PRUNUS AFRICANA

A MONOGRAPH

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Front cover: *Prunus africana* bark collectors emerging from the forest in Madagascar (Ian Dawson).
Back cover: Distribution of *Prunus africana*. Sources of distribution data: collecting localities noted on voucher specimens held in various herbaria, supplemented by specimen localities noted in literature (cited in text). Herbaria: Royal Botanic Garden, Kew (RBG); Laboratoire de Phanérogamie MNHN, Paris (P); National Botanic Garden of Belgium, Brussels (BR); Natural History Museum, London (BM); Daubeny Herbarium, Oxford (FHO); Kenya National Herbarium, Nairobi (NMK); Missouri Botanical Garden, St. Louis (MO). Note: Map extent is 20^{o} W to 60^{o} E, 38^{o} N to 35^{o} S. Map scale is 1:53,000,000. Dot resolution is 2200 km^2. Dot frequency reflects collecting intensity, not population density.

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FOREWORD

The stimulus for devoting a monographic study to *Prunus africana*, the African cherry, a source of bark extractives for the pharmaceutical industry, was its listing as a potentially threatened species under CITES regulations. When the case was made for inclusion in CITES Appendix II, little information on the species was readily available for evaluating its status or planning management and domestication. This monograph fills this need by reporting the current state of knowledge as the outcome of an in-depth review of the many widely scattered references to the species, in eight principal chapters covering not only conventional descriptive information (such as ecology, biology and wood) but also topical issues surrounding its conservation and sustainable exploitation (conservation and policy).

This is the fifth multipurpose tree monograph produced at the School of Agricultural and Forest Sciences of the University of Wales, Bangor, with funding from the Forestry Research Programme of the UK Department for International Development. Previous monographs have covered economically important dryland trees. This is the first to focus on a forest tree and is, more significantly, the first where Bangor has enjoyed major collaboration with external colleagues in writing the monograph - from the International Centre for Research in Agroforestry, Nairobi, Kenya and the Mount Cameroon Project, Limbe, Cameroon. Colleagues in Kenya, Cameroon and Madagascar have produced extension materials and organised dissemination events on *Prunus africana* linked to the monograph. These extension materials and activities complement the monograph and are making a difference in some of the rural communities for which *Prunus africana* is a valuable asset.

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1 IMPORTANCE

E. M. O' Brien

The trees and shrubs of Africa's forests and woodlands are of increasing importance to the economic and social well-being of African peoples. In addition to being sources of timber for building materials or export, of firewood, and of wood for making tools, furniture and carvings, some trees also provide dietary resources, others medicinals. The latter typifies *Prunus africana*, typically a straight-boled evergreen canopy tree with rough bark (for a detailed description see Appendix 1) which is widespread in the mountainous and volcanic highlands of subsaharan Africa. It is the only species of the genus *Prunus* in Africa and, unlike many other Afromontane species, is effectively restricted to Afromontane ecosystems. The species is therefore a good monitor of the health of these ecosystems, especially in terms of global warming while, in terms of palaeobotanical studies, it is a good indicator of past changes in their distribution and the climatic conditions associated with them.

This monograph takes the first steps towards providing the knowledge base needed for decision-making and policy development. It is a synthesis of information published on this tree and noted on herbarium specimen vouchers since its initial collection by Friedrich Welwitsch in Angola almost 150 years ago. We bring together knowledge on the species that is currently geographically disparate and uneven in depth, especially in terms of its ecology and biology (Chapter 2). Not even the distributional range has previously been documented in detail. Being only a minor timber tree (Chapter 6), the timber industry has produced no literature specific to the management and conservation of *Prunus africana*. With the exception of Cameroon, where it has been a focus of political, scientific and ethnobotanical attention for at least a decade, and more recently Kenya, it has been neglected scientifically. By synthesising and integrating what is known we have increased the breadth and depth of present knowledge and exposed its limitations.

What is known about the management and conservation of *Prunus africana* is reported in Chapters 3 and 7 respectively. International and governmental policy issues, beginning with protective legislation (e.g. CITES Appendix II), are outlined in Chapter 8. As discussed in Chapter 4, during the last decade various international and governmental agencies have begun work on developing alternative sources of *Prunus africana* bark, including domestication, for use in plantations and by traditional farmers as a cash-crop. In the meantime, demand exceeds supply, especially in areas where pharmaceutical firms have set up preliminary processing plants. By and large, the pharmaceutical firms have tried to cooperate with government agencies in monitoring and limiting harvesting of bark, but with limited success. It is to the advantage of both that the species is protected and managed to provide a sustainable supply.

