Africa, the timing of natural availability is stressed more (Bille, 1978) as a favourable factor than its quality. Bille notes that more than half the nutritive value of the leaf material remains at leaf fall. At the onset of the dry season, when the foliage is shed, nitrogen concentration in the grasses is falling to negligible values but subsp. *birrea* leaf litter dry matter contains 4% digestible protein. For this subspecies, formal evaluations of leaf foliage quality as browse (Tables 7.7-7.9) are presented by Houérou (1980).

There appear to be no outstandingly positive nutritional qualities. Most elemental concentrations (Table 7.7) are at acceptable levels, although calcium levels are high and lead to unfavourably high calcium:phosphorus ratios. Browse elemental concentrations often reflect qualities of the associated soil (Houérou, 1980), however, and this limits interpretation.

Table 7.7. Silica and element concentrations reported for foliage of *Sclerocarya birrea* subsp. *birrea*

Material and origin	Concentrations (% in dry matter)				
	Silica	Calcium	Magnesium	Phosphorus	Potassium
Young leaves (Senegal)	2.9	1.6	0.6	0.19	1.2
Green leaves (Burkina Faso)	0.8	3.1	0.6	0.14	0.8
Dry leaves (Tchad)	6.3	-	-	-	-

-, no value specified

Source: Houérou (1980)

In terms of proximate fractions (Table 7.8), nitrogen free extract (carbohydrate), crude fibre and ash levels are broadly favourable but the ether extract (crude fat) level is a little higher, and crude protein level lower, than desirable.

Table 7.8. Proximate analysis values reported for foliage of *Sclerocarya birrea* subsp. *birrea*

Material and origin	Proximate fractions (% of dry matter)				
	Crude protein	Crude fibre	Ether extract	Nitrogen free extract	Ash
Young leaves (Senegal)	10.5	13.4	2.2	63.2	10.7
Green leaves (Burkina Faso)	13.3	11.2	3.6	62.1	9.9
Green leaves (Senegal)	6.1	4.0	7.6	62.3	19.9
Dry leaves (Tchad, 1973)	5.7	20.2	5.9	51.7	16.5
Dry leaves (Tchad, 1974)	7.7	16.2	5.2	57.3	13.6

Source: Houérou (1980)

The net energy level (Table 7.9) is acceptable but the digestible protein level is low – despite the seasonal superiority over that of the accompanying grass sward mentioned by Bille (1978) – and the nutritional ratio is also low as a consequence.

The extent to which anti-nutritional factors further reduce attractiveness as browse has apparently not been quantified. Nevertheless, reference has been made to mildly toxic effects on stock which have been eating the leaves of subsp. *birrea* (International Board of Plant Genetic Resources, 1984; Maydell, 1986). Tannins and flavonoids are reported to be present in the leaves of subsp. *caffra*

(Shackleton *et al.*, 2001) – both types of compound are considered deterrents of herbivory (Harborne, 1988; Paterson, 1993).

Table 7.9. Digestibility and energy values reported for the foliage of *Sclerocarya birrea* subsp. *birrea*

Material and origin	Digestible protein (% dry matter)	Net energy (MJ kg^{-1} dry matter)	Nutritional ratio*
Young leaves (Senegal)	6.2	-	-
Green leaves (Burkina Faso)	8.8	7.6	12
Green leaves (Senegal)	2.2	-	-
Dry leaves (Tchad, 1973)	4.9	5.0	10
Dry leaves (Tchad, 1974)	3.6	6.4	6

*g digestible protein per unit of dry matter providing 1 MJ net energy; -, no value specified

Source: Houérou (1980)

Laurens & Paris (1977) investigated polyphenols in the leaves of subsp. *birrea* (apparently from Senegal) and subsp. *caffra* (from Madagascar). Attempts to quantify total phenols, and the contribution of tannins to these, gave results varying with analytical procedure, although the presence of tannins was consistently confirmed. Colorimetry, based on gallic acid content, indicated low values (total phenols <5%; tannin <2.5%) while from a method considered more promising (collagen binding) corresponding values were 25-30% and 7.0-7.5%, respectively. In all analyses, material from subsp. *caffra* proved more tanniniferous than that from subsp. *birrea*. However, in the absence of more samples, whether this indicates a subspecific difference or simply the contrast between the tested samples remains unclear.

Various phenolic compounds were detected by Laurens & Paris (1977). Phenolic acids present in both subspecies included p-coumaric acid (hydroxyl-cinnamic) and four benzoic acids (p-hydroxybenzoic, protocatechic, gentisic and, the most abundant, gallic). Flavonoids were also characterised and proved to be predominantly derivatives of kaempferol and quercetol, with more compounds in the former group found in the sample of subsp. *birrea*. One quercetol derivative (quercetol 3-rhamnoside) was detected in both subspecies. There were two other quercetol derivatives in each subspecies (quercetol 3-glucoside, quercetol 3 galloylglucoside – subsp. *birrea*; quercetol-3 arabinoside, quercetol 3 xyloside – subsp. *caffra*). In subsp. *birrea*, three kaempferol derivatives were also present: kaempferol-3 rhamnoside, kaempferol-3 glucoside, kaempferol 3-galloylglucoside).

8 PROPAGATION AND MANAGEMENT

Kago Phofeutsile, H. Jaenicke and B. Muok

Sclerocarya birrea occurs in arid and semi-arid areas which experience low rainfall and high temperatures resulting in high potential evapotranspiration. The plants growing in these areas are, therefore, often water-stressed. In addition, soils may be shallow, inherently infertile and prone to capping which reduces rainfall infiltration and increases water runoff. There are also a number of agents that cause damage to young trees in dryland areas, such as livestock and wild animals. To establish trees successfully in drylands, special techniques are required to make scarce water resources available for tree growth and protect young trees from damaging agents.

8.1 NATURAL REGENERATION

Most existing *Sclerocarya birrea* trees have naturally established and, in the natural range, it is common to find the species regenerating on farmlands under mature female trees soon after the rains. Seed germinates readily once the bond between the opercula and the rest of the endocarp has been weakened. Exposure to conditions at the soil surface leads to this in time, allowing the seeds within to imbibe moisture. However, natural regeneration is slow and growth rates among the seedlings are uneven. Furthermore, regenerating seedlings are rarely recruited to the sapling stage due to destruction by browsing animals and cultivation for agriculture.

To ensure natural regeneration the following steps can be taken: uproot some seedlings to leave the number required, at the spacing required; construct water harvesting structures around the seedling; protect the remaining stems from browsing animals by putting a fence around every stem, and weed regularly to control competition from unwanted vegetation.

Today's *Sclerocarya birrea* populations are comprised mainly of those left growing in farmers' fields. There have been few attempts to date to propagate *Sclerocarya birrea* in the nursery or to transplant seedlings into fields. Attempts to propagate from seed raise several key issues. Germination rates are low unless proper storage and pre-treatments are observed. The dioecious nature of *Sclerocarya birrea* means many seedlings raised will be male and unable to contribute directly to fruit supply on reaching maturity. This and the relatively late onset of fruiting make vegetative propagation through cuttings or grafts very attractive. However, once established, the long taproot means that nursery production in small pots can be detrimental to healthy tree development in the field due to root coiling and damage.

8.2 NURSERY PROPAGATION

A sex ratio of 1:1 has been estimated for *Sclerocarya birrea* (S. Mateke, pers. comm.). This means. Thus, half of each seedling population is potentially of fruit-bearing female trees. However, seedling production for *Sclerocarya birrea* is justified and important for raising rootstocks for nursery grafting or later top working in the field.

8.2.1 Propagation from seed

For practical nursery purposes, a stone (endocarp) is considered a seed. The large, oval, woody stones of subsp. *caffra* may weigh up to about 12 g each, contributing about 50% of the weight of the whole fruit, but some reports suggest smaller sizes. Thus, Msanga (1998) has estimated, for the same subspecies, that on average endocarps constitute only 20% of fruit weight and weigh as little as 2 g each (500 kg^{-1}, compared with 295 kg^{-1} for subsp. *birrea* in Burkina Faso - Nikièma *et al.,* 1993). Other estimates are 400 kg^{-1} for subsp. *birrea* (Maydell, 1986) and 200 kg^{-1} (Shone, 1979) and 400-450 kg^{-1} (Mbuya *et al.*, 1994) for subsp. *caffra*.

One stone is found in each fruit with 2-3 embryos (the seeds, in the strict sense) per stone. Examination of 50 endocarps in Botswana (Moss & Taylor, 1983) indicated that 62% were bilocular and 38% trilocular. The embryos per endocarp together account for only about 5% of the fruit's fresh weight (Shone, 1979; Teichman, 1982). Each embryo cavity in the stone is closed by an 'operculum', which can be removed mechanically (Msanga, 1998). Leakey *et al.* (in press, b) have reported variation in kernel traits (mean kernel number, kernel mass and shell mass per fruit) with locality for several sites in South Africa and Namibia.

8.2.1.1 Pre-preparation and implications for germination

Propagation of *Sclerocarya birrea* from seed requires pre-preparation because there is seed dormancy. Seed dormancy can be broken through the following process:

- Carefully take the skin and pulp off the stone.
- Dry the stones in the sun for at least seven days – in Zimbabwe, drying periods of up to three weeks have been recommended (Maruzane *et al.*, 2002).
- Store the dry stones in a well-aerated, shady place and expose them to low temperatures (<10°C) in winter. Ensure the stones are kept dry.
- The seed coat in the strict sense is very thin and is not a barrier to germination. However, it and the seed lie within the wall of the endocarp and, using a knife or a small chisel, the operculum (which is part of the wall) must be removed or loosened before sowing. Kernels are left within the stones as they are prone to damage in removal.
- Soaking in cold water for 12-24 h, but not more than 36 h, has also been recommended as a means of making operculum removal easier.

Msanga (1998) suggests for preparation on a large scale that fruits are soaked in water (24 h), then churned in water in a concrete mixer with gravel (2 parts by weight fruit: 1 part by weight gravel). The water, with the fruit skins and pulp is poured off after churning and the endocarps picked out of the gravel by hand. In the absence of a mixer, large scale preparation can be undertaken by pounding fruits in a mortar with coarse sand, after 24 h soaking in water. Endocarps retrieved are sun-dried for at least two days.

Under suitable conditions, germination may take as little as four days (or even less in terms of the first sign of the radicle emerging from the endocarp) to 4 weeks, and rates of up to 100% have been achieved within four weeks of sowing. There is, nevertheless, wide variation.

Using endocarps, Teichman *et al.* (1986) investigated in laboratory conditions the influence of several factors on the germination of subsp. *caffra*, including scarification with concentrated sulphuric acid which proved ineffective. Seed moisture uptake was checked for endocarps that had been stored for six months, were enclosed in saturated wadding for 80 h in the dark at 27°C. Seed moisture content from intact, base-rasped and de-operculated endocarps was estimated at 23%, 23% and 22%, respectively. It was concluded that the endocarp of subsp. *caffra* does not restrict seed water uptake. In a related study, Were & Munjuga (1998) tested desiccated endocarps for germination after 3 months storage to a series of moisture levels, loosening the opercula before sowing. The moisture content level associated with storage had no marked effect on initial germination: 24% germination with 5% moisture content; 27% germination with 40% moisture content; 9-19% germination with 8-30% moisture content.

Intact and de-operculated endocarps were compared by Teichman *et al.* (1986) with respect to the effect of exposure to low light from cool white fluorescent tubes over an unspecified period. Under both treatments, a temperature of 27°C and 1.2 kPa vapour pressure deficit were maintained during the test. With or without exposure to light there was no germination from intact endocarps. When opercula were removed, however, light exposure led to 49% germination, but more endocarps (73%) kept in darkness germinated. White light was concluded to have a slight inhibitory effect on germination. Teichman *et al.* also considered germination responses to varying leaching, oxygen concentration and temperature treatments (Table 8.1). Operculum removal clearly leads to a much more pronounced increase in germination than any of the other treatments applied by Teichman *et al.* (1986). Nevertheless, soaking in potassium hydroxide solution and leaching with cold water further increased germination over the six days observation period, suggesting intact endocarps protect seeds from leaching that might dilute or remove germination inhibiting substances. The high germination success at temperatures in excess of 21°C is consistent with a tropical/subtropical distribution range.

Table 8.1. *Sclerocarya birrea* subsp. *caffra*: mean cumulative germination (%) after six days subject to treatments indicated

Treatment	State of endocarp			Comments
	Intact	Base rasped	Operculum removed	
Untreated	0	-	74	Dark conditions at 27°C and 1.2 kPa vapour pressure deficit using endocarps previously stored for 4.5 months
Leached (24 h cold running water)	2	-	97	
Soaked (24 h) in potassium hydroxide (1 mol dm^{-3})	0	-	100	
Ambient oxygen level (21%)	8	18	88	Dark conditions at 27°C and 1.2 kPa vapour pressure deficit using endocarps previously stored for 10.5 months
Pure oxygen (100%)	17	43	96	
At 21°C	-	-	25	Dark conditions at 27°C and 1.2 kPa vapour pressure deficit using endocarps previously stored for 16.25 months
At 27°C	-	-	94	
At 32°C	-	-	100	
At 37°C	-	-	92	

Source: Teichman *et al.* (1986)

Germination from endocarps subjected to cold water soaking has also been compared with germination from untreated endocarps and from endocarps added to boiling water as the heat source was removed and a 24 h period of cooling effected (Mateke & Tshikae, 2002). Endocarps harvested *ca* 9 months earlier were used. Soaking in water accelerated germination from endocarps (after 6 weeks: no germination from unsoaked endocarps *vs* a cumulative value of *ca* 10% from soaked endocarps). The cumulative percentage germination also rose initially after soaking: unsoaked control 6% *vs* soaking treatments 66%, after 12 weeks. After a further two weeks, which included the highest ambient mean temperature (27.5°C over 14 days), however, the contrast in cumulative germination percentage was much reduced (cold water soaking, 67%; cooling from boiling, 70%; unsoaked control, 59%). Shone (1979), apparently referring to intact endocarps, reported no improvement in germination after treatment with hot water, but noted satisfactory germination from endocarps discarded after completion of 'beer' preparation. Mbuya *et al.* (1994) pretreated endocarps (apparently intact) of subsp. *caffra* by 24 h soaking in cold water, achieving 40% germination success after 6 weeks. Soaking in water cooling from boiling has given 53% germination success with subsp. *birrea* in Mali. Msanga (1998) reports faster germination of pre-treated endocarps of subsp. *caffra* (soaked, opercula loosened) in Tanzania: cumulative germination 70% after 1 week and 85% after 2 weeks. Untreated endocarps germinated sporadically over 2-9 months, although mainly 3-5 months after sowing, and the cumulative percentage rose to only *ca* 50%.

Prolonged seed storage is another possible way to increase germination success and has been investigated by Teichman *et al.* (1986) and Were & Munjuga (1998). At 27°C, and in dark conditions, Teichman *et al.* (1986) found that de-operculated endocarps of subsp. *caffra* previously stored for short periods (0.5-2 months) were slower to germinate (<50% success in 6 days) than de-operculated endocarps previously stored for 14-23 months (>60% success in 4 days; >80% success in 6 days). Were & Munjuga (1998) stored samples of endocarps at -20°C, 5°C and 15°C for 3, 6, 9 and 12 months, by Were & Munjuga (1998), the opercula being loosened before sowing. Germination percentages were consistently higher (20-40%) after storage at 15°C than after storage at lower temperatures.

8.2.1.2 Sowing and the germination process

Recommended nursery guidance to achieve germination is as follows:

- Sow the seeds at the onset of the rainy season: October, November or December in Southern Africa; October or March in East Africa; April or May in West Africa (Nikièma *et al.,* 1993). In the part of the range where there is a distinct winter season, 92% germination success followed spring sowing (October, Botswana), while from winter sowing (July, Botswana) the percentage was only 5% (Mateke & Tshikae, 2002).
- Use a loose sandy mix (such as rich soil mixed with sand or vermiculite or jute-covered sand) as the substrate and ensure that it is kept moist but not waterlogged. After watering, they can be covered by jute or black plastic sheeting, and signs of germination (emergence of the radicle) may be evident within 24 h. Unless germination takes place where the seedling is to grow further, transfer should be undertaken at this stage.
- Directly sow into large (four litre) plastic bags or pots, or grow seedlings in deep (>50 cm) seedbeds for germination and later bareroot transplanting. Endocarps should be covered with sand to a depth equalling the diameter.

Germination is epigeal. A thick, pale radicle initially emerges, and then the pinkish-red hypocotyl, which elongates, bends and ultimately pulls the flat, fat, oily cotyledons from the endocarp and raises them above the growing medium. Once exposed, the cotyledons change colour from white to green before shrivelling and turning brown as the true leaves develop (Msanga, 1998). The swollen seedling root shrinks as its food reserves are utilized and the system of true lateral and vertical roots develops.

Stems should reach knee height before being transplanted to the field. This will take 2.5-6 months, depending on the climate, substrate, and watering regime. With container-grown subsp. *birrea* in Burkina Faso (Nikièma *et al.,* 1993), watering is carried out twice daily and the containers are relocated or root-pruned monthly. After re-potting or root pruning, shade is provided for two days. Subsp. *birrea* seedlings in Burkina Faso remain in the nursery for 11 weeks, by which time they are 20-30 cm tall.

The susceptibility of seedling root systems to physical damage makes direct sowing into final growing stations a realistic alternative to reliance on nursery stock. Pre-treated (soaked, and possibly with the opercula loosened or removed) endocarps are used, planted at 10 m spacing (Maruzane *et al.*, 2002). Mateke & Tshikae (2002) found indications that in subsp. *caffra* early height growth (after 100 days in the field) was enhanced by association with arbusco-mycorrhizal fungi. The inoculum used contained *Acaulospora trappei*, *Acaulospora* sp. and *Glomus claroideum* Schenk & Smith. Bâ *et al.* (2000) have undertaken inoculation of subsp. *birrea*, also with arbusco-mycorrhizal fungi, through a nursery trial lasting three months. Two species of *Glomus* were used as inoculants – local *G. aggregatum* Schenk and exotic *G. intraradices* Schenk & Smith. Surface-sterilized (sulphuric acid) endocarps were sown and maintained in conditions of 12 h light per day at 30°C, with daily watering to field capacity. At assessment after three months, mycorrhizal associations had developed with both fungi, root colonization being estimated at 70%. There was no detectable effect of inoculation on seedling biomass production (3-4 g seedling^{-1}), or shoot potassium concentration (0.8%), but inoculation with *G. aggregatum* raised shoot phosphorus concentration from 0.06% to 0.11%. Relative mycorrhizal dependency was concluded to be low (15-20% with *G. aggregatum*; 4-5% with *G. intraradices*) and subsp. *birrea* classed as “marginally dependent” for both inoculants.

8.2.1.3 Storage

The seed of subsp. *caffra* has been described as orthodox and amenable to storage for future use by Msanga (1998). However, without reference to subspecies, Were & Munjuga (1998) suggest *Sclerocarya birrea* seed is "intermediate" in terms of retention of viability because of a high germination percentage (39%, with opercula loosened) after one year's storage. At the other extreme, Mbuya *et al.* (1994) report, for subsp. *caffra* in Tanzania, that seed viability is three months at ambient temperature.

In southern Africa, dormant seed for nursery and planting activity is stored through the winter/cold season (up to 7-8 months) under closed but ventilated, cold, dry conditions. It has been suggested (Maruzane *et al.*, 2002) that dark conditions are also desirable. Prior to storage, seed is dried to a moisture content below 10%. Teichman *et al.* (1986) record successful germination from three years old endocarps of subsp. *caffra* in South Africa. The viability of well-stored seed is retained for an estimated 4 years, after which is gradually lost (Msanga, 1998). If they are to be transported, the dry endocarps are packed in cotton bags, plastic drums or cardboard boxes.

8.2.2 Vegetative propagation

Vegetative propagation of *Sclerocarya birrea* is important for two main reasons. Since the plant is dioecious, the planter may want to have more female, fruit bearing trees, than male pollinators. Also, the fruit quality of trees varies greatly. Experience has shown that young trees of subsp. *caffra* readily produce coppice shoots (Mbuya *et al.*, 1994) indicating that it should be relatively easy to capture some of the existing genetic diversity using vegetative propagation methods. Shone (1979), expresses doubt over how often trees arising from coppice shoots attain the sizes reached at maturity by individuals which have grown directly from seed. Several methods of vegetative propagation have been tested with. *Sclerocarya birrea*: branch cuttings with juvenile wood, truncheons, budding, air layering, root severance and grafting (Maruzane *et al.*, 2002).

8.2.2.1 Grafting

Grafting seems the most promising means of vegetative propagation for *Sclerocarya birrea* and has been used successfully in Botswana, South Africa and Zimbabwe. For subsp. *caffra* fruiting of scions has been observed within short periods of carrying out grafting. Taylor & Kwerepe (1995) report fruit production, in Botswana, from half of 20 grafted plants in the fourth year after grafting, and fruiting after two years in one case (although there were no fruits in the subsequent year). Maundu *et al.* (1999) note fruit production in subsp. *caffra* three years after grafting.

Grafting can be carried out on established saplings/young trees or on specially raised seedling rootstocks. The most commonly used technique is top wedge grafting. Trials have shown that grafting *Sclerocarya birrea* is most successful when carried out immediately after dormancy breaks (around September in Southern Africa) using scion material from the tips of branches (Holtzhausen *et al.*, 1990; Taylor & Kwerepe, 1995). Because the tissue of excised scions hardens relatively fast, use of sharp grafting knives to detach scions is advisable. According to Maruzane *et al.* (2002), scion wood is best collected in cool late evening or early morning conditions to avoid temperature induced moisture loss. Success rates of over 95% have been reported (S. Mateke, pers. comm.), based on the following procedure:

- Use seedlings whose stem diameter is at least pencil thickness, and chose healthy scions from superior mother trees. The scion has to be of the same diameter as the rootstock for optimal graft take, although slightly thinner or slightly thicker scions can also perform well. Cut any leaves off the scion, but leave some on the rootstocks below the graft union.
- Decapitate the rootstock at or above 20 cm (two hand widths) from the old surface and make a 1-2 cm (thumb width) deep vertical cut.

- Cut the basal end of the scion into a wedge with a slicing (not pressing) movement.
- Insert the scion into the rootstock ensuring a tight match of the clearly visible green cambial rings. It is most important that the green rings of both scion and rootstock match perfectly. There should be some of the cut on the scion visible above the surface of the rootstock, so that callus growth will strengthen the graft union.
- Tie the graft using thin plastic strips.
- Cover the graft with a plastic bag or move the grafted plant into a greenhouse. In either case keep the newly grafted plants under shade.
- The graft should take within 4-6 weeks, by which time new leaves will be sprouting from the scion. Remove any shoots that might develop on the rootstock.
- After 6-8 weeks, remove the plastic cover and tying material and move the plant from the greenhouse into a shaded area.
- Gradually harden the plant to full sunlight.

Whip grafting was used in Botswana by Mateke & Tshikae (2002) to combine scions from selected wild trees with the rootstocks of spring-raised nursery seedlings 12 months old grown at 50% of full daylight. In terms of "biovolume" (mm height x mm stem diameter), after 36 months in the field, grafted plants (mean biovolume 15 329) were significantly larger than non-grafted plants (mean biovolume 11 222).

8.2.2.2 Cuttings

Cuttings are pieces of stem or shoot induced to grow their own roots and shoots. Various media have been successfully used for raising cuttings including soil, sand, humus, sand/soil mixtures and the more costly vermiculite (Maruzane *et al.*, 2002). Stem cuttings are usually most successful when taken from young seedlings which have not yet expressed their sex so, although the propagation of *Sclerocarya birrea* is possible from such cuttings, their use is of limited value because of the dioecy of the species. However, stem cuttings can be used to produce clonal rootstocks for later grafting. Shone (1979) suggests use of young growth from branch tips, taken when the buds are swelling.

More successful than small leafy cuttings from immature plants is propagation through truncheons. Shone (1979) suggests these should be 10 cm in diameter and 2 m long, with the proximal 0.6 m inserted in the ground, and that it is important to keep the surrounding soil damp. More slender truncheons, about 5 cm diameter, are suggested by Taylor & Kwerepe (1995), and stouter ones (as much as 15 cm diameter) by Wyk (1972-1974). Truncheons can be cut from mature trees and will generate trees of the same sex as the source plant. Rooting hormones can be used to enhance rooting from truncheons but are not essential and, provided there is enough moisture, roots are usually readily produced from the buried butt ends (Maruzane *et al.*, 2002).

Root severance promotes suckering from the detached root branches. The severed end is left protruding from the soil surface and shoots develop around the perimeter (Maruzane *et al.*, 2002).

8.3 PLANTING

Within the natural range of *Sclerocarya birrea*, planting initiatives have been reported from a number of countries but have always been on a small scale or of single trees, and generally experimental or ornamental. For subsp. *caffra*, Keet (1950), Shone (1979) and Campbell (1986) refer to planting in Namibia, South Africa and Botswana, respectively. Shone's report suggests attempts to promote planting more widely, as he refers to sales of seedlings. For subsp. *birrea*, Delwaulle (1979) refers to planted trees in West Africa, while more purposeful planting is recorded for Ghana (Stewart, 1942 – forest restoration) and Senegal (Mailly *et al.*, 1994 – dune fixation).

Sclerocarya birrea trees are planted during the rainy season (from November to February in the Southern Hemisphere; November/December and March/April under bimodal rainfall regimes; July and August in West Africa). In subtropical latitudes, they need moisture to grow after a cold spell. Mature trees generally reach about 12 m in height with crowns 8-16 m in diameter. The crowns of grafted trees are smaller. Ungrafted trees should be planted at least 10 m apart; 6 m is suggested as the minimal interval between grafted trees.

Planting holes should be made 80 cm deep and 80 cm wide and square, as round holes encourage roots to grow in a circle causing poor anchorage. Dig out the first 40 cm of topsoil and put it in a pile. Dig out the next 40 cm of subsoil and put it in another pile. Mix 5 kg of compost or old manure with the topsoil and return to the hole. Fill the hole with half of the remaining subsoil and use the rest to make a small wall or dam in a circle 50 cm from the edge of the hole. This will help collect water and improve water infiltration. Mulch the hole with grass or other material to reduce water loss and then water. The hole should be left for one week before the tree is planted. Never use fresh manure as it will burn the roots.

Whilst still in the four litre container, the sapling should be watered two hours prior to planting out. A hole should be made within the prepared planting hole that is the same size as the container from which the seedling is being transferred. Carefully tear off the plastic bag, making sure the soil is not taken away from the roots, and place the seedling into the hole maintaining the current soil level. It is very important to prevent disease attacks that the current soil surface is maintained and the seedling is not planted any higher or lower than previously. In the case of grafted trees it should be ensured that the graft union is at least 20 cm above ground level.

When planting a bare root seedling, place in a bucket of water for two hours prior to planting. Seedlings being transferred from another location should be watered *in situ* before they are dug up. Ensure that the hole prepared for planting is bigger than the roots of the seedling and make a small mould in the hole. Root contact with soil can be inhibited by an intervening layer of air and once planted the roots will not receive nutrients and water. Roots should therefore be coated with sand so that are not in contact with the air. Residual air can also be removed by spreading the roots out sideways from the trunk and putting two spades of soil on top of the roots and then shaking the trunk. The seedling should then be placed on the mould in the hole, again ensuring for grafted saplings that the graft union remains 20 cm above the soil level once covered. Carefully place the soil around the roots to fill the hole and compress to the soil around the sapling to ensure that it is straight and sitting firmly.

When the seedling has been planted, mound up the small dam made during preparation of the hole and water the sapling with 40 litres or two buckets of water. This will further dispel the air spaces from the roots. A mulch, such as dry grass, newspaper, rocks or plastic, should be applied around the tree without touching the stem, otherwise stem rot or other diseases from wet mulch can result. To prevent wind damage, the sapling should be tied to a stake in the ground for support. Newly planted trees should be protected against animals by fencing around each tree with wire, poles or branches bound together.

8.4 MANAGEMENT

Recorded management experience seems limited to measures to promote vigorous growth as trees grow to maturity. There are no accounts of systematic single-tree management to control crown shape, size or depth using lopping, pollarding or pruning. However, reference to judicious lopping to obtain fuelwood or fodder in Zimbabwe (P. Sola, pers. comm.) could well be combined with such manipulation.

8.4.1 Tending

Sclerocarya birrea grows best in areas with no frost, generally hot, and where the air is dry. Young plants can be damaged by frost but can survive drought. Frost damage can be avoided by tying sacking or grass around the trees during the winter months for the first two years after planting. *Sclerocarya birrea* needs direct sunlight to grow and for the fruit to ripen and trees should therefore be grown under such conditions. Protection from wind is equally important because strong winds can break shoots, dry out new leaves, reduce or arrest growth and blow flowers and fruits off the trees.

Sclerocarya birrea grows in a range of soil types but does not flourish where drainage is poor. As its roots penetrate deeply, the soil where the trees are planted should be at least 3 m deep. Dry, sandy soil with high aeration promotes the production of more fruit. Compost or manure should be used during the first year after planting, applied as 5 kg per tree at the start of the rainy season and supplemented with a further 5 kg towards the end of the rainy season.

During the first two years after planting 10 litres of water should be supplied every two weeks to each tree, except during rainy periods. An easy and cheap way to water young trees during this initial two years period is by drip-feeding via a small hole in the bottom of a two litre plastic bottle positioned in the soil near the seedling. The bottles are refilled every two weeks.

8.4.2 Fruiting

Numerous comments on fruit crops have been published for subsp. *caffra* (Table 8.2) but most concern opportunistic observation of heavy crops and not systematic monitoring. Fruit crop data are rarely supported with information on the sizes of the trees assessed but C. Shackleton (2002) has established a positive relationship in each of three mean annual rainfall categories in South Africa (24°30'-25°00'S; 31°00'-31°35'E; 550 m). It has also been suggested (Fox & Young, 1982) that fruit size (and, therefore, weight) is related to the previous season's rainfall.

Shackleton's equations, which assume 65.3% moisture content in fruits in the fresh state, are:

Arid (*ca* 500 mm): $\log_{10}$ fruit dry mass (g) = 0.00036 basal area (cm^2) + 3.12

Semiarid (*ca* 670 mm): fruit dry mass (g) = 12.1 basal area (cm^2) – 4513

Mesic (>850 mm): fruit dry mass (g) = 6.48 basal area (cm^2) + 994.

These equations indicate the fruit crops shown in Table 8.3. Leakey *et al.* (in press, a) have reported variation in fruit traits (mean mass per fruit of pulp, separated into skin and flesh, and of entire fruits) with locality for several sites in South Africa and Namibia. Namibian fruits, having more flesh, were larger, and in South Africa larger fruits were borne on trees in farmers' fields than on trees in woodland or on communal land.

Individual trees clearly vary markedly in the crops produced in a season and Todd (2001) and C. Shackleton (2002) highlight the frequency of seasonal crops far lower than the widely cited values reported by Quin (1959) and Moss & Taylor (1983), although C. Shackleton (pers. comm.) has noted much higher yields on homestead trees than on trees in wild populations (perhaps reflecting the influence of selection or management, or both). Todd (2001) recorded, from single day, mid-season (January) counts, fewer than 500 fruits for most of the 40 individuals examined. In several cases <10 fruits were counted, and for only three individuals did counts exceed 1500 fruits. C. Shackleton (2002), for the same area of South Africa's Limpopo Province, had found a similar situation a few years earlier but reports somewhat higher numbers because observations extended through the entire fruiting season. Fruiting is thought to occur in cycles of years of high yield followed by years of scarce fruit set. However, year to year variation within individuals has received little systematic study, although both Todd (2001) and C. Shackleton (2002) assessed sets of the same individuals in two successive fruiting seasons. Todd counted <10 fruits on the same six individuals both years, possibly an indication that persistently low yielding individuals are not infrequent. Counts for most other monitored individuals were lower, sometimes dramatically, in 2001 than in 2000. C. Shackleton recorded no fruiting in the second (1994/1995) season for most of the 64 individuals monitored and small crops on the others, while Todd (2000) concluded that not all reproductively mature trees in populations in South Africa's Limpopo Province were reproductively active within the same season or year.

Among eleven trees monitored at Gabane, Botswana (Moss & Taylor, 1983), fruits fell over an extended period and in one instance a daily drop of 13 370 fruits (21% of the season's crop) was recorded. 3000-4000 fruits falling per tree in a day were not unusual. Individuals with a small seasonal crop completed fruit drop relatively quickly, in 2-3 weeks (Moss & Taylor, 1983). Fruit yields from prolific individual mature trees at full production may reach 1600 kg (approximately 90 000 fruits), and exceptionally over 3000 kg (Taylor, 1985; Taylor & Kwerepe, 1995).