It was in the early 1970s that the discovery was made that chemical compounds from *Prunus africana* bark (Chapter 5) were suitable for treating benign prostatic hyperplasia, a disease causing non-cancerous enlargement of the prostate, afflicting elderly men worldwide. Given global demographics, the increasing number of individuals surviving into old age means that the demand for bark should continue to increase well into the middle of this century. Until the active chemical compounds needed by pharmaceutical firms have been isolated and synthesised, the natural bark will remain a major source. Even if synthesis in the laboratory is possible, natural sources may still present the cheaper and more attractive option.

At present, the bark is only available from wild populations. However, if management and domestication hopes are eventually fulfilled, supplies from planted sources will meet a growing proportion of the demand. *Prunus africana* is not unique as a source of phytochemicals used in the pharmaceutical sector for treating benign prostatic hyperplasia. Extracts from at least eight other plants have been recognised as having similar potential. Domestication and increased reliance on planted trees would make the pharmaceutical future of *Prunus africana* bark extract much more secure in the face of competition from its rivals. The main rivals are the fruit of saw palmetto, which is the American palm, *Serenoa repens* (BARTRAM) SMALL, and the seed of a pumpkin, *Cucurbita pepo* L.

Even without domestication, the harvesting, transporting, and processing of the bark has opened up economic opportunities for indigenous peoples. However, in some places, such as Madagascar and Cameroon, where *Prunus africana* has been exploited for almost two decades, the species is in rapid decline. To prevent this decline continuing, whether in Madagascar, Cameroon or elsewhere in Africa, without inhibiting the potential economic and social benefits, will be a challenge to African governments. Their success or failure will depend in large part on knowledge of the species' ecology, biology and distribution, and adopting preservation, conservation, and management policies and practices appropriate for sustainable exploitation. The bark of *Prunus africana* is a renewable resource. Harvesting is theoretically possible for the life of a tree. However, it is often harvested in a fashion that kills the tree, eliminating individuals that could have provided bark and thus income for decades into the future.

Ethnobotanically, other than its international value to the pharmaceutical industry, *Prunus* is typical of many forest trees, being traditionally exploited for a variety of purposes - its wood for producing tools, furniture and building supplies, as well as firewood; its leaves and other parts of the plant for medicinals for livestock as well as humans. In terms of wood products, its economic value is realised mainly by timber companies with the equipment needed to fell, harvest and process mature individuals for lumber. Saplings and immature trees, which can be more readily cut and worked with the tools available, are exploited by indigenous peoples.

Whether we wish to conserve *Prunus africana*, manage it, or exploit it either as a wild plant or domesticated, we must understand its biology and ecology, and its potential for domestication. This understanding is the necessary baseline for evaluating its economic and social benefits, and any constraints to achieving sustainable harvesting, trade, management and marketing.

2 ECOLOGY AND BIOLOGY

John. B. Hall, E.M. O'Brien, M. Munjuga

Sound knowledge of the ecology and biology of a species must underpin management initiatives. When, as in the case with *Prunus africana*, products from the species enter international trade, the need for sound management becomes urgent. In this chapter we report the state-of-knowledge in terms of ecology and biology as background for the subsequent chapters on management (Chapter 3) and conservation (Chapter 7).

After our introductory comments on the affinities and origin of the species, our treatment of the ecology takes at first a broad approach. This has been enabled through preparation of a detailed distribution map which can be related to the parameters of the physical environment, also mapped on the continental scale. We complement this with a synthesis of available information at a local scale.

Our treatment of the biology of *Prunus africana* centres on the life cycle, phenology and the reproductive biology as indication of how the species functions and interacts in the ecosystem.

2.1 ECOLOGY

2.1.1 Affinities and origin

Kalkman (1988) undertook a phylogenetic analysis of the large family Rosaceae (*ca* 100 genera, *ca* 3000 species) using conventional morphological characters and concluded that it was "a very distinct and isolated family". Two areas of uncertainty were highlighted in the course of Kalkman's study: how the Rosaceae could be most satisfactorily subdivided and which other families were the sister-groups.

Differing views on subdivision have emerged during the last 20 years: a generalised scheme of current thinking is indicated in Fig. 2.1. Kalkman considered 22 groups of genera from the family, mostly tribes. He related these groups to the four subfamilies (Spiraeoideae, Rosoideae, Maloideae and Prunoideae) of Schulze-Menz (1964) although questioning the validity of the first two. Thorne (1992) recognises an additional subfamily, the Quillajoideae, separating this from other genera placed in the Spiraeoideae and preferring the name Amygdaloideae to Prunoideae. Recent phylogenetic analysis based on sequence variation in the chloroplast encoded *rbc*L gene (Morgan *et al.*, 1994), supports the general integrity of three of Schulze-Menz's subfamilies: the Rosoideae, Maloideae and Amygdaloideae. These authors consider the Maloideae and Amygdaloideae the more advanced subfamilies and suggest derivation from "spiraeoid-like ancestors". They suggest, too, that the Spiraeoideae has arisen from three lineages. In a study restricted to the Amygdaloideae, Evans & Dickinson (1999) recognise *Exochorda* (5 species), *Oemleria* (1 species), *Prinsepia* (3-5 species), *Prunus* (*ca* 200 species) and probably *Maddenia* (3-5 species) as the genera in a monophyletic Amygdaloideae. The species of *Prunus* are divided between two subgenera, *Padus* and *Laurocerasus* (Kalkman, 1965). *Padus* contains the deciduous species and *Laurocerasus* contains the evergreen species. *Prunus africana*, the only African and Madagascan species, is included in *Laurocerasus* as are all the Eurasian and tropical Asian species of the genus.

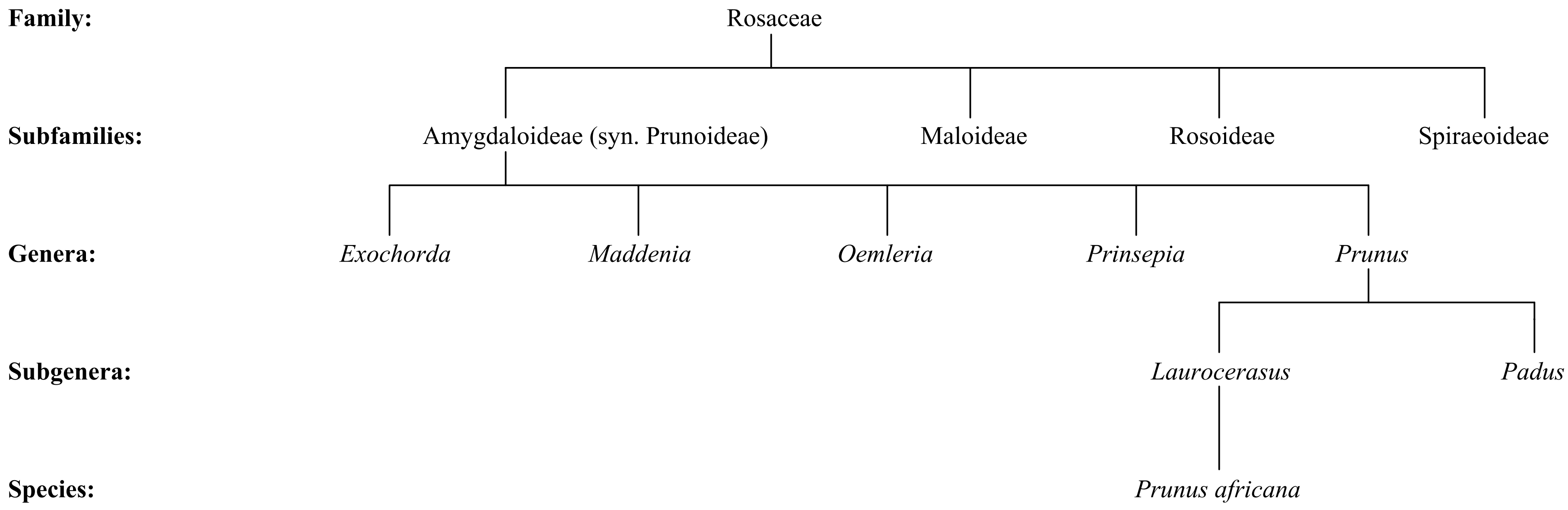

Figure 2.1 Position of *Prunus africana* within the family Rosaceae. Circumscriptions - family (Morgan *et al.*, 1994); subfamilies (Schultz-Menz, 1964); genera (Evans & Dickinson, 1999); subgenera (Kalkman, 1965).