Table 8.2. Fruit production and fruit fresh weights of *Sclerocarya birrea* subsp. *caffra*

Locality	Fruits per tree	Fresh weight of fruit per tree (t)	Fresh weight per individual fruit (g)	Duration of fruiting season	Comments and reference
Botswana (Gabane)	Mean: 36550; Range: 17445-66822	0.550	15	Collectively 12 Feb-19 Apr; individually from 15 days (15 Feb- 1 Mar) to 57 days (22 Feb-19 Apr)	11 individuals monitored in 1982 (Moss & Taylor, 1983)
Botswana (Gabane)	32				Tree 6 years old and 3.4 m tall (Moss & Taylor, 1983)
Botswana	35000		30		"Average" fruit crop per individual and "average" fruit size (Taylor *et al.*, 1996)
Botswana			70-98		"Superior" fruits (Taylor *et al.*, 1996)
Botswana	70000	0.570	8		(Shackleton *et al.*, 2001)
Botswana (eastern); mean annual rainfall 550 mm	1004				Mean values (ten 'superior' individuals) in the least productive (1997) year in the period 1997-2001 (Mateke & Tshikae, 2002)
Botswana (eastern); mean annual rainfall 550 mm	13402				Mean values (ten 'superior' individuals) in the most productive (1999) year in the period 1997-2001 (Mateke & Tshikae, 2002)
Botswana (eastern); mean annual rainfall 550 mm	>1500		40		Individuals with 'superior' fruit crop: 11.4 m tall; 78 cm diameter; 9.1 m crown diameter (Mateke & Tshikae, 2002)
South Africa (Zebedelia, Transvaal)	91272	1.647	18	Season: 64 days (30 Dec-2 Mar)	One individual monitored December 1951-January 1952 (Quin, 1959)
South Africa (Zebedelia, Transvaal)	21667, 21967, 28939			Seasons: 24 days (2-25 Jan); 42 days (17 Jan-28 Feb); 45 days (21 Jan-6 Mar)	Three individuals monitored January-March 1952 (Quin, 1959)
South Africa (Tzaneen, Transvaal)	9601	0.270	28		Single tree (Shone, 1979)
South Africa (Western Transvaal)	2000				Single "Smaller" individual in "unfavourable circumstances" (Peters, 1988)
South Africa		1.000			Generalized estimate (Holtzhausen *et al.*, 1990)
South Africa (24°30'-25°00'S; 31°00'-31°35'E)	1753±343 (mean ±standard deviation)	0.037±0.008 (mean ± standard deviation)	20.6±0.7 (mean ± standard deviation)		64 individuals monitored in 1993/1994 season (Shackleton, in press)
South Africa (Klaserie and Tshipse)		0.017 (1999/2000) 0.004 (2000/2001)			122 (1999/2000) and 40 (2000/2001) individuals monitored; some fruit probably missed (Todd, 2001)

Table 8.2 (continued). Fruit production and fruit fresh weights of *Sclerocarya birrea* subsp. *caffra*

Locality	Fruits per tree	Fresh weight of fruit per tree (t)	Fresh weight per individual fruit (g)	Duration of fruiting season	Comments and reference
South Africa (Klaserie, Northern Province)	794 (1999/2000), 354 (range 5-1055, 2000/2001)				20 individuals monitored in 1999/2000 and 2000/2001 seasons (some fruit probably missed) (Todd, 2001)
South Africa (Tshipse, Northern Province)	642 (1999/2000), 95 (range 15-229, 2000/2001)				20 individuals monitored in 1999/2000 and 2000/2001 seasons (some fruit probably missed) (Todd, 2001)
Zambia	2036				Mean of 111 individuals from one month of Monitoring (Lewis, 1987)
Zimbabwe (Matopos)	6900-12100				Range of yields in five seasons (Shackleton, in press)

Table 8.3. *Sclerocarya birrea* subsp. *caffra*: Projected fruit crops (kg fresh weight) based on allometric equations, in relation to tree diameter

Climate	Tree diameter (cm)			
	40	50	60	70
Arid	11	19	40	92
Semiarid	30	56	87	120
Mesic	26	40	56	75

Fruit are usually collected off the ground soon after falling, because trees are too high to climb. After collection, fruits continue to ripen and can be stored on the ground or on shelves. Fruits should be processed or consumed within a few days (Redelinghuys *et al.*, 1976; Weinert *et al.*, 1990), as they ripen quickly and attract fruit flies (Schoeman & Wet, 1987). The fruit ferments rapidly, due to a high sugar content, and rots very quickly.

8.4.3 Pest and disease control

Apart from damping off and root collar restriction caused mainly by fungal attacks, no major nursery diseases of *Sclerocarya birrea* have been reported. It is, nevertheless, susceptible to a variety of pests and diseases, including insect pests and pathogenic fungi, particularly Ascomycetes (Tables 8.4 and 8.5). Other potential nursery problems arise from susceptibility to continuous root disturbance and mortality due to excessive root pruning at shallow depth.

Table 8.4 Pests of *Sclerocarya birrea*

Pest	**Scientific name**	**Symptoms / damage**	**Control**
Thrips	*Heliothrips haemorrhoidalis* and *Selenothrips rubrocinctus*	Cause light brown blemishes on the skin of the fruit.	Spray malathion.
Fruit flies	*Pterandrus rosa*	White larvae in ripe fruit, causing the fruit to rot.	Spray with a mixture of malathion and sugar in large drops.
Locusts	Species not yet identified	Attack seedlings	
Mites	Species not yet identified	Mites damage the flower buds; flowers are malformed, flower stalks turning black and woody. Also damage young shoots causing young leaves and stems to become malformed. Young trees remain small, while old trees develop galls in the folks of the branches.	Destroy infected trees.
Nematodes	Species not yet identified	Old trees begin to die. Roots do not have the usual colour, but are shortened and malformed.	Use clean stock and sterilise seedbeds with Bromide.
Scales	*Protopulvinaria pyrifomis*	Three types: two are brown and one is white.	Change pesticides often as scales develop resistance easily.

Table 8.5. Pathogens of *Sclerocarya birrea*

Category	Genus/species	Comments
*Ascomycetes (Capnodiales):	*Capnodium* sp.	Sooty mould
Ascomycetes (Erysiphales):	*Phyllactinia gorterii* Eicker	On leaves (described as a new species – (Eicker, 1988)
Ascomycetes (Erysiphales):	*Oidium mangiferae* Berthet	Powdery mildew on shoots, young leaves and small fruit. A problem in damp weather as in 50% shade netting. (Control: spray Benlate or copper oxychloride)
*Ascomycetes (Erysiphales):	*Phyllactinia* sp.	Powdery mildew
*Ascomycetes (Microthyriales):	*Microthyriella* sp.	
*Ascomycetes (Pleosporales):	*Guignardia citricarpa* Kiely	
*Ascomycetes (Pleosporales):	*Herpotrichia australis* Bose	
*Deuteromycetes (Hyphomycetales):	*Ovulariopsis* sp.	A state of *Phyllactinia*
*Yeasts		Present in fruit
Bacterial spot	*Pseudocercospora pupurea*	Small yellow leaf spots that turn brown. Small green spots on the fruit, which enlarge, break open, turn black and give off a gummy liquid. (Control: copper oxychloride 85% w.q.)

*Source of record: Parker (1978)

9 CONSERVATION

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Sclerocarya birrea displays subspecies and provenance variation. It is also dioecious, and there is a potential sex bias in populations through the preferential retention of fruiting (female) individuals. Both these characteristics necessitate conservation provision for the maintenance of genetic variation and maximising the value of the tree to local livelihoods through selection for preferred characteristics. Thus, although the continued existence of the species is not immediately threatened, conservation awareness is an important aspect of management and conservation strategies need to be developed nationally, regionally and for the area of natural distribution overall. This chapter explores the current status of *Sclerocarya birrea* as a genetic resource, in terms of distribution at the species and subspecies level and genetic variation within populations, and considers current conservation provisions.

9.1 CONSERVATION STATUS

9.1.1 Geographic variation

Making provision for the conservation of a species involves knowledge of its distribution and any links between this and genotypic variation, so that frameworks drawn up for protecting, sampling and evaluating germplasm are comprehensive. In the case of *Sclerocarya birrea*, the great extent of the natural range (Fig. 2.1) can be expected to indicate the presence of regional genetic variation and a number of features of the range are of interest in this regard. The most prominent of these is the presence of largely separate northern and southern sections, connected by only a relatively narrow equatorial belt in eastern Africa. In the northern section, there appears to be one area of high frequency of occurrence from the Senegal coast to Cameroun and another from southern Sudan to Kenya. Between these, the lower number of reports may reflect lower levels of botanical exploration but much of the low-lying terrain of the Nile Basin in this interval is covered with vertisols offering a relatively poor habitat for the species. South of the equator, noteworthy features are the isolation, by an interval of at least 400 km, of the Madagascar occurrences from the nearest ones on the African mainland and a western area of relatively high frequency in south-west Angola and adjoining Namibia. It appears that between south-west Angola and the concentration of occurrences extending from the Indian Ocean coast to southern Zambia and Zimbabwe suitable habitat is limited to a narrow corridor between moister climates to the north and arid climates to the south. Present day climate could be reflected in genotypes of subsp. *caffra* associated with relatively low temperatures inland from the eastern coastal belt ofSouth Africa, and genotypes associated with the relatively arid conditions at the northern border of South Africa and the adjoining parts of Botswana, Mozambique and Zimbabwe.

There is no question that the northern and southern parts of the range support genetically different populations. The morphological distinctions between subsp. *birrea* and subsp. *caffra* are effectively differences between the plants in the northern and southern sections, respectively, of the range. These, and the restricted distribution of subsp. *multifoliolata* (also morphologically distinct), are the strongest physical expressions of regional variation. Special conservation interest applies to the area (Tanzania/Kenya) where the different subspecies occur in proximity, and to how they may be segregated ecologically.

Subspp. *birrea*, *caffra* and *multifoliolata* are the only infraspecific taxa of *Sclerocarya birrea* currently recognized in formal taxonomy. However, in the past, variation within subsp. *caffra*, was noted by Adolf Engler (1895) when he distinguished the more typical form on Madagascar (calling this *Sclerocarya caffra*) from plants in Tanzania with more oblong leaflets (calling these *Sclerocarya caffra* var. *oblongifoliolata*). Descriptions of other infraspecific taxa proposed in the past, with distinctive toothed leaflets (subsp. *birrea* forma *aubrevillea* - Roberty, 1954; subsp. *caffra* var. *dentata* - Engler, 1883), may have been based on typical juvenile foliage and not geographic variation.

There has been some use of approaches that should potentially provide direct evidence of genetic variation. A chromosome count (2n = 26) for subsp. *caffra* has been reported, from Mozambique (Paiva & Leitao, 1989), but additional counts for this subspecies and counts for the subsp. *birrea* and subsp. *multifoliolata* will be needed to expose any variation in chromosome number. Anacardiaceae chromosome numbers vary from 2n = 24 to 2n = 60, and for the related genus *Lannea* values (2n) of 28, 30 and 40 have been reported (Ding Hou, 1978). However, as no other value of 2n = 26 seems to have been reported from the family, verification of this is desirable.

Several recent studies which have used modern genetic tools are of considerable interest, although none of the documents seen refers to herbarium voucher specimens, and without these confirmation of the subspecies represented by Kenyan and Tanzanian populations will be difficult. The foliage of 24 seedling (12) or grafted (12) plants raised from material representing natural populations in Botswana (Gaberone) and South Africa (Kruger National Park), was subjected to random amplified polymorphic DNA (RAPD) analysis by Gutman *et al.* (1999). In another investigation, carried out in 1996-1997, foliar samples from 150 individuals representing 16 populations in eight countries (Botswana, 2; Kenya, 1; Mali, 1; Malawi, 2; Namibia, 2; Swaziland, 2; Tanzania, 4; Zambia, 2) were used for RAPD analysis and complemented with restricted fragment length polymorphism analysis (Agufa, 2002). Agufa's RAPD analysis enabled a cluster analysis based on genetic distance to summarize relations among the 16 populations and estimates of within-population genetic diversity. On the basis of groupings differentiated at the level of 0.04 genetic distance units (accumulated number of gene substitutions per locus), a geographically coherent group of seven subsp. *caffra* populations from Namibia, northern Botswana, Zambia and Malawi emerged, alongside a group of the Swaziland and southern Botswana subsp. *caffra* populations and a group of three Tanzania populations (subspp. *birrea* and *multifoliolata*). The populations from Kenya (subsp. *caffra*) and Mali (subsp. *birrea*) were distinct and isolated, as was the fourth Tanzania population (subsp. *caffra*). Population genetic diversity (Nei's measure of average heterozygosity over all gene loci examined) varied from 0.06 (subsp. *caffra* at Magamba, Tanzania) and 0.08 (subsp. *birrea*, Mali) to 0.18 (subsp. *caffra* at Oshikondilongo, Namibia) and 0.19 (subsp. *caffra* at Mangochi, Malawi), but values within cluster analysis groups varied widely. Five additional Kenya populations, not identified to subspecies, were included by Muok (2000), in a supplementary RAPD analysis, and both Agufa (2002) and Muok (2000) included the Chyulu (Kenya), Mangochi (Malawi) and Missira (Mali) populations in their investigations. Muok found little evidence of groupings among the eight populations in his study, but the six Kenya populations were more closely related to each other than to the Malawi or the Mali population. The closest relationship was of the Chyulu, Meru and Ndumoni populations. However, while Agufa (2002) concluded that the Mali population was the most distinct of those studied, Muok (2000) found the Malawi (Mangochi) population more distinct, possibly because of small differences in the spectrum of primers used to disclose the genetic variation present. The two studies differ also in the estimated values of population diversity, Muok's (2000) value for the Chyulu population (0.17) exceeding that of the Mangochi population (0.16), a reversal of the relative values assigned by Agufa (2002), but agree in the low value (0.08) for the Mali population.

Agufa's (2002) restricted fragment length polymorphism analysis led to the recognition of four chloroplast haplotypes among the 16 populations sampled, relating to some extent to the cluster analysis groupings based on the RAPD work. One haplotype was encountered throughout the geographical range of the study, and represented in both subsp. *birrea* and subsp. *caffra*. This was the only haplotype revealed in the large group of seven populations and in the single population Kenya and Mali groups. The other haplotypes were geographically restricted - two to the Tanzanian populations (one restricted to the subsp *caffra* population at Magamba, and the other in the subsp. *birrea* populations at Mandimu and Mialo and in the subsp. *multifoliolata* population at Makadaga) and one to the Swaziland subsp. *caffra* populations. In both Swaziland populations and in the Mandimu population, the widespread haplotype also occurred.

The analysis of Gutman *et al.* (1999) confirmed the presence of genetic differences between clones but did not indicate consistent differences between populations of Botswanan and South African origin. The results of the other studies indicate that patterns of variation are subject to influences additional to geographic location.

9.1.2 Local variation – ethnotaxonomy

As with other geographically widely ranging useful tree species, such as *Parkia biglobosa* (Hall *et al.*, 1997), local communities can be expected to recognize different varieties of *Sclerocarya birrea*. However, this is an aspect of the species which has been almost totally neglected in published accounts. The exception is Quin's (1959) report, which has also been highlighted (although without amplification) by several later authors. Quin draws attention to the three varieties of female trees of subsp. *caffra* recognized by the Pedi communities of Limpopo Province, South Africa. The distinctions drawn are based on the taste and smell of the fresh fruits:

- *Morula o mobose* – the preferred variety, by virtue of the sweet fruits. Individually protected trees in rural areas tend to be of this variety.
- *Morula wa gobaba* – a variety distinguished on account of the sourness of the fruit and unpopular.
- *Morula wa go nkga* – a variety distinguished on account of an objectionable fruit odour.

9.1.3 Population characteristics

Sclerocarya birrea is a sparsely distributed tree with low natural stocking levels reported (for both subsp. *birrea* and subsp. *caffra*) from various countries through the range. Parkland situations in the sense of Boffa (1999), equating approximately to White's (1983) category of "Anthropic landscapes: wooded farmlands", and wooded grasslands subject to high levels of human impact (pastoralism, commonly associated with annual burning), account for most *Sclerocarya birrea* populations. With rare exceptions, in these open communities stocking levels are <1 individual ≥10 cm dbh per hectare, even when *Sclerocarya birrea* is one of the commonest large species. As it is not unusual for the species to exceed 80 cm dbh, individuals >50 cm dbh often comprise high proportions of those which are reproductively active. Poor representation of seedlings, saplings and immature trees has often been revealed during assessments of the species. In the case of subsp. *caffra* in a protected area at Nylsvley, South Africa, Walker *et al.* (1986) offer episodic regeneration success, at intervals possibly exceeding 10 years, as the explanation.