In the past, despite awareness that the Rosaceae was such a distinct family, it was widely accepted that the Crassulaceae, Fabaceae and Saxifragaceae were related. Kalkman (1988) challenged this and suggested the Cunoniaceae as the closest relative, although not sufficiently close to merit sister-group status. The current view, based on *rbc*L gene sequence variation (Judd *et al.*, 1999) relates the Rosaceae to a quite different set of relatives. Judd *et al.* (1999) combine the Rosaceae with ten other families in the monophyletic order Rosales. Soltis *et al.* (2000) describe the Rosaceae as sister firstly to the Rhamnaceae and secondly to a complex of six other families (Cannabaceae, Cecropiaceae, Celtidaceae, Moraceae, Ulmaceae, Urticaceae).

In terms of the fossil record very little appears to be known. Muller (1981) gives the Oligocene period (*ca* 25-30 million years before present) as the start of records of the Rosaceae. However, all the specific pollen records Muller cites are for taxa since separated from Rosaceae as members of the Chrysobalanaceae (Malpighiales). The fossil pollen evidence that exists underlines a further complication - great pollen uniformity at family level, making separation of species difficult. Nevertheless, *Prunus* pollen grains have been reported from younger deposits (<40 000 years old) on Mount Kilimanjaro, Tanzania, and on Mount Kenya (Coetzee, 1967; Zinderen Bakker & Coetzee, 1972). Coetzee (1967) draws attention to the indicator value of *Prunus* pollen for interpretation of past vegetation conditions. Where *Prunus* accounts for at least 10% of the pollen spectrum over a long period of geologic record, an Afromontane forest community under a wet climate is indicated.

The chain of events leading to the present distribution of *Prunus africana* has been a matter of speculation. Aubréville (1976) and Kalkman (1988) infer quite different migration paths based on the present pattern. Aubréville (1976) considers *Prunus* subgenus *Laurocerasus* (taken to include *Prunus africana*) as Laurasian, and suggests movement into Africa from the north-east, along a route where no species of *Prunus* survives today. Kalkman (1988) argues that the origin was in Gondwanaland from where species of the tribe Pruneae (containing the genera *Maddenia*, *Prinsepia* and *Prunus*) moved northwards via paths starting in Australia, South America and Africa. The last path could explain the present distribution of *Prunus africana*.

According to Kalkman (1965) *Prunus africana* is morphologically most similar to *P. pygeoides* KOEHNE, which occurs in parts of India and China. Both species are also similar to *P. lusitanica* L., native to northern and central Portugal, the Canary Islands and Madeira, and *P. laurocerasus* L., a native of the Caucasus and Baltic regions. Unfortunately *Prunus africana* has not been included in any study attempting to clarify relationships between different species of *Prunus* using the power of modern molecular/genetic tools. Inferences based only on morphology must be treated with reservations considering the uniformity in features across the genus. *Prunus africana* displays characteristics which suggest it may be rather isolated. It is the sole African species and Kalkman's (1988) suggested migration path would reduce the likelihood of recent ancestry shared with the species he found morphologically similar. It appears to be chemically distinctive - hence its pharmaceutical importance. It is the largest of all the species of *Prunus* (Cunningham *et al.*, 1997) and its wood structure, too, is distinctive: “quite unlike any of the European woods belonging to the same natural order” (Stone, 1924).

2.1.2 Natural range

Prunus africana has been reported from twenty-two countries, most on the eastern side of the African continent (back cover). From eastern Africa the range extends westward into central Africa (Katanga, Democratic Republic of Congo; Congo-Zambezi River Basin Divide). Further west, there are disjunct populations in west Africa (Bioko, Cameroon/Nigeria and Sao Tome) and Angola. Populations in the Comoros and Madagascar are also disjunct.

2.1.3 Environmental factors

2.1.3.1 The broad picture

Topography

There are three basic physiographic domains in Africa: the Atlas Mountains, 'Low Africa', and 'High Africa'. With the exception of its narrow coastal margins, the continent is at least 200 m in elevation. 'Low Africa' encompasses most of Africa north of the equator, including west Africa and the Sahara. Average maximum elevation is less than 900 m, although some massifs and volcanic uplands reach higher elevations (*e.g*. Gotel Mountains, Mount Cameroon). 'High Africa' encompasses eastern, south central and southern Africa, and has a minimum elevation of 900 m. With the exception of some disjunct populations, *Prunus africana* is confined to 'High Africa', extending from latitude 33º40' S in South Africa to latitude 11º55' N near the Gulf of Aden (Fig. 2.2a; back cover). Within 'High Africa' the species is restricted primarily to mountains or volcanic regions, particularly the Great Escarpment in southeastern Africa and the Eastern and Western Rift Valley systems and Ethiopian Highlands of eastern Africa. The species skirts areas of high elevations where frost days arise in more than three months, suggesting it can withstand mild or infrequent frost, but not severe or prolonged frost.

The elevation at which *Prunus africana* occurs is highly variable, but broadly correlated with latitude. As latitude decreases towards the equatorial regions (0º), there is a general tendency for increases to occur in both the minimum and maximum elevations of occurrence, and thus in the range between them, per degree of latitude (Fig. 2.3). The range in southern Africa, according to comments with voucher specimens, is between 600 m and 1000 m but elevations as low as 60 m have been reported (Geldenhuys, 1981) in the Bloukrans River Gorge, South Africa. Both the range in elevation (1000-3500 m) and the maximum elevation (3500 m) are greatest in equatorial Africa. It is noteworthy that while most of 'High Africa' falls well within this range of elevation, *Prunus africana* is restricted to mountainous terrain within it.

Climate

In Africa, there is very little variation in day length and only temperature, rainfall and cloud cover appear to play significant roles in the distribution of *Prunus africana*. Intra-annual extremes in monthly mean temperature and the associated rainfall regimes, in particular, seem to be important (Figs. 2.2b-d).

From Natal to southern Tanzania, wet and relatively warm periods coincide with each other. The duration of the rainy season tends to increase towards the equator and near the equator there is either year-round rainfall (central and west Africa) or bimodal rainfall (as in Kenya) with two dry seasons per year. In terms of temperature, the striking pattern that emerges is that, for any given latitude, the distribution of *Prunus africana* is associated with areas of Africa where the monthly temperatures are low, especially during the warmest times of the year (Figs. 2.2c-d). For any given latitude, the intra-annual range in temperature (between the warmest and coldest month) varies as a function of elevation and rainfall. Fig. 2.2b shows that *Prunus africana* is geographically associated with mean annual rainfall from 500-700 mm (high latitudes) to over 3000 mm (low latitudes). The lower limits of this range do not reflect the contribution of orographic rainfall, cloud cover and/or ground water in ameliorating growing conditions.