9.2 CONSERVATION THREATS

Expanding rural settlements and increasing numbers of people and pastoralist livestock are changing Africa's grazing lands and parklands. On grazing lands tree cover is being reduced by overexploitation for browse and fuelwood (Houérou, 1989) and, with mean annual rainfall >600 mm, fires late in the dry season have a more destructive impact on small woody plants. In parklands of the kinds which contain *Sclerocarya birrea*, fallow phases are becoming shorter, even being eliminated in extreme cases (Boffa, 1999). These changes have implications for the sustainability and character of *Sclerocarya birrea* populations.

In the face of the changes, the frequency of reports that regeneration is deficient are cause for concern, even if the idea of episodic (Walker *et al.*, 1986 – subsp. *caffra*; Delwaulle, 1975 – subsp. *birrea*) regeneration is accepted. Dispersal is the initial stage of regeneration and it is suggested by Lewis (1987) that the principal natural disperser of subsp. *caffra* is elephant, whose natural range includes all the mainland African range of all three subspecies of *Sclerocarya birrea*. Elephants have, in effect, been eliminated from the areas where most *Sclerocarya birrea* populations are located, but the large *Sclerocarya birrea* individuals typifying the present populations may have become established before the elephant population was displaced.

Today, cattle and human beings play dispersal roles and the change in disperser may affect regeneration success. Where cattle are concerned, the seedlings (Delwaulle, 1979 – subsp. *birrea*) are palatable and at risk if cattle remain in, or return to, the vicinity. In contrast, elephants apparently do not select the seedlings as browse. Livestock are thus one threat to the survival of young *Sclerocarya birrea* in grazing lands. Fire is another. Shone (1979) suggests that it is necessary for young plants of subsp. *caffra* to escape fire for the first three years to become securely established.

Seed discarded when local people have eaten fruits, has enabled many young trees to become established along roadsides (Shone, 1979). Many roadside sites, especially those which are fenced or in urban areas, are subject to relatively low grazing pressure. However, they are public spaces (Rocheleau *et al.*, 1988) with weakly defined ownership and informally managed and often treated as common property. In the absence of regular fires, significant livestock use or food-cropping, aggressive woody plants invade such sites and modify their ecology. Shone (1979) expresses concern over encroachment by the thicket-forming caesalpiniaceous exotic *Caesalpinia decapetala* (Roth) Alston at Sibasa, near South Africa's northern frontier, preventing the successful regeneration of subsp. *caffra*.

The parkland environment exposes the populations to a different combination of threats. The main one is the frequent land preparation for crop planting. In the course of this process, regenerating woody vegetation is destroyed before it can reach a size where its potential is recognized and becomes retained as part of the stand of parkland trees. Loss of mature parkland trees without replacement is an inevitable consequence simply of natural mortality. In the case of *Sclerocarya birrea*, fuelwood demands and tree removals to simplify use of animal or mechanical traction in land preparation invite selective male tree culls. This increases separation distance between pollen sources and female trees. It may also, therefore, reduce the quantities of pollen reaching receptive female individuals which are retained. However, there are reports (Shone, 1979 – subsp. *caffra* in South Africa) of caution being exercised over removal of non-fruiting (*i.e.* male) trees, and these are consciously retained because their presence is associated with good fruit harvests.

Shone (1979) for subsp. *caffra*, and several authors for subsp. *birrea* in West Africa, identify severe drought as a major threat to populations of *Sclerocarya birrea*. Shone (1979) reports the susceptibility of larger trees when there are extreme drought events, underlining drought as a threat to parkland populations of *Sclerocarya birrea*, in particular.

In West Africa, there has been more detailed appraisal of drought impact on woody species. For two decades the subsp. *birrea* populations of northern Senegal, at the drier limit of the natural range, have progressively declined (Akpo *et al.*, 1995). This seems indicative of events over an extensive area in West Africa where subsp. *birrea* grows under low (<600 mm) mean annual rainfall. The impact of the 1970-1973 drought (Houérou, 1989) has been a fall in the relative numbers of more mesophytic species (including *Sclerocarya birrea*) compared with more xerophytic species. The decline continued in the 1979-1982 period, during which the subsp. *birrea* population in the Senegal Ferlo suffered 15.6% mortality (Houérou, 1989; Berger *et al.*, 1995). After the 1983-1985 drought, 11-15% of standing trees of subsp. *birrea* at Faira, Niger, were dead (Bergeret, 1986). In Senegal, away from valley bottoms, subsp. *birrea* populations in low rainfall areas (mean annual rainfall 350-600 mm), suffered higher mortality than any other woody species in this drought (Breman & Kessler, 1995).

9.3 CONSERVATION OPTIONS AND INITIATIVES

No framework for the conservation of *Sclerocarya birrea* has been published. However, various actions of some conservation relevance have been taken, including measures to strengthen capacity to use the genepool more effectively (FAO, 1994, 1996). It is also apparent that progressing from protection of existing natural genepools to instigating measures ensuring their longer-term future will require deeper, and more geographically comprehensive, understanding of the population ecology of the species.

9.3.1 Domestication

Steps towards the domestication of *Sclerocarya birrea* have been taken. However, while recorded plantings of the species date back to the first half of the last century (*e.g.* Stewart, 1942 – subsp. *birrea*; Keet, 1951 – subsp. *caffra*), planting as a declared prelude to formal domestication programmes is recent. The momentum behind these has been awareness of variation within the subspecies at the local, and on more extensive, scales - particularly in the characteristics of the fruits. An initial suggestion of attractive qualities was expressed, for subsp. *caffra*, by Teichman (1983) – large fruits with small stones, anticipating emphasis on juice production. Recent work with subsp. *caffra* (Leakey, in press) based on fruit, including endocarp and kernel, evaluations for a number of Namibian and South African localities, has revealed a low incidence of trees producing fruits approaching desired fruit and kernel ideotypes. This underlines the importance of tree improvement programmes for the species and suggests that if these were successful, there could be considerable enhancement of product quality. For subsp. *birrea* (International Board for Plant Genetic Resources, 1984), a wider range of characteristics, not all of which can be combined, has been specified - large seeds with high oil content; small-seeded fruits with a high proportion of edible flesh; less toxic, more palatable foliage. In Kenya, where both subsp. *birrea* and subsp. *caffra* occur, G. Mwachala (pers. comm.) notes that the latter subspecies is considered to have more useful fruits, although this is somewhat at variance with C. Ruffo's (pers. comm.) observation that local people in Tanzania make no distinctions between subspecies.

The first major domestication initiative with subsp. *caffra*, in progress since 1980, was the Marula Improvement Project of the University of Pretoria, which has also involved the South Africa Council for Scientific and Industrial Research (Goosen, 1985; Holtzhausen, 2001). Nursery routines for seedling production and procedures for grafting scions of superior quality material on to nursery produced seedling rootstocks were developed within ten years and research orchards established. Interest in this project has centred on finding high yielding wild trees with superior fruit quality (large, juicy, correct sweet-sour flavour balance) and propagating these. Currently, the ideal fruit sought is large (100 g), juicy (60% juice, with 20% total soluble sugars) and with very high Vitamin C content and Holtzhausen has suggested such fruits will be found in populations in the Kruger National Park, South Africa. Holtzhausen has also speculated that the Kruger National Park populations of subsp. *caffra* represent the largest genepool of wild variants of the taxon (Shackleton *et al.*, 2001).

Female clones have been selected on the basis of individual fruit size and quality and yield per tree with a view to registration as cultivars. A male clone, to provide ornamental trees, is based on potentially large size. The first four cultivars to be considered for registration have been indicated by Holtzhausen (2001):

- "Chopperula" (from Skukuza Airport, South Africa): tree yield >1 t fruit per year; individual fruits of 20 g; 16% sugar; 1% acid
- "Phalurani" (from Phalaborwa, South Africa): tree yield >1 t fruit per year; individual fruits to 98 g; 60% juice; 10% sugar; 1% acid
- "Mhalarula" (from Mhala, near Kruger Gate, Kruger National Park, South Africa): tree yield >1 t fruit per year; individual fruits to 85 g; 10% sugar; 1% acid
- "Nqawanarula" (from Pafuri, South Africa/Mozambique border area): a cultivar based on a male individual.

A second significant domestication programme has been the Israel research and development project "Introduction and domestication of rare and wild fruit trees to the Israeli Negev Desert", which commenced in 1984 (Nerd *et al.*, 1990), in which *Sclerocarya birrea* (subsp. *caffra*) was one of forty species included. In this project interest is in domestication beyond the limits of the natural range. An initial 10 years phase therefore centred on assessing survival, growth, phenology, yields and seedling quality (Mizrahi & Nerd, 1996). Nursery procedures enabling near-perfect levels of seed germination were developed early in the project and, using one year old nursery-raised seedlings, introduction orchards (each of about 30 plants) were established over the 1985 to 1987 period (Nerd & Mizrahi, 1993). *Sclerocarya birrea* was considered worth taking forward to the second phase (economic aspects) of the programme and, initiating this, additional test plots of grafted clonal material were established (Mizrahi & Nerd, 1996; Gutman *et al.*, 1999). As in the South Africa project, cultivar registration is anticipated, including adoption of DNA fingerprints as registerable characteristics for morphologically indistinguishable proprietary cultivars (Gutman *et al.*, 1999).

Domestication programmes with subsp. *caffra* are also underway in Botswana, particularly for phenotypes with unusually large and sweet fruits (Taylor, 1985; Taylor & Kwerepe, 1995), and Namibia, particularly for kernel oil production (Krugman, 2001). For Botswana, nursery routines for seed germination and raising containerised and seedbed stock, and grafting, have been standardized (Taylor & Kwerepe, 1995). The main activities in the Namibia programme concern oil extraction rather than propagation-refining procedures.

Together, the four domestication programmes have utilized germplasm of subsp. *caffra* from three contiguous countries: Botswana (Israel project; Botswana initiative), Namibia (South Africa project; Namibia initiative), South Africa (Israel project; South Africa project). This limits the conservation significance, particularly as detailed attention has been restricted to a small number of phenotypically attractive sources, but the horticultural knowledge accumulated will be advantageous for wider conservation initiatives.

9.3.2 Evaluation

Geographically more comprehensive programmes to survey and evaluate *Sclerocarya birrea* have been urged through the FAO Panel of Experts on Forest Gene Resources in the last 10-15 years. At the 8th meeting of the Panel (FAO, 1994), *Sclerocarya birrea* was listed as an African priority species, with the need for population studies, and provenance and progeny studies stressed. At the 9th meeting of the Panel (FAO, 1996), regional initiatives taken in West Africa (subsp. *birrea*), and in southern Africa (subsp. *caffra*), were noted. In contrast with the domestication programmes mentioned above (9.3.1), the priority of the programmes reported by the Panel is not commercial domestication. Their immediate aim is to establish a sound technical basis for the improvement of *Sclerocarya birrea* germplasm, and the optimisation of its use by rural communities.

The West African activities are organized by the Comité Permanent Inter-États de Lutte contre la Sécheresse au Sahel (CILSS) and involve the francophone countries bordering the southern Sahara, from Senegal to Tchad. The programme in southern Africa is co-ordinated by the World Agroforestry Centre and involves the Southern African Development Community (SADC) countries of Botswana, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe. Collection of provenance material to represent the populations of individual countries has been guided by farmer-selection, and in the case of Tanzania has been extended to include subsp. *birrea* and subsp. *multifoliolata*, in addition to subsp. *caffra*. Germplasm exchange has taken place and multilocational trials, with three populations from each country, except Swaziland (one population), have been established in Malawi, Tanzania, Zambia and Zimbabwe (Kindt & Were, 2000). Ngulube (2000) reports that, even in the early years, at the Malawi trial site provenance differences were emerging, including faster height growth by Tanzanian provenances. In addition to its participation in the SADC programme, Swaziland has initiated a national provenance trial (Edje, 2000). Muok (2000) indicates that a Kenya national trial is also being established.

9.3.3 Management

To complement domestication and evaluation initiatives, management strategies for conserving genetic variation in the natural populations are needed. Natural populations of *Sclerocarya birrea* are not at present subject to active management, even though they are all exposed to influences suppressing or restricting regeneration. However, each of the three main management contexts of protected areas, grazing lands and parklands invites certain management approaches.

9.3.3.1 Protected areas

Many protected area populations have the advantages that seed dispersal is still efficiently effected by elephants and that the negative impacts of free-ranging livestock are minimal. *Sclerocarya birrea* is sometimes a keystone species in these circumstances, especially in the case of subsp. *caffra* (Shackleton *et al*., 2002), and more generally is a flagship species meriting special management consideration as old, full-sized individuals are strikingly attractive in their own right and fruiting individuals are seasonally focal points for wildlife activity. In protected areas, the most serious threat to the establishment and survival of *Sclerocarya birrea* regeneration is wildfire, making the timely implementation of appropriate fire management practices an essential conservation tool. Some protected areas of particular importance where *Sclerocarya birrea* is concerned have strong traditions of including fire regulation in management routines, the prime example being the Kruger National Park, South Africa (Wyk, 1970; Eckhardt *et al.*, 2000). As normally implemented, however, fire management schedules operate to contain woody growth, and favour grasses at its expense (Wyk, 1970). In contrast to regenerating individuals, the principle threat to older individuals is severe drought.

Successful promotion of regeneration will offset the risk of loss of older individuals through drought. Areas where there are concentrations of *Sclerocarya birrea* individuals need to be distinguished and regeneration encouraged within them by preventing severe fires with early-burn measures in combination with years of fire exclusion. This is not always necessary, however, as high concentrations of large herbivores may suppress the grass layer to an extent precluding controlled burning. Under these circumstances, it is likely to be browsing that is suppressing regeneration and while existing plants may increase in size, recruitment is negligible or lacking. Exclosure approaches are an option for regulating browser utilization levels but are expensive to maintain. In the case of *Sclerocarya birrea*, exclosures in some situations might exclude potential wild dispersers, requiring further management inputs to compensate. Taking into account the importance of elephant dispersal and the tendency for elephants to move along roads and tracks (Coetzee *et al.*, 1979) indicates that road and track fringes constitute important corridors, meriting recognition as a management unit.

9.3.3.2 Grazing lands

Like those of protected areas, the *Sclerocarya birrea* populations of grazing lands tend to be deficient in regeneration and exposed to unregulated and destructive fires. Older *Sclerocarya birrea* individuals on grazing land are at risk from drought. A more serious practical problem, however, is that of the fruits of *Sclerocarya birrea* in grazing lands usually being a common property resource.

Identification of areas of higher stocking of *Sclerocarya birrea* will allow attention to be concentrated where it should be simpler to promote regeneration. Studies extending over areas large enough to contain numerous individuals of the species have underlined the presence of local concentrations associated with certain conditions. Marchal (1980) associated subsp. *birrea* with soils deeper than 60 cm at Yatenga, Burkina Faso. Subsp. *caffra* was associated with deep, well-drained soil in the Luangwa Valley, Zambia (Lewis, 1987) and with old village sites with richer soils in the Nylsvley Nature Reserve, South Africa (Scholes & Walker, 1993).

Sustaining a *Sclerocarya birrea* resource base perceived as common property will entail communal acceptance of a management need fostered by sympathetic and enlightened professional involvement. In the short term, benefits could result from simple measures centred on areas where the species is concentrated. Ensuring early burning (late summer/autumn burning in the subtropical southernmost parts of the range of subsp. *caffra*) would reduce losses of young plants to fire and limit the localized thickening of the woody plant cover, lowering the fuel load at early burns in the succeeding years.

However, it would be necessary to combine such action with reduced post-fire grazing impact, by restricting livestock use of the burned areas while regenerating shoots are palatable and vulnerable.

Where, in the longer term, management of grazing land becomes acceptable, practical interventions could make *Sclerocarya birrea* populations secure. Installation of fire breaks would offer flexible use of burning as a management tool. Regulation of fires is desirable to create conditions where regeneration can become established and can also enable localized fire exclusion in particular years. Fire breaks will also delimit units of land temporarily excluded from the grazing area.

Close control over destructive influences, achieved with fire and livestock access regulation, would permit enrichment planting to be carried out. Any enrichment planting should in the first instance be undertaken within existing areas of concentration of *Sclerocarya birrea*, anticipating replacement of trees which die of old age, perhaps provoked by drought. Within concentrations of *Sclerocarya birrea*, individual trees are often 10-20 m from their nearest conspecific neighbour, indicating 10 m x 10 m or 20 m x 20 m as prospective spacings for enrichment purposes.

9.3.3.3 Parklands

In parkland situations, *Sclerocarya birrea* regeneration deficiencies can be countered by agroforestry interventions. Other actions will be necessary to reinstate an appropriate numerical and spatial gender balance. The principle options are to enrich fields in a fallow state, to establish trees beside homesteads and to establish trees along boundaries. Seedlings for planting should be raised from locally collected seed in informal nurseries or professionally managed nurseries. Extension professionals might co-ordinate access to seedlings of superior phenotypic quality raised under national programmes or by other communities.

It is unclear if the male:female ratio of cohorts of *Sclerocarya birrea* seedlings departs from unity because the sex cannot be determined before the onset of reproductive activity. There is no information on this for subsp. *birrea* but onset of reproductive activity is at an age as low as three or years in the case of planted subsp. *caffra* (Nerd *et al.*, 1990). The interval is presumably longer in natural populations. However, as their sex becomes evident, male individuals may be removed (Shone, 1979). In Namibian parkland (E. Nghitoolwa, pers. comm.), the ratios (male:female:indeterminate) for dbh classes 41-50 cm, 51-60 cm, 61-70 cm and 71-80 cm were all biased in favour of females (respectively: 7:20:1, 11:24:0, 4:24:0, 9:29:0). Among small (<20 cm dbh) individuals, 25% were indeterminate and in the dbh classes 21-30 cm and 31-40 cm representation of males and females did not differ significantly. In Limpopo Province, South Africa, Todd (2000) recorded the sex of individuals in four population samples of 40 to 120 individuals, including 4-29 which were indeterminate. The data were not categorized by size classes, but three transects constituting a sample from Tshipse, two land categories (homesteads and communal land) involved in an Acornhoek sample, and four disturbance categories in the Wits Rural Facility, are separately reported. The transects at Tshipse proved individually biased: two with significantly more females and one with significantly more males, although in combination the sexes were balanced. Todd suggests selection through management has created the biases in favour of female trees and that the case of a bias in favour of males has arisen from vegetative reproduction – because the trees are in close proximity and rather uniform in size. At Acornhoek and the Wits Rural Facility no bias was detected in any separately recognized category or for either locality population overall. A further population (of 40 trees), along 25 km of roadside near Messina, was strongly biased in favour of males. To explain this situation, Todd speculates that disturbance might favour the development of male individuals.

As planting will be needed to modify an unsatisfactory gender situation, and seedling gender is indeterminate, seedlings in groups should be planted, and surplus individuals removed when the gender is known. A more complex option is to introduce grafted plants (Goosen, 1985; Taylor & Kwerepe, 1995; Holtzhausen, 2001) given a female crown. As an option, this has the added attraction of reducing the time to first fruiting to as little as two years after the grafting is effected (Taylor & Kwerepe, 1995).

10 POLICY

John B. Hall, E. M. O'Brien & E. Youde

The importance of *Sclerocarya birrea* for rural communities and its commercial potential have policy implications. Currently, however, there is little coordination of approaches aimed at promoting the use of products from the tree. Nevertheless, strong traditions underline the antiquity of policies regulating and safeguarding use of the species at local level in many societies. Lately, the significance of the *Sclerocarya birrea* resource has been more widely acknowledged among land use professionals and it has received attention at the international level. As a consequence, domestication and conservation measures have been recommended to encourage management initiatives introduced by national governments. In this chapter we illustrate traditions associated with the harvesting and use of the fruits, the main product gathered from the tree, and draw attention to instances where national laws have been enacted to protect trees from opportunistic and inappropriate exploitation. In the policy context, the concerns of international agencies and the growing interest in commercial exploitation are also outlined.

10.1 TRADITION AND POLICY

The information reported here has been gathered only for subsp. *caffra*. In many southern African countries *Sclerocarya birrea* is widely protected through traditions which treat the trees as "sacred". As *Sclerocarya birrea* fruits have long been vital for the rural diet, and the trees are strongly associated with habitation, traditional authority has come to regulate use. Thus, in Swaziland, rural society expects the fruits to be used locally in accordance with customary practice, and not traded or diverted to urban markets. Community elders use their influence to ensure this (O.T. Edje, pers. comm.).

In several countries there are at least some areas where the Head of the local community plays a key decision-making role when the fruit gathering season commences. In Namibia (C. Ng'ona, pers. comm.), the Head may be recognized as the owner of trees within a community, including trees on land owned by others. Even where other individuals own the trees, approval from the Head may be needed before harvesting begins. Such authority may also extend to communal grazing land beyond the village farmlands. The trees on such communal lands are not owned by individuals and anyone from the community can gather fruit from them, given the Head's approval. Shone (1979) has also noted the involvement of the Head ("local chief") in opening the harvesting season. In this instance, in northern South Africa, a brew from the fruit must be ceremonially offered to the Chief before others can consume it.

Traditional protection (bans on felling) of *Sclerocarya birrea* are widespread (*e.g.* Botswana – Taylor & Kwerepe, 1995; Namibia – Rodin, 1985; Tanzania – Luoga *et al.*, 2000; Zimbabwe – P. Sola, pers. comm.). Judicious lopping for fuelwood or fodder is not always prohibited, provided that everything removed is used (P. Sola, pers. comm.). Restrictions may be relaxed where male trees are concerned, as when a large tree has to be felled for making a mortar or a drum (Shone, 1979; Rodin, 1985). Restrictions have sometimes arisen even where there is less interest in the fruit. *Sclerocarya birrea* trees in eastern Tanzania have been safeguarded from felling because they serve as sites for traditional worship and because of associations with ancestral sacrifices (Luoga *et al.*, 2000).

10.2 NATIONAL LEGISLATION AND BY-LAWS

Legislation of various kinds has formalized and reinforced the traditional respect for *Sclerocarya birrea* trees in recent decades. Apparently, the earliest legal measure referring to the species by name was introduced about 50 years ago. This was the proclamation for what are now the Gauteng, Limpopo, Mpumalana and Northwest Provinces of South Africa, in 1951, which declared *Sclerocarya birrea* a fully protected tree – to halt exploitation for timber which would potentially deprive local communities of a major, and vital, source of non-timber products. Shone (1979) outlines subsequent developments. There was a brief relaxation of the felling restriction in 1952-1953, permitting trees >23 cm dbh to be felled under license. This, however, attracted a disconcerting number of felling applications and from 1953 the Department of Forestry only approved fellings for agricultural purposes. Under revised legislation in 1962 *Sclerocarya birrea* was redesignated as a protected fodder species. According to Shone (1979), applications for felling permits ceased in 1963. In 1971 completely revised legislation superseded all that had previously existed, and this has been periodically amended since. It may be noted that provision remains for felling *Sclerocarya birrea* trees >40 cm dbh under license for sale or barter.

Botswana and Namibia have enacted relevant legislation more recently. In Botswana, general regulation of the exploitation of resources in gazetted forests is specified through the 1968 Forest Act and later amendments. Under the Act, *Sclerocarya birrea* is protected on State Lands but an exemption allows local people to harvest its fruits in the Kasane Forest Reserve for domestic use. The situation is similar in Namibia. Under the 1968 Forest Act, *Sclerocarya birrea* receives protection as an indigenous fruit tree but collection of the fruits for domestic use is permitted, while male trees can be pollarded/lopped for fodder and fuelwood. In other countries only general and unspecific forestry legislation applies nationally to protect *Sclerocarya birrea* and does not usually extend to trees outside legally protected areas (including gazetted forests).

Forest and communal lands legislation has been complemented by relevant administrative legislation through the traditional Authorities Act (Namibia), and the Rural District Councils Act and the Traditional Leaders Bill (Zimbabwe). Through these instruments, traditional authorities in conjunction with rural district councils, or their equivalent, exercise authority on behalf of the national government, and in the context of national laws, in the use of *Sclerocarya birrea* products, primarily the fruit.

A feature of local legislation is provision for individuals or concerns to benefit commercially from *Sclerocarya birrea* through trade in its products. Where such interests arise in Zimbabwe, appropriate permits must be issued by the Rural District Council/traditional leaders, with the approval of the Forestry Commission. In other countries where the tree is protected it is usually the Forests Department, or an equivalent, that takes responsibility for approving and supervising commercial exploitation of the tree or its products.

10.3 COMMERCIAL INTERESTS

The commercial potential of *Sclerocarya birrea* has been demonstrated most emphatically in South Africa, with the development of a range of nationally and internationally marketed products (Chapter 5). Government in Namibia is encouraging the development of cottage industries based on *Sclerocarya birrea* products, particularly oil extracted from the kernels, for international sale (C. Ng'ona, pers. comm.). Stress is being placed on processing and refinement near source, to maximize economic benefits within-country. In Botswana, Veld Products Research is already operating a programme to domesticate phenotypes of *Sclerocarya birrea* with superior fruit quality (sweetness and weight), using clonal propagation, with a long-term aim of supplying an export market (Taylor & Kwerepe, 1995).

We have traced no reference to policies applying to commercial/industrial processes that use *Sclerocarya birrea* as raw material, and the only relevant patent of which we are aware is over 80 years old, relating to a dye prepared from bark extract (Chapter 5). As advances in domestication are made, policy issues will increasingly affect both the growing of the tree and the processing of its products. Progress has already reached the stage where, based on the identification of superior genotypes, the registration of cultivars is taking place (Holtzhausen, 2001). Future production involving *Sclerocarya birrea* grown as an exotic tree will call for policies on the export of germplasm originating in the natural range.

10.4 THE INTERNATIONAL POLICY DIMENSION

Sclerocarya birrea is not regarded as an endangered genetic resource, and the natural occurrences are not considered threatened. It is, therefore, not among the trees listed in the appendices to the Convention on International Trade in Endangered Species (CITES). Both subsp. *birrea* and subsp. *caffra*, however, are seen as deserving increased attention as important dryland tree resources and the Food and Agriculture Organization of the United Nations (FAO) has been promoting this at continental and regional level.

Overviews of forest gene resources are produced at intervals by the FAO Panel of Experts on Forest Gene Resources and at the Panel's 7th meeting (FAO, 1990) subsp. *birrea* was reported to be a priority genetic resource for Burkina Faso, Mauritania and Sudan. At the Panel's 8th meeting (FAO, 1994), *Sclerocarya birrea* was included in the list of African priority species drawn up by the Panel itself, with the need for population studies, and provenance and progeny studies stressed. *Sclerocarya birrea* was retained among the priority species at the 9th meeting of the Panel (FAO, 1996) and regional initiatives taken by the Comité Permanent Inter-États de Lutte contre la Sécheresse au Sahel, in West Africa (subsp. *birrea*), and by the International Centre for Research in Agroforestry in the coutries of the Southern African Development Community (subsp. *caffra*), were noted. The Panel specified conservation provision, and germplasm collection, evaluation, selection and improvement as immediate needs.

11 FUTURE PROSPECTS

John B. Hall and Fergus L. Sinclair

Many changes are affecting the rural communities that have traditionally made use of *Sclerocarya birrea*. There is growing impact on them from interactions with urban areas and national development initiatives. Nevertheless, *Sclerocarya birrea* remains important for many people, mostly in low income groups, and at the same time is increasingly required as raw material for fledgling cottage and larger scale industries. The continuance of household usage of the species and the supplying of commercial needs call for different, although complementary, measures to ensure a satisfactory *Sclerocarya birrea* resource base for the future. Much of what seems likely to be part of future consolidation and reinforcement of this resource base calls for wider application of practices already in use, sometimes as research activity rather than routine management. However, in addition there are aspects of domestication and utilization which have hitherto been almost or entirely disregarded but which appear fertile ground for new initiatives.

11.1 SUSTAINING RURAL LIVELIHOODS

In the household context, losses of trees from existing populations are a major problem, more so for male trees than females. This is compounded by the low incidence of regeneration in the natural populations that are currently being exploited. It is unclear whether the paucity of young plants is the outcome of normal episodic events or a consequence of land use pressure. Applying the precautionary principle, populations with unsatisfactory numbers of small individuals should be invigorated with nursery raised plants. Excessive removal of male trees at landscape scales is causing problems with pollen flow. Furthermore, as females become less productive because too little pollen reaches them, they too may be removed. There is a key knowledge gap regarding pollination distance which demands early resolution by determining the sex ratio and proximity of male and female trees required for effective pollination.

While global positioning system technology now facilitates easy and rapid recording of tree positions, and determination of tree sex is relatively straightforward for larger (>15 cm dbh) individuals, the practicality of managing populations at local community level is more challenging. The relatively low numbers of reproductively mature trees per hectare preclude meaningful management of populations by individual smallholders. Management will have to be based on co-ordinated activity among smallholders at a community level, particularly in avoiding disproportionate depletion of male trees. While this may require new institutional structures, the significant social capital already associated with subsp. *caffra* in southern Africa could be a focus for developing capacity for community resource management. While there is a similar need for community management of subsp. *birrea* populations, this may be more difficult to achieve given its lower social profile.

While local people manipulate individual trees to control their impact upon associated land uses, there is a paucity of structured information about individual tree management. There is a need for better documentation of crown development as trees age and for pruning guidelines for farmers. These need to include information about what pruning does to the tree's productive capacity, what products result from pruning and what it achieves for associated agriculture. This will require systematic experiments on effects of pruning intensity and frequency that would best be done on-farm.

In contrast, grafting techniques to control fruit quality have been developed by researchers and their potential to hasten fruiting onset has been demonstrated (Chapter 8). The next step should be the wider dissemination of these grafting skills to farmers, which features in recent extension literature in Tanzania and Zimbabwe, produced in association with ICRAF, as part of this monograph project. A farmer field school approach would be appropriate for disseminating these skills further. There is no information on appropriate procedures for micropropagation, but it can be expected that they could be readily developed. Once this is done they should be disseminated through agroforestry extension activity.

The tree could be particularly important as a resource for improving livelihoods in marginal environments. The combination of its succulent roots and large size relative to surrounding vegetation indicates ability to survive and grow very successfully in extreme environments.

11.2 COMMERCIALISATION

In the commercial context, domestication advances are the priority, with a view to securing consistent year-to-year supplies of products of desirable quality. We are presently unable to project productivity regionally as a guide for policy formulation and planning of *Sclerocarya*-based enterprises. The dearth of understanding of increment introduces uncertainty about when newly created stands will be productive. For trees that are at a productive stage it is still not possible to predict fruit yield at population or stand level with any confidence. There is limited information on the nature and extent of year-to-year variations in production by individuals, and ignorance of longer-term production cycles and trends. Long term studies of stands throughout the tree's range are required. What little information is available on increment and production is almost entirely for subsp. *caffra* in northwest South Africa. In the case of subsp. *birrea*, there is a further need for data on fruit quality, to evaluate whether it shares *caffra*'s commercial potential.

Although the fruit quality of subsp. *birrea* is clearly a neglected area of study, the wider reality is that the genepool of the species as a whole has barely been tapped in any organized or systematic way. It would obviously be desirable to move towards judicious use of the huge genepool while it still survives. Available information on variation is not balanced in geographical or subspecies terms, and is not sufficiently related to resource quality. It would be timely to build on the foundation of pilot genetic studies (Chapter 9) with range-wide sampling and evaluation of variation, not least to allow better-informed exploration of medicinal potential. Present knowledge would permit sampling within a framework providing for local perceptions of variation, and taking into account occurrence under extreme or unusual conditions. The international cooperation required to achieve this could be coordinated by existing regional institutions such as the Comité Permanent Inter-États de Lutte contre la Sécheresse au Sahel (CILSS) and the Southern African Development Community (SADC).

How rapidly and widely benefits from identifying the qualities and prospective sources of germplasm with commercial appeal emerge, will depend on improved familiarity with the reproductive process and the factors controlling reproductive success. These are both areas of very patchy knowledge. Effective management implies capacity to apply fine-tuning to the fruit production process. This requires identification of the environmental triggers for phenological events, and understanding how developmental bottlenecks between floral bud initiation and the fall of mature fruits might be minimised.

The significance of introducing practices exploiting a comprehensive understanding of reproduction in *Sclerocarya birrea* will become evident only as the details of the economic and marketing picture are established. Attention has already been given to aspects of the economics and marketing of subsp. *caffra* for Limpopo Province, South Africa, by researchers at Rhodes University and their co-workers. Elaborating chains of custody would link and quantify the activities and relationships between farmers and product gatherers on the one hand, and the consumers of marketed products on the other. Whether, and if so, where, demand for *Sclerocarya birrea* products is sufficient to justify more commercial initiatives would be clarified, and inequities along the custody chains that could be challenged through ‘Fair trade’ approaches would be exposed. Maintaining an appreciation of the various products derived from the tree is important to maximise benefits along the chains of custody as they are determined. This includes not only the established products from fruit pulp, juice and the kernel, but also the possibility of developing apiculture and mushroom cultivation. The establishment of orchards, as has begun in South Africa and Israel, offers opportunities for consistently higher product quality and supply through tighter management control, but may also have impacts upon markets for locally produced fruit and kernels.

11.3 RECOMMENDATIONS

Ten specific recommendations for action follow, that are derived from the preceding discussion. They are presented under four headings covering immediate action for development of the resource, marketing and short term and strategic research.