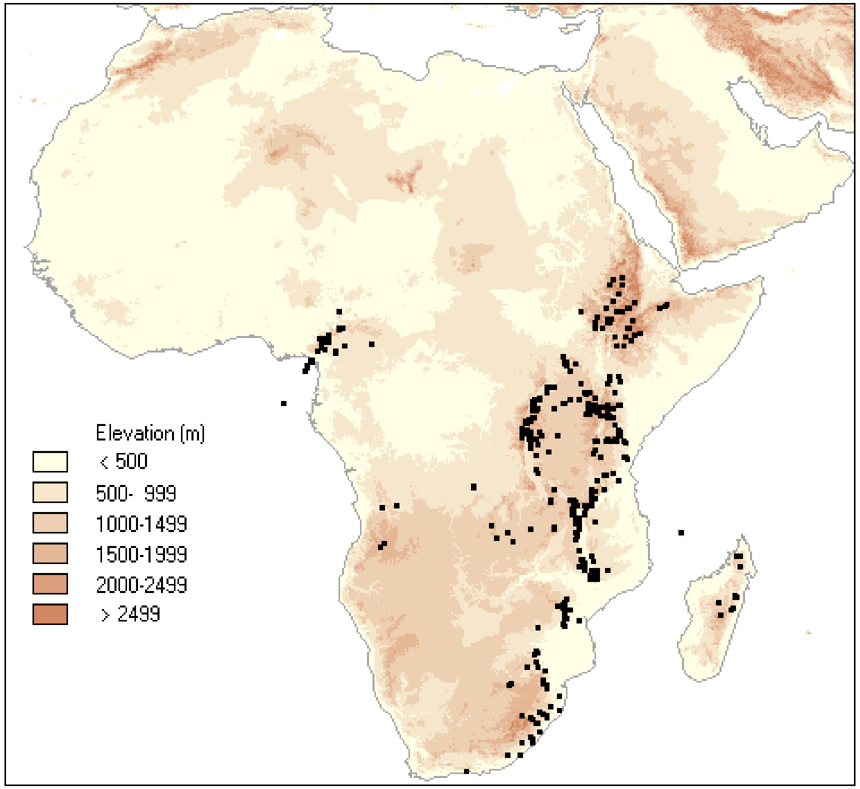

Figure 2.2a Distribution of *Prunus africana*: elevation

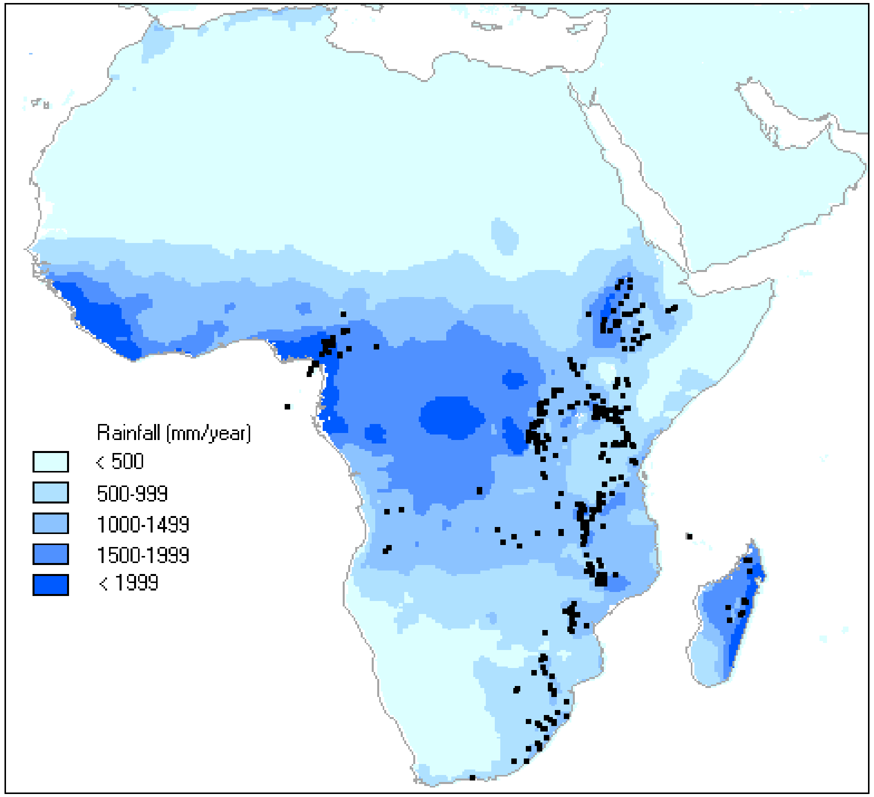

Figure 2.2b Distribution of *Prunus africana*: annual rainfall

Sources of distribution data—collection localities noted on voucher specimens held in various herbaria, supplemented by specimen localities noted in literature (cited in text). Herbaria: Royal Botanic Garden, Kew (RBG); Laboratoire de Phanérogamie MNHN, Paris (P); National Botanic Garden of Belgium, Brussels (BR); Natural History Museum, London (BM); Daubeny Herbarium, Oxford (FHO); Kenya National Herbarium, Nairobi (NMK); Missouri Botanical Garden, St. Louis (MO). Elevation and climate data from Legates & Willmott (1992).
Note: Map extent is 20ºW to 60ºE, 38ºN to 35ºS. Map scale is 1: 53,000,000. Dot resolution is 2200 km^2. Dot frequency reflects collecting intensity, not population density.