Immediate local action

1. Institutional structures need to be developed at community level for management of *Sclerocarya birrea* populations at a landscape scale. With subsp. *caffra*, these can be built on existing social capital associated with the tree, while entirely new structures may be required for subsp. *birrea*.

2. Local communities should be encouraged to re-invigorate populations of *Sclerocarya birrea* using nursery-raised stock. With current capability and experience large numbers of seedlings could and should be generated within a five-year period. Use of grafting is recommended as a means of ensuring an appropriate proportion of fruit bearing trees and would lead to yields of high quality fruit from new trees within four years of grafting.

3. Farmer field schools should be used to transfer grafting skills to farmers so that they can enhance fruit yield and quality from their trees. Micropropagation techniques for the tree should also be developed and disseminated.

4. *Sclerocarya birrea* should be more specifically promoted as a resource for reducing the vulnerability of rural livelihoods in marginal environments.

Emerging markets

5. Documentation of chains of custody at national and regional scales for major *Sclerocarya birrea* products should go hand in hand with the expansion and diversification of markets. This will facilitate identification of specific opportunities to enhance the value that accrues to local people who currently utilise the wild resource, through promoting ''Fair trade' or equivalent practices.

Short term research and development

6. The sex ratio and proximity of male and female trees required for effective pollination should be determined and disseminated for incorporation in tree management protocols.

7. Systematic on-farm experiments on pruning intensity and frequency should be initiated as a matter of urgency and the results disseminated as guidelines for individual tree management.

Strategic research and monitoring

8. Long term fruit production data should be collected in relation to tree age and increment, from a series of monitored stands distributed throughout the range of the tree to improve the accuracy of production forecasting.

9. For both subspp. *birrea* and *caffra*, a range wide evaluation of genetic variability linked to fruit quality and yield should be conducted under the auspices of appropriate regional institutions, such as CILSS and SADC. This would represent the first systematic data collection on fruit quality for subsp. *birrea* and will clarify its commercial potential.

10. A comprehensive research programme on reproductive processes in *Sclerocarya birrea* should be implemented to improve the efficiency of fruit production. This should involve specific consideration of developmental biology and how it is regulated by environmental factors.

There has been a surge of interest in *Sclerocarya birrea* in recent years, particularly in relation to opportunities for commercial exploitation of the fruit and kernels. As domestication proceeds, it is imperative that a balance is struck between efforts to expand commercial marketing and ensuring that greater benefits accrue to rural people. In the southern part of the range there are already fast developing markets being supplied by local fruit collectors, while the tree and its products are undervalued further north. Where markets are developing for *Sclerocarya birrea* products, three sectors can be distinguished. These are rural households using products directly, commercial scale processing enterprises whose products enter national and international trade and increasing numbers of low income consumers in urban areas. The recommendations made above, for enrichment and landscape level management of existing tree populations, should ensure sustainability of the household role of *Sclerocarya birrea* in rural areas where it is already valued, and expansion of its contribution to rural livelihoods elsewhere within its range. The recommendations for enhancing fruit quality and yield stabilisation have particular relevance for the development of commercial markets, already driven by industry in southern Africa but which could be stimulated further north. Left to itself, commercial pressure may favour development of large scale orchard monocultures, not involving rural communities. Proactive development of locally based organisations at community level and above, will be required to ensure that benefits from expanding markets accrue locally. The growing urban consumer base demonstrated for kernels and marula based drinks in southern Africa, represents a new marketing opportunity that rural collectors could seize, where infrastructure permits and they are sufficiently well organised. If the markets continue to grow, in addition to the maintenance and management of existing tree populations, establishment of orchards by rural communities using high quality germplasm might be necessary to meet demand. Collective action at community level is the key to both raising the productivity of existing tree populations, and maximising revenue for local people from emerging markets through development of planted stands.

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APPENDIX 1 TAXONOMY AND DESCRIPTION

John B. Hall

NOMENCLATURE

Over 150 years have passed since the first recorded botanical specimen of what is now named *Sclerocarya birrea* was collected by Perrottet in Senegal. The series of taxonomic actions that has followed is summarized in Table A1. Initial referral to the genus *Spondias*, still regarded as a related genus, was soon superseded by creation of a new genus to accommodate the species, however, even though field use of *Spondias* as the name lingered until 1922, at least in Nigeria (Lely, 1925). Separation from *Spondias* was based on floral differences, particularly the higher numbers of stamens in *Sclerocarya*. Awareness of South African plants with different leaflet characteristics, but evidently closely related to the West African *Sclerocarya,* arose soon after this generic name was introduced. A second species was therefore described (Sonder, 1850). The existence of a matching specimen from Mauritius, collected more than a decade earlier, was not appreciated for nearly another 30 years and even then it was considered the third species of the genus (Baker, 1877). Soon after, however, the number of species in the genus was reduced to two when Engler (1883) concluded that the South African and Mauritian species were the same. A further species from Namibia, distinguished in 1888 as *Sclerocarya Schweinfurthiana* survived much longer as a taxonomic entity – until 1968 – when this, too, was absorbed into *Sclerocarya caffra*. *Sclerocarya caffra* continued to be regarded as specifically distinct from *Sclerocarya birrea* until 1980 when Kokwaro & Gillett (1980) reduced both taxa to subspecific rank. At the same time, however, a variety of *Sclerocarya birrea* described by Engler (1921) was raised in rank to make it a third subspecies, subsp. *multifoliolata*, and a new species of *Sclerocarya*, *Sclerocarya gillettii*, was described. Kokwara & Gillett declined to maintain Engler's two varieties of subsp. *caffra* (var. *dentata* – Engler, 1883; var. *oblongifoliata* – Engler, 1895).

The taxonomic circumscription for *Sclerocarya*, and taxa within it, of Kokwaro & Gillett (1980), and adopted by Kokwaro (1986), has been taken for this monograph:

Genus *Sclerocarya* Hochst.

Sclerocarya birrea (A.Rich.) Hochst.

Sclerocarya birrea (A.Rich.) Hochst. subsp. *birrea*
Sclerocarya birrea (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro
Sclerocarya birrea (A.Rich.) Hochst. subsp. *multifoliolata* (Engl.) Kokwaro

Sclerocarya gillettii Kokwaro.

CIRCUMSCRIPTION

Recognition of *Sclerocarya* as a distinct genus remains controversial and the debate about its differentiation from *Poupartia* remains active. Both Friedmann (1997) and Schatz (2001) maintain *Poupartia* as the generic name for what is called *Sclerocarya* here. This view can be traced back to Marchand (1869), Bâthie (1944) and Aubréville (1950), and is treated with some respect by Ronald Keay (Hutchinson & Dalziel, 1954-1958) and Kokwaro (1986) even though these retain *Sclerocarya* for the floras of West Tropical Africa and Tropical East Africa, respectively. The argument for reducing *Sclerocarya* to synonymy is that separation on the basis of the number of stamens is insufficiently robust, and when Bâthie (1944) followed this course, he speculated that *Lannea, Poupartia* and *Sclerocarya* should possibly be combined. Keay, whilst retaining *Sclerocarya* as a distinct entity, broadened the group of closely related genera by adding *Haematostaphis* and *Pseudospondias*. Kokwaro follows Keay's view. Wannan & Quinn (1991) describe *Antrocaryon, Harpephyllum, Lannea, Poupartia, Pseudospondias* and *Sclerocarya* as members of "a close-knit group" of genera (*Haematostaphis* was not included in their study). Schatz (2001) provisionally combines *Sclerocarya* and *Poupartia* under the latter name, pending reassessment of generic limits throughout the African/Indian Ocean Spondiidae (Spondiadeae) and adds *Operculicarya* to the list of genera seemingly very close to *Poupartia/Sclerocarya*. Where a distinction is made between *Poupartia* and *Sclerocarya*, the usual basis is: *Poupartia* – 8(-10) stamens, 5 stigmas; *Sclerocarya* – 12-16(-26) stamens, (2-)3 stigmas. More recently, Randrianasolo (2001) has noted additional differences – a many-flowered female inflorescence in *Poupartia* (in contrast with 1-3-flowered female inflorescences in *Sclerocarya*) with the individual flowers sessile or on very short pedicels (the pedicels of female flowers in *Sclerocarya* are 10-15 mm long).

Separation of the taxa currently recognized in *Sclerocarya* is primarily based on gross inflorescence and foliar characteristics (Kokwaro, 1986). *Sclerocarya gillettii* has much more slender shoots (<4 mm in diameter) and, mostly, dentate unifoliolate leaves, and is relatively small (2-5 m in height. Among the subspecies of *Sclerocarya birrea*, subsp. *caffra* is recognized by the long (typically 0.5-3.0 cm) petiolules of the lower pairs of leaflets, the acuminate or cuspidate leaflet apices and the frequently long (up to 22 cm) inflorescences of male plants. Subspp. *birrea* and *multifoliolata*, share the characteristics of subsessile or very shortly petiolulate lower leaflets, blunter leaflet apices (obtuse or acute) and male inflorescences no more than 9 cm long. Differences in leaflet shape, size and number separate these two subspecies. Subsp. *birrea* has relatively few (up to 21, rather than 25-37) elliptic or obovate (rather than circular) leaflets which exceed 2 cm in length (rather than being under 1.5 cm long).

Several authors have drawn attention to unrelated species which could be confused with *Sclerocarya birrea* subsp. *caffra* in the vegetative state. Two other species of Anacardiaceae are among these: Shone (1979) and Shackleton *et al.* (2002), respectively, refer to *Lannea discolor* (Sond.) Engl. and *Lannea schweinfurthii* (Engl.) Engl. Kokwaro (1986) refers to past misidentification of *Ekebergia capensis* Sparrm. (Meliaceae) as having very similar foliage. Storrs (1979) highlights similarity to *Kirkia acuminata* Oliv., which is commonly found with subsp. *caffra* (Chapter 2), and is a member of a further family, the Simaroubaceae.

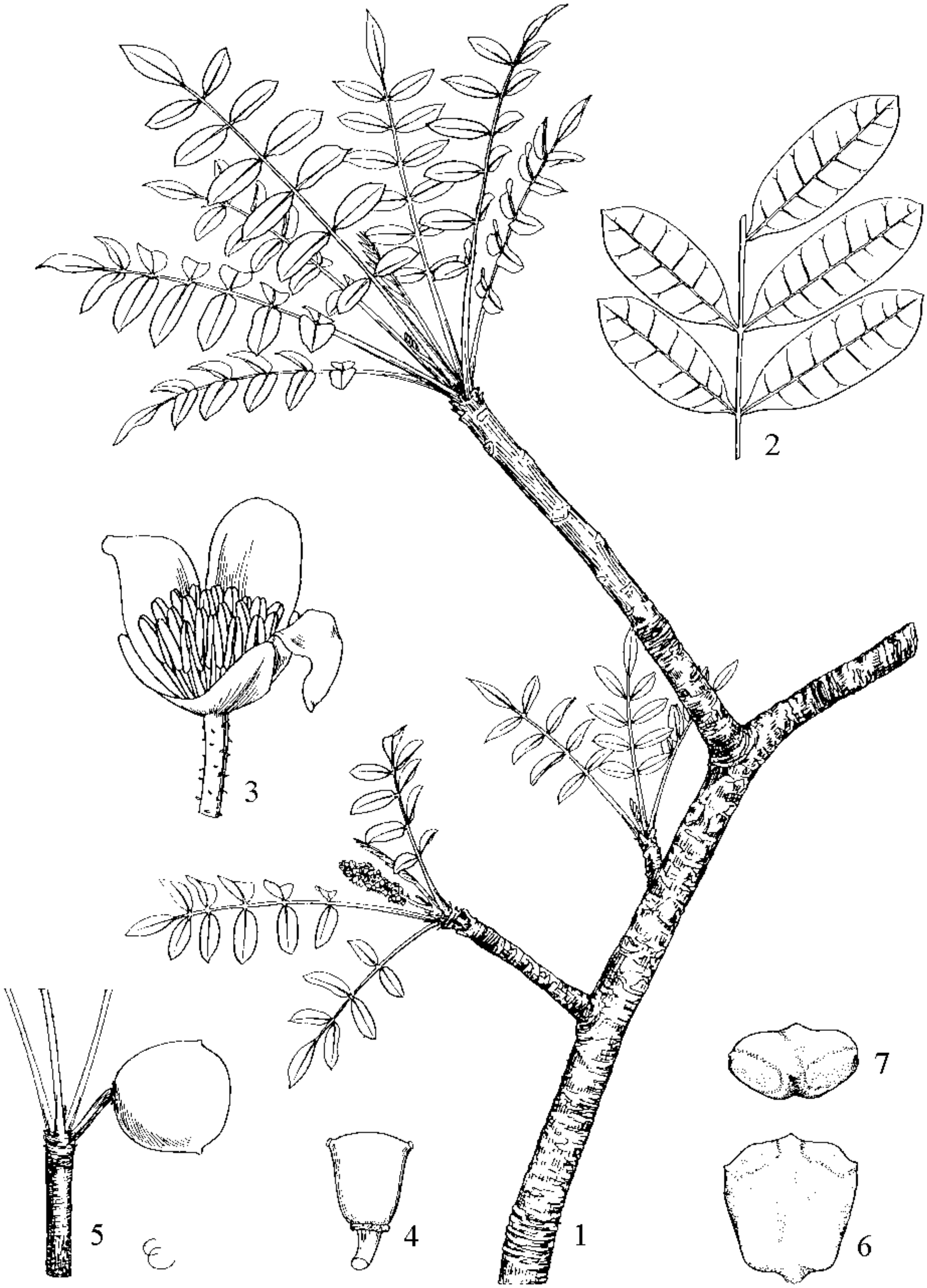

Figure A1. *Sclerocarya birrea* subsp. *birrea*. 1: branch with leaves and young inflorescence; 2: mature leaflets (x ⅔); 3: male flower, single petal removed (x 8); 4: young fruit (x 2); 5: mature fruit (x ⅔); 6 and 7: endocarp (side and top views). From Hedberg, I. and Edwards, S. 1989. *Flora of Ethiopia: Volume 3 Pittosporaceae to Araliaceae.* National Herbarium, Addis Ababa University, Ethiopia and Uppsala University, Sweden. 660 pp+lxxi pp. Reproduced with permission of the Board of *Flora of Ethiopia*.

Figure A2. *Sclerocarya birrea* subsp. *caffra*. 1: upper part of leafy branch (x ⅔); 2: upper part of flowering male branch (x ⅔); 3: male flower (x 6); 4: disk of male flower from above (x 8); 5: female flower with a very young fruit (x 6); 6: fruit (x ⅔). From Excell, A.W., Fernandes, A. and Wild, H. 1963-66. *Flora Zambesiaca: Volume Two.* Crown Agents for Overseas Governments and Administrations, London. 653 pp. Reproduced with the permission of the Royal Botanic Gardens, Kew.

Table A1. *Sclerocarya birrea*: chronology of nomenclature and synonymy

Year	Name	Reference and remarks
1831	*Spondias birrea* A.Rich.	Guillemin *et al.* (1830-1833): the first scientific description of the species, by Achille Richard, who at the time referred it to the Linnean genus *Spondias*, which had been introduced for some neotropical Anacardiaceae. The epithet "*birrea*" (or the orthographic variant "*birroea*" of some authors) latinizes the vernacular name (*ber*) used by the Wolof community in Senegal. The type specimen, preserved in Paris, was collected by George Perrottet (Perrottet 186) in the period 1824-1829.
1837	*Spondias Chakoua* Bojer; *Shakua excelsa* Bojer	Bojer (1837): apparently the first scientific reference to what is now known as *Sclerocarya caffra* subsp. *caffra,* based on a cultivated plant in Mauritius. Considering this a hitherto undescribed species, Wenzel Bojer provided new names (the second superseding the first) but without an accompanying description, so they are *nomina nuda*. This is apparently the first separation of the taxon now understood as *Sclerocarya* from *Spondias*. Bojer's choice of "*Shakua*" was as a written form for a vernacular name widespread in Madagascar. The name under genus *Spondias* is written on an herbarium sheet (Bojer *s.n.*, at Kew) of the plant, perhaps the oldest herbarium specimen of subsp. *caffra*.
1844	*Sclerocarya birrea* Hochst. (in modern style: *Sclerocarya birrea* (A.Rich.) Hochst.)	Hochstetter (1844): because it has more stamens but fewer locules in the ovary, Christian Hochstetter separated the West African species represented by Perrottet's specimen from other species placed in *Spondias* and made it the sole species of a new genus *Sclerocarya*. This generic name combines the Greek for "hard" and "walnut", and describes the characteristic endocarp.
1850	*Sclerocarya caffra* Sond.	Sonder (1850): Otto Sonder, described South African specimens (Drege 4063; Gueinzis 70; Zeyher 1857) as a second species of *Sclerocarya*, differing from *S. birrea* in having larger and more acute leaflets with longer petiolules. He applied the specific epithet "*caffra*" to denote the geographical origin of the Gueinzis material – the area then known as Kaffraria (around present day Durban). The whereabouts of the three specimens is unclear: Kokwaro (1986) suggests they may be in Melbourne.
1869	*Poupartia excelsa* Marchand	Marchand (1869): Nestor Marchand sank Bojer's *Shakua*, including *Shakua excelsa*, into the genus *Poupartia*, a name introduced by Philibert Commerson almost a century earlier and given formal standing by Antoine Laurent de Jussieu in 1789. Whether or not *Sclerocarya* is distinct from *Poupartia* has remained a matter of debate to the present day.
1877	*Sclerocarya Shakua* Baker	Baker (1877): referral of Bojer's *Spondias Chakoua* to *Sclerocarya* (with an orthographic change to the epithet and a short description in English) as a third species in the genus - and a suggestion that *Shakua excelsa* was no more than a synonym.
1883	*Sclerocarya caffra* Sond. var. *dentata* Engl.	Engler (1883): the first published indication of complicating variation in *Sclerocarya*. Adolf Engler thought material from South Africa (Rehmann 4734, 5140 – probably collected 1879-1880) with shorter petiolules and toother leaflet margins should be distinguished at varietal level. In the same publication Engler restored independent generic status to *Sclerocarya* but reduced *Sclerocarya Shakua* to synonymy under *Sclerocarya caffra*.
1888	*Sclerocarya Schweinfurthiana* Schinz	Schinz (1888): Hans Schinz described a plant from northern Namibia as a further species of *Sclerocarya*. His grounds were that the Namibia plant had more pairs of leaflets, and fewer flowers per female inflorescence, than *Sclerocarya caffra* and fewer pairs (of larger leaflets) than *Sclerocarya birrea*. The type specimens were collected by August Lüderitz, around 1884-1887 and Kokwaro & Gillett (1980) suggest they may survive in Berlin.

Table A1 (continued). *Sclerocarya birrea*: chronology of nomenclature and synonymy

Year	Name	Reference and remarks
1895	*Sclerocarya caffra* Sond. var. *oblongifoliolata* Engl.	Engler (1895): Adolf Engler accords varietal rank to a second taxon within *Sclerocarya*, on the basis of a specimen, Stuhlmann (1) 604. This was collected by Franz Stuhlmann on the Tanzania coast, presumably in 1888 or 1889, and a duplicate survives in the herbarium at Kew.
1912	*Commiphora subglauca* Engl.	Engler (1912): assuming the material to hand (Holtz 1064), collected by Wilhelm Holtz on the Tanzania coast in 1903, was referable to the Burseraceae, Adolf Engler described it as a new species of *Commiphora*. A fragment of the material survives in the herbarium at Kew.
1921	*Sclerocarya birrea* (A.Rich.) Hochst. var. *multifoliolata* Engl.	Engler (1921): without citing a specimen, Adolf Engler gave varietal status within *Sclerocarya birrea* to plants from central Tanzania with 14-18 pairs of leaflets on each leaf, applying the epithet "*multifoliolata*" to denote this.
1944	*Poupartia caffra* (Sond.) H.Perrier	Bâthie (1944): Henry Perrier de la Bâthie revived the idea of inclusion of *Sclerocarya* within *Poupartia*, using the epithet "*caffra*" combined with *Poupartia* and treating Sonder's name (*Sclerocarya caffra*) as a synonym.
1950	*Poupartia Birrea* (Hochst.) Aubr. (=*Poupartia birrea* (A.Rich.) Aubrév.)	Aubréville (1950): André Aubréville extended Bâthie's concept to western and northeastern African plants to refer these also to *Poupartia*, as a separate species, making *Sclerocarya birrea* a synonym of *Poupartia birrea*.
1954	*Sclerocarya birrea* (A.Rich.) Hochst. forma *aubrevillei* Roberty	Roberty (1954): declining to adopt the name preferred by Aubréville, Guy Roberty retains the longer-standing name of Hochstetter. He also formally distinguishes a minor taxon – forma *aubrévillei* - within it. This forma was simply to distinguish what Roberty explicitly indicated were plants with juvenile foliage, best expressed by the serrate-dentate margins of the leaflets. The type specimen for the new taxon is Aubréville 6436, from Senegal. Subsequent authors have made no reference to this taxon and it hardly warrants formal taxonomic recognition.
1966		Fernandes & Fernandes (1966): in the treatment of the Anacardiaceae for the Flora Zambesiaca, Rosette and Abilio Fernandes reduced vars *dentata* and *oblongifoliolata* to synonymy within the circumscription of typical *Sclerocarya caffra*.
1969		Merxmüller & Schreiber (1968): *Sclerocarya Schweinfurthiana* is reduced to synonymy under the name *Sclerocarya caffra*.
1980	*Sclerocarya birrea* (A.Rich.) Hochst. subsp. *birrea* *Sclerocarya birrea* (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro *Sclerocarya birrea* (A.Rich.) Hochst. subsp. *multifoliolata* (Engl.) Kokwaro *Sclerocarya gillettii* Kokwaro	Kokwaro & Gillett (1980): in the process of revising the taxonomy of the Anacardiaceae for the Flora of East Tropical Africa, John Kokwaro and Jan Gillett reduced the two taxa previously known as *Sclerocarya birrea* and *Sclerocarya caffra* to subspecific rank under the earlier name, *Sclerocarya birrea*. Reconsideration of Holtz 1064 led to its re-identification as *Sclerocarya caffra* – *Commiphora subglauca* became a synonym of *Sclerocarya birrea* subsp. *caffra*. *Sclerocarya birrea* var. *multifoliolata* was raised from varietal to subspecific rank within *Sclerocarya birrea*. A new species of *Sclerocarya* (*S. gillettii*) was described.
2001	*Poupartia birrea* (A.Rich.) Aubrév. subsp. *caffra* (Sond.) G.E.Schatz	Schatz (2001): in connection with floristic work for Madagascar, George Schatz accepted Kokwaro & Gillett's subspecific rank but within the broad circumscription of *Poupartia*.

DESCRIPTION

Seedling

No detailed description of the seedling of *Sclerocarya birrea* appears to have been published. However, casual comments indicate that small seedlings of subsp. *caffra* have pink to red stems (Shone, 1979) and that the first true leaves are trifoliolate with almost sessile penninerved leaflets (Shone, 1979), having deeply serrate margins (Teichman, 1982). At the earliest stage after germination, the cotyledons which have been drawn out of the endocarp by the extending hypocotyls are very elongated. Bâthie (1946) and Msanga (1998) present line drawings of young seedlings; Teichman (1982) presents a photograph.

Mature tree

Habit, size and form

An unarmed tree which usually reaches heights of 9-12 m but, particularly subsp. *caffra*, occasionally attains 18 m. Randrianasolo (2001) gives an upper limit of 25 m for Madagascar. The bole is generally short, straight and fairly cylindrical. Lengths of up to 4.5 m are not unusual and, for subsp. *caffra* in the Democratic Republic of Congo, Veken (1960) gives a length of 12 m, although noting somewhat sinuous form. Where the bole is short it is often stout and diameter may reach 1.2 m (Fanshawe, 1972 – subsp. *caffra* in Zambia). The crown is rounded, with thick, heavy branches, and variously described as having rather dense foliage (Geerling, 1982 – subsp. *caffra*, West Africa) or being rather open (Jackson, 1973 – subsp. *birrea*, Nigeria; Veken, 1960 – subsp. *caffra*, Democratic Republic of Congo). In large, old trees the crown spread is wide; Shone (1979) refers to a specimen tree of subsp. *caffra* in South Africa with a crown spread of 21 m. The diverging, thick (8-10 mm diameter) ultimate branchlets are distinctive, usually greyish in colour and with conspicuous leaf scars and the leaves clustered at the ends. Randrianasolo (2001) notes reddish pubescence at the distal tip. In deep soil there is a well-developed tap root (Shone, 1979) and the sturdy lateral roots may extend as far as 30 m from the bole (Soumaré *et al.*, 1994).

Bark

The bark is pale silvery or purplish grey and smooth or somewhat wrinkled on small individuals. On large individuals, the bark is thick and rough, sometimes described as fissured but more frequently as flaking. The flakes are variable in size and irregularly discoid or quadrangular in shape, the edges separating from the bole before they are shed. After falling they leave yellowish depressions which generally turn grey with exposure. The resultant effect is a mottled appearance of whitish or yellowish patches against a reddish-brown or grey-purple, or darker, background.

Shone (1979) describes three layers, combining to give a thickness of around 20 mm, which are discernible in the blaze. The outermost is a grey-brown corky zone of mature bark within which is the distinctive reddish phloem, this covering the thick, pinkish spongy innermost layer. Storrs (1979) describes the general appearance of the blaze as reddish or pinkish, with darker stripes. Keay *et al.* (1964) draws attention to the exudation of a nearly colourless gum from the cut surface.

Foliage

The compound, imparipinnate, leaves are exstipulate and alternate, the crowding at the shoot ends imposing a spiral disposition. Together the petiole (1.5-8 cm long) and rhachis form a leaf axis 8-38 cm long bearing 3-18 pairs of lateral leaflets. In general, more pairs (7-10) of lateral leaflets typify subsp. *birrea* and fewer pairs (3-6) typify subsp. *caffra*. However, for subsp. *birrea*, numbers as low as 4-5 pairs fall within normal variation (Berhaut, 1971; Gilbert, 1989). Similarly, relatively high numbers (8-9 pairs) of lateral leaflets arise in subsp. *caffra* (Veken, 1960; Compton, 1975). There appear to be consistently more leaflets (12-18 pairs) in subsp. *multifoliolata* (Brenan & Greenway, 1949; Kokwaro, 1986). The petiole is thickened at the base for 3-5 mm (Berhaut, 1971), hemicylindric with sharp lateral margins and glabrous. The slender rhachis, also hemicylindric and glabrous, is adaxially channelled.

Individual leaflets are 0.8-9 cm long and 0.7-3.5 cm broad. Longer leaflets (typically 3-9 cm) typify subsp. *caffra* and shorter leaflets (2-4 cm) subsp. *birrea*. However, in subsp. *birrea* lengths as great as 5 cm, and in subsp. *caffra* lengths as short as 3 cm, have often been reported. Some of this complicating variation is likely to reflect inclusion of leaflets from shoots of subsp. *birrea* with the juvenile characteristic of large leaflet size. Variation in leaflet size within single leaves may also contribute. Shone (1979) has noted for subsp. *caffra* that the leaflets of pairs in the middle of a leaf are longer than those in more proximal or more distal positions. The leaflets of subsp. *multifoliolata* are consistently short – 1-1.5 cm (Brenan & Greenway, 1949; Kokwaro, 1986). The lateral leaflets are subsessile or with glabrous petiolules, channelled above, up to 30 mm long; the petiolule of the terminal leaflet is similar but may reach 50 mm in length. In subsp. *birrea* there is a tendency for the proximal leaflets to have petiolules shorter than 5 mm or to be subsessile. In subsp. *caffra*, all leaflets usually have petiolules 5-20 mm long, if not longer. In subsp. *multifoliolata*, the leaflets are shortly petiolulate (Kokwaro, 1986). The leaflet lamina varies in shape from round to oblong or lanceolate. A round or broadly elliptic leaflet is typical of subsp. *multifoliolata*. More elongated leaflets are characteristic of the other subspecies, although in subsp. *caffra* leaflets in the lower pairs may be somewhat rounded (Bâthie, 1946). An elliptic-obovate shape predominates in subsp. *birrea* as opposed to an oblong-ovate shape in subsp. *caffra* but intermediate shapes are frequent in both. More characteristic of subsp. *caffra* are the asymmetric leaflet base, rounded or abruptly narrowed on one side and cuneate on the other, and the tapering acuminate-caudate apex – as much as 10 mm long (Fernandes & Fernandes, 1966). Subsp. *birrea* usually has a more symmetric, cuneate base and an acute, mucronate, apex. In subsp. *caffra* the terminal leaflet tends to be more lanceolate than the lateral leaflets and not asymmetric (Shone, 1979). In the crown foliage the leaflet margins are typically entire although it is not unusual for leaflets bearing occasional teeth to be present. Rejuvenated or young shoots, however, display the dentate-serrate margins typical of immature individuals only two or three years old. Possibly reflecting differences in texture between subsp. *birrea* and subsp. *caffra*, the leaflet margins of the latter may be slightly undulate (Shone, 1979).

The leaflets are membranous to subcoriaceous in texture, glabrous and, in the case of subsp. *caffra*, discolorous, the abaxial surface being paler. The upper surface of the subsp. *caffra* leaflet has been variously described as smooth, shining or sub-glossy, terms not used for subsp. *birrea*, which is most frequently described as glaucous. However, Palmer & Pitman (1972-1974) have remarked on a blue-green colour in subsp. *caffra*. The leaflets have penninerved venation. The midrib is prominent and raised on both surfaces and there are 6-16 pairs of fairly distinct lateral nerves, slightly raised above and impressed or slightly raised, and more conspicuous, below. Tertiary venation is closely reticulate and rather obscure.

Inflorescences and flowers

Male individuals bear flowers in subterminal or axillary racemes arising from buds in the axils of recently fallen or new leaves. The racemes of subsp. *birrea* do not exceed 9 cm in length and, according to Eggeling & Dale (1951) and Maydell (1986), are erect. Those of subsp. *caffra* are commonly longer (to 22 cm) and have been described as pendulous or drooping (Dale & Greenway, 1961; Teichman, 1982). Close to the base of the inflorescence axis are two small, subulate bracts (Gomes e Sousa, 1966-1967). Individual flowers occur in groups of 3-4 on the lower part of the inflorescence axis but tend to be solitary towards its apex. Teichman (1982), referring to subsp. *caffra* suggests *ca* 20 as the typical number of flowers in a male inflorescence. Occasional female flowers occur among the male flowers of a few otherwise male trees. The axis is angled and subpuberulent (Veken, 1960) with individual flowers subsessile or on flattended glabrous or puberulent pedicels. The pedicels are up to 2 mm long, rarely longer (to 5 mm – Veken, 1960) and described by Shone (1979) as light green with red spots. A reddish, ciliolate, obtuse, concave, broadly ovate bract *ca* 2 mm long and 1.5 mm broad subtends each flower (Bâthie, 1946; Kokwaro, 1986). The female inflorescences are reduced, subterminal and spiciform, 1-5 cm long, with 1-4 flowers. The smooth, brownish-green pedicels are 10-30 mm long and *ca* 2 mm thick. The associated bract is triangular 2-2.5 mm long and 1.5-3 mm broad and externally glabrous (Randrianosolo, 2001).

Individual male flowers are 6-8 mm in diameter and about 10 mm long, and female flowers are slightly larger. Aestivation is imbricate. Colour varies but greenish-yellowish and pinkish, reddish or purplish tones are usually evident. Munjuga (2000), for Kenya subsp. *birrea*, noted that male flowers were darker in colour than female flowers. The calyx is of 4-5 free, or almost free, spreading, ovate-round, usually reddish, sepals, 1-2.5 mm long and 2-3.5 mm wide. The corolla is of 4-5 obovate to oblong-ovate, glabrous, yellowish to reddish petals, 4-6 mm long and 2.5-4 mm wide, becoming strongly reflexed in male flowers at anthesis. In the male flowers there are (10-)15-25(-30) stamens inserted on the outer surface of a glabrous, fleshy, subentire, yellow disc (Randrianasolo, 2001). The erect pinkish subulate filaments, are 2-4 mm in length and support bilocular anthers 1-1.5 mm long and *ca* 0.8 mm wide (Munjuga, 2000). Each anther is dorsifixed, ovate to oblong in shape, glabrous, and pale yellow to yellow in colour. Dehiscence is introrse (Randrianosolo, 2001). In the female flower the ovary is subglobular and encircled by a denticulate annular disc on the outer surface of which 15-26 erect staminodes are inserted, with filaments *ca* 2 mm long (Munjuga, 2000) and mostly with anthers *ca* 1 mm long, as on the stamens, but narrower and empty (Randrianasolo, 2001). Each of the 2-3(-4) locules contains a single pendulous ovule with a dorsal raphe. There are usually 2-3 short, lateral styles, each ending in a capitate stigma.

Fruit and seed

The fruit is an obovoid to subglobose drupe, usually 3-4 cm in diameter when ripe, on a 10-15 mm long pedicel. The outer layer of the exocarp is thin and tough, covered with small rough spots and 2-3 obscure points representing stylar remnants near the apex (Shone, 1979; Teichman, 1982). At maturity the colour is yellow and under the thick (2-3 mm) exocarp is a fibrous, fleshy, juicy mesocarp adherent to the hard stone (endocarp). The endocarp is obovoid, 2-3 cm long and 1.5-2.5 cm in diameter, with (1-)3(-4) compartments, each operculate towards the tip with an irregularly elliptic or discoid operculum. Within each compartment is a flattened seed 15-20 mm long, 4-8 mm wide and 2.5 mm thick. The seed is oleaginous and lacks endosperm. It is enclosed in a papery brown testa. The cotyledons are plano-convex, thick and fleshy (Bâthie, 1946).

APPENDIX 2 LIST OF VERNACULAR NAMES

E. M. O’Brien and John B. Hall

Vernacular names recorded for *Sclerocarya birrea* subsp. *birrea*, by country

Country	Name	Language/Ethnic group	Reference
Benin	manyi		Souza (1988)
Burkina Faso	bunamagbu	Mooré	Maydell (1986)
	kegue	Senufo-Tusia	Burkill (1985)
	noabega	Mooré	Maydell (1986)
	noabegha	Mooré	Maydell (1986)
	noagba	Mooré	Guinko & Pasgo (1992)
	nobéga	Mooré	Burkill (1985)
	nobray	Koussaré	Glew *et al.* (1997)
	sorah	Bissa	Glew *et al.* (1997)
Central African Republic	banda	Banda	Sillans (1958)
	taktéché	Yulu	Sillans (1958)
Eritrea	abengul	Tigre, Tigrina	Bein *et al.* (1996)
	abengula	Bilen	Bein *et al.* (1996)
	habedengul	Hidareb	Bein *et al.* (1996)
	hangutate	Nara	Bein *et al.* (1996)
	homeid	Arabic	Bein *et al.* (1996)
	tugla	Kunama	Bein *et al.* (1996)
Ethiopia	abengelle	Tigre	Breitenbach (1963)
	abengul	Tigre	Breitenbach (1963)
	gomales	Amharic	Breitenbach (1963)
	kumal	Amharic	Breitenbach (1963)
Gambia	bait	Wolof	Burkill (2000)
	birr	Wolof	Burkill (1985)
	bri	Fula-Pulaar	Burkill (2000)
	dib		Burkill (1985)
	eri	Fula-Pulaar	Burkill (1985)
	findibasu	Diola	Burkill (1985)
	kundingho	Fula-Pulaar	Burkill (1985)
	kuntan-jawo	Manding-Mandinka	Burkill (1985)
Ghana	buronogo	Sissala	Burkill (1985)
	mu-mugga	Dagbani	Burkill (1985)
	nanogba	Nankani	Burkill (1985)
	nobiga	Moore	Burkill (1985)
Guinea*	kunan	Manding-Mandinka	Burkill (1985)
	kuntan	Manding-Mandinka	Burkill (1985)
	kuntango	Manding-Mandinka	Burkill (1985)
Guinea Bissau	éri	Fula-Pulaar	Burkill (1985)
Kenya	arol	Marakwet	Maundu *et al.* (1999)
	didisa	Borana	Maundu *et al.* (1999)
	didissa	Borana	Dale & Greenway (1961)
	ekajikai	Teso	Maundu *et al.* (1999)
	ekajiket	Turkana	Maundu *et al.* (1999)
	katetalam	Sabaot	Dale & Greenway (1961)
	kotelalam	Sabaot	Maundu *et al.* (1999)
	mang’u	Luo	Maundu *et al.* (1999)
	ng’ong’o	Luo (Kanyamwa)	Maundu *et al.* (1999)
	olemo	Luo	Maundu *et al.* (1999)
	ong’ong’o	Luo (Gwasi)	Maundu *et al.* (1999)
	oroluo	Marakwet, Pokot	Maundu *et al.* (1999)
	oroluwo	Pokot	Maundu *et al.* (1999)
	tololokwo	Tugen	Maundu *et al.* (1999)
Mali	bii	Dogon	Burkill (1985)
	bibii	Dogon	Burkill (1985)
	dineygna	Songhai	Burkill (1985)
	éri	Fula-Pulaar	Burkill (1985)
	hédéhi	Fula-Pulaar	Burkill (1985)

Country	Name	Language/Ethnic group	Reference
	hédi	Fula-Pulaar	Burkill (1985)
	kédé	Fula-Pulaar	Burkill (1985)
	kunan	Manding-Bambara, Maninka	Burkill (1985)
	kuntan	Manding-Bambara, Maninka	Burkill (1985)
	kuntango	Manding-Bambara, Maninka	Burkill (1985)
	mguna	Manding-Bambara	Burkill (1985)
	tauila'h	Tamachek	Maydell (1986)
	touhila	Tamachek	Maydell (1986)
	tuila	Tamachek	Burkill (1985)
Mauritania	dambu	Arabic (Maure)	Burkill (1985)
Niger	bu namagbu	Gurma	Maydell (1985)
	bunamubu	Gurma	Burkill (1985)
	dama	Hausa	Burkill (1985)
	dânia	Hausa	Maydell (1986)
	díinéy	Songhai	Burkill (1985)
	dinégna	Songhai	Burkill (1985)
	éri	Fula-Fulfulde	Burkill (1985)
	hédéhi	Fula-Fulfulde	Burkill (1985)
	hédi	Fula-Fulfulde	Burkill (1985)
	kemaà	Kanuri	Burkill (1985)
	kédé	Fula-Fulfulde	Burkill (1985)
	lúuley	Songhai	Burkill (1985)
	namabu	Gurma	Maydell (1986)
Nigeria	danya	Hausa	Burkill (1985)
	danyaá	Hausa	Burkill (1985)
	edere (= the fruit)	Fula-Fulfulde	Burkill (1985)
	eedere	Fula-Fulfulde	Burkill (1985)
	hedi	Fula-Fulfulde	Burkill (1985)
	heri	Fula-Fulfulde	Burkill (1985)
	homeid	Arabic	Burkill (1985)
	homeid	Arabic-Shuwa	Burkill (1985)
	huli	Hausa	Burkill (1985)
	kemaà	Kanuri	Burkill (1985)
	ludu (= the fruit)	Hausa	Burkill (1985)
	lule (= the fruit)	Hausa	Burkill (1985)
	nunu (= the fruit)	Hausa	Burkill (1985)
Senegal	a-ngúd'y	Basari	Burkill (1985)
	a-nguit	Basari	Burkill (1985)
	a-nguk	Basari	Burkill (1985)
	ari	Serer	Burkill (1985)
	arid	Non	Burkill (1985)
	arik	Non	Burkill (1985)
	arit	Serer	Baumer (1995)
	aritj	Serer	Burkill (1985)
	a-tẹma	Konyagi	Burkill (1985)
	bér	Fula-Pulaar, Wolof	Burkill (1985)
	béri	Fula-Pulaar	Burkill (1985)
	biѐt	Wolof	Burkill (1985)
	bir	Wolof	Burkill (1985)
	birr	Wolof	Maydell (1986)
	bör	Wolof	Burkill (1985)
	edi	Fula-Pulaar	Maydell (1986)
	éri	Fula-Pulaar	Burkill (1985)
	findibasu	Diola	Burkill (1985)
	gi-kúd'y	Bedik	Burkill (1985)
	gna	Bambara	Maydell (1986)
	hédéhi	Fula-Pulaar	Burkill (1985)
	hédi	Fula-Pulaar	Burkill (1985)
	indarid	Non	Burkill (1985)
	kédé	Fula-Pulaar	Burkill (1985)
	konnan	Maninka	Burkill (1985)
	kuna	Bambara	Maydell (1986)
	kuntan	Maninka	Burkill (1985)
	kuntango	Maninka	Burkill (1985)
	kutaŋ	Mandinka	Burkill (1985)
	kutan dao	Soce	Burkill (1985)

Country	Name	Language/Ethnic group	Reference
	kuten dao	Soce	Burkill (1985)
	mguna	Manding-Bambara	Burkill (1985)
	nôné	Soninke-Sarakole	Burkill (1985)
	sugu	Serer-Non	Burkill (1985)
	sungul	Serer-Non	Burkill (1985)
Sudan	akamil	Arabic	Grossinsky & Gullick (2000)
	gummel	Arabic, Dinka	Grossinsky & Gullick (2000)
	hemaid	Arabic	Ghazali *et al.* (1987)
	hemaidai	Arabic	Grossinsky & Gullick (2000)
	homeid	Arabic	Wickens (1976)
	kyele	Moru	Sharland (1991)
	likok	Dongotona	Grossinsky & Gullick (2000)
	ngepe	Mödö	Persson (1986)
	rufi		Broun & Massey (1929)
	tuwa	Fur	Wickens (1976)
Tchad	homeid	Arabic	Aubréville (1950)
Uganda	ejikai	Ateso	Eggeling & Dale (1951)
	ejikaiskoi	Ateso	Katende *et al.* (1995)
	ekajikai	Ateso	Eggeling & Dale (1951)
	eko	Ateso	Katende *et al.* (1995)
	ijakait	Langi	Katende *et al.* (1999)
	jakayit	Luo (Lango)	Eggeling & Dale (1951)
	kamunyemunye	Lusoga	Eggeling & Dale (1951)
	katetalam	Sebai	Eggeling & Dale (1951)
	kisoromosi	Lugishu	Katende *et al.* (1995)
	kisoromoss	Lugishu	Eggeling & Dale (1951)
	lanyumu	Madi	Eggeling & Dale (1951)
	luguotu	Luo (Acholi)	Katende *et al.* (1995)
	otitimo	Luo (Acholi)	Eggeling & Dale (1951)
	wemunyemunye	Lusoga (Kilamogi)	Katende *et al.* (1999)

*Burkill's (1985) reference to vernacular names from Guinea are the only published indication seen suggesting that *Sclerocarya birrea* occurs in that country.

Vernacular names recorded for *Sclerocarya birrea* subsp. *caffra*, by country

Country	Name	Language/Ethnic group	Reference
Angola	gongo (= the fruit)		Fernandes (1969)
	hongo	Nyaneka	Bossard (1996)
	kaxama	lower Cubango area	Gossweiler (1950)
	mjong	Amboland area	Gossweiler (1950)
	mungongo	Serra da Chela	Gossweiler (1950)
	muongo (= the wood)	Serra da Chela	Gossweiler (1950)
	ngongo	Vila Arriaga	Bossard (1996)
	omuongo (= the wood)		Fernandes (1969)
	ongo	Gambos; Huíla	Bossard (1996)
	ongongo		Fernandes (1969)
	uongo		Gossweiler & Mendonça (1939)
Botswana	marula	Tswana	Tredgold (1986)
	morula	Tswana	Watt & Breyer-Brandwijk (1962)
	ufuongo	Okavango	Watt & Breyer-Brandwijk (1962)
Democratic Republic of Congo	kamukungu	Kanioka, Tshiluba	Veken (1960)
	kani	Kibembe	Veken (1960)
	muhonga	Kibemba	Malaisse & Parent (1985)
	muonga	Kabalo	Veken (1960)
	mwongo	Kiala	Veken (1960)
	tshikosokoso	Baluba	Lebacq & Dechamps (1967)
Kenya	mngongo	Digo, Duruma, Swahili	Dale & Greenway (1961)
Madagascar	sakoa	Sakalave	Heckel (1910)
	sakoana	Sakalave	Heckel (1910)
	saokoa		Heckel (1910)

Country	Name	Language/Ethnic group	Reference
Malawi	mfula	Chicheŵa, Yao	Williamson (1975)
	mtondowoko	Yao	Williamson (1975)
	musele	Nkhonde	Williamson (1975)
	musewe	Tumbuka	Pullinger & Kitchin (1982)
Mozambique	inhamarre	Landim	Fernandes & Fernandes (1969)
	isi-lignamaash		Shone (1979)
	mefula		Fernandes & Fernandes (1969)
	mepepo	Macua	Fernandes & Fernandes (1969)
	m'kôko	Lumué	Fernandes & Fernandes (1969)
	muchangua	Chindao	Fernandes & Fernandes (1969)
	mudangua		Fernandes & Fernandes (1969)
	muganu	Chindao	Fernandes & Fernandes (1969)
	mutual	Malolo	Fernandes & Fernandes (1969)
	nkanye	Ronga	Watt & Breyer-Brandwijk (1962)
	ocanheiras		Shone (1979)
	ocanho	Ronga	Gomes e Sousa (1966-1967)
	okania		Shone (1979)
	tsula	Ronga	Gomes e Sousa (1966-1967)
	umkanya	Ronga	Fernandes & Fernandes (1969)
	unganu		Scott (1950)
Namibia	goaros	Nama	Teichman (1982)
	omuongo	Herero, Kwanyama	Teichman (1982)
	omwoongo	Kwanyama	Rodin (1985)
	ongongo (= the nut)	Kwanyama	Rodin (1985)
South Africa	amaganu (= seeds)	Zulu	Teichman (1982)
	dikôkô (= fresh seed)	Sotho	Teichman (1982)
	iganu	Ndebele	Teichman (1982)
	ikanyi	Ndebele	Teichman (1982)
	kanye (= the fruit)	Thonga	Teichman (1982)
	lehlabula la marula (= fresh fruit)	Sotho	Teichman (1982)
	lerula (= fruit)	Sotho	Teichman (1982)
	marula (= fruit)	Sotho	Teichman (1982)
	merula	Sotho	Teichman (1982)
	mongo (= seed)	Thonga	Teichman (1982)
	morula	Sotho	Teichman (1982)
	mufula	Venda	Teichman (1982)
	murula	Sotho	Watt & Breyer-Brandwijk (1962)
	nganu	Sotho	Watt & Breyer-Brandwijk (1962)
	nkanya	Thonga	Teichman (1982)
	nkanyi	Tsonga, Zulu	Shone (1979)
	thambo (= seed)	Venda	Teichman (1982)
	thebvu (= stone)	Venda	Teichman (1982)
	umganu	Ndebele, Zulu	Teichman (1982)
	umkano	Ndebele	Teichman (1982)
Swaziland	marula		Compton (1975)
	umganu	Swazi	Compton (1975)
Tanzania	gulgurchandi	Gorowa, Iraqw	Mbuya *et al.* (1994)
	mbwegele	Matengo	Mbuya *et al.* (1994)
	mbwejele	Gogo	Msanga (1998)
	mn'gongo	Swahili	Greenway (1940)
	mng'ongo	Swahili, Zaramo	Mbuya *et al.* (1994)
	mng'ong'o	Nyamwezi, Nyaturu, Pare, Swahili, Nguu,	Msanga (1998)
	mongo	Swahili	Greenway (1940)
	monyangu	Mbugwe	Mbuya *et al.* (1994)
	mtondoko	Matengo	Mbuya *et al.* (1994)
	muhuri	Nyaturu	Mbuya *et al.* (1994)
	mungango	Swahili	Greenway (1940)
	ngongo	Zaramo	Watt & Breyer-Brandwijk (1962)
	ng'ongo	Sukuma	Mbuya *et al.* (1994)
	olmang'oi	Arusha	Mbuya *et al.* (1994)
	omongwe	Kuria	Mbuya *et al.* (1994)
Zambia	mgamu	Nyanja	Storrs (1979)
	mongwe	Toka	Mitchell (1963)
	msewe	Nyanja	Storrs (1979)

Country	Name	Language/Ethnic group	Reference
	mubongo		Shone (1979)
	mugongo		Shone (1979)
	mulula	Lozi	Storrs (1979)
	muongo	Kaonde, Lozi, Tonga	Storrs (1979)
	musebe	Bemba	Storrs (1979)
	muyombo	Lozi	Storrs (1979)
Zimbabwe	bufuna		Shone (1979)
	ganyi		Goldsmith & Carter (1981)
	iganu		Shone (1979)
	ikanyi	Shona	Shone (1979)
	manganu		Shone (1979)
	mapfura	Shona	Tredgold (1986)
	marula	Shona	Goldsmith & Carter (1981)
	mufuna	Shona	Goldsmith & Carter (1981)
	mufura	Shona	Shone (1979)
	muganu	Shona	Watt & Breyer-Brandwijk (1962)
	mukwakwa	Shona	Shone (1979)
	munogo		Goldsmith & Carter (1981)
	mupfura	Shona	Goldsmith & Carter (1981)
	mushomo	Shona	Watt & Breyer-Brandwijk (1962)
	musomo	Shona-Mtoko	Shone (1979)
	mutsomo	Shona	Goldsmith & Carter (1981)
	pfura (= fruit)	Shona	Tredgold (1986)
	umganu		Goldsmith & Carter (1981)
	umkano (= seed)		Shone (1979)

• PRIFYSGOL CYMRU •
UNIVERSITY OF WALES
BANGOR
1884