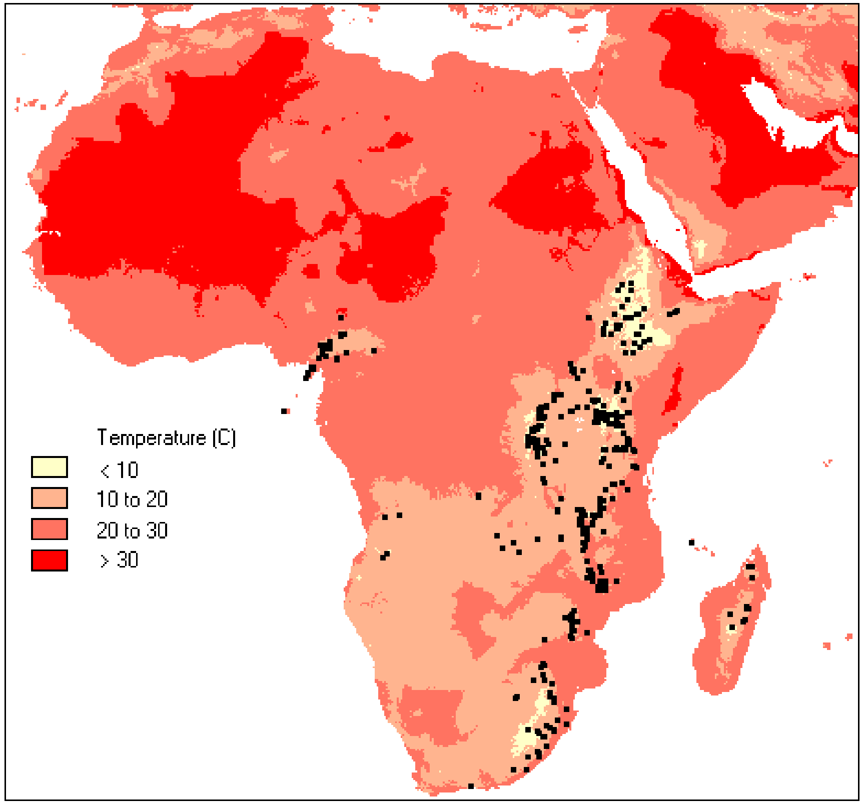

Figure 2.2c Distribution of *Prunus africana*: average temperature of warmest month

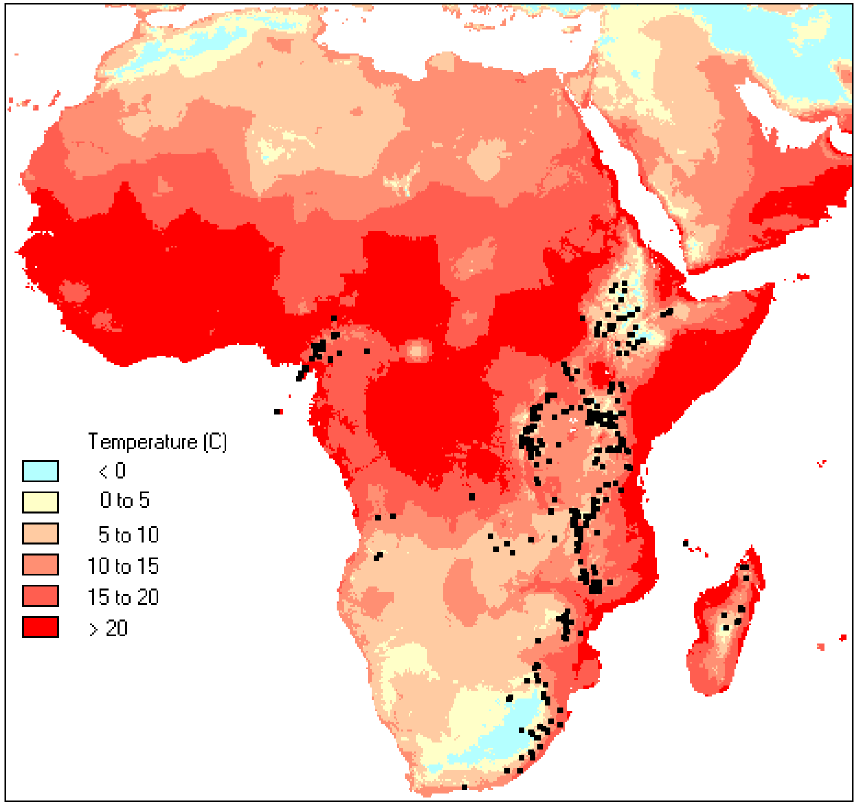

Figure 2.2d Distribution of *Prunus africana*: average temperature of coldest month

Sources of distribution data—collection localities noted on voucher specimens held in various herbaria, supplemented by specimen localities noted in literature (cited in text). Herbaria: Royal Botanic Garden, Kew (RBG); Laboratoire de Phanérogamie MNHN, Paris (P); National Botanic Garden of Belgium, Brussels (BR); Natural History Museum, London (BM); Daubeny Herbarium, Oxford (FHO); Kenya National Herbarium, Nairobi (NMK); Missouri Botanical Garden, St. Louis (MO). Elevation and climate data from Legates & Willmott (1992).
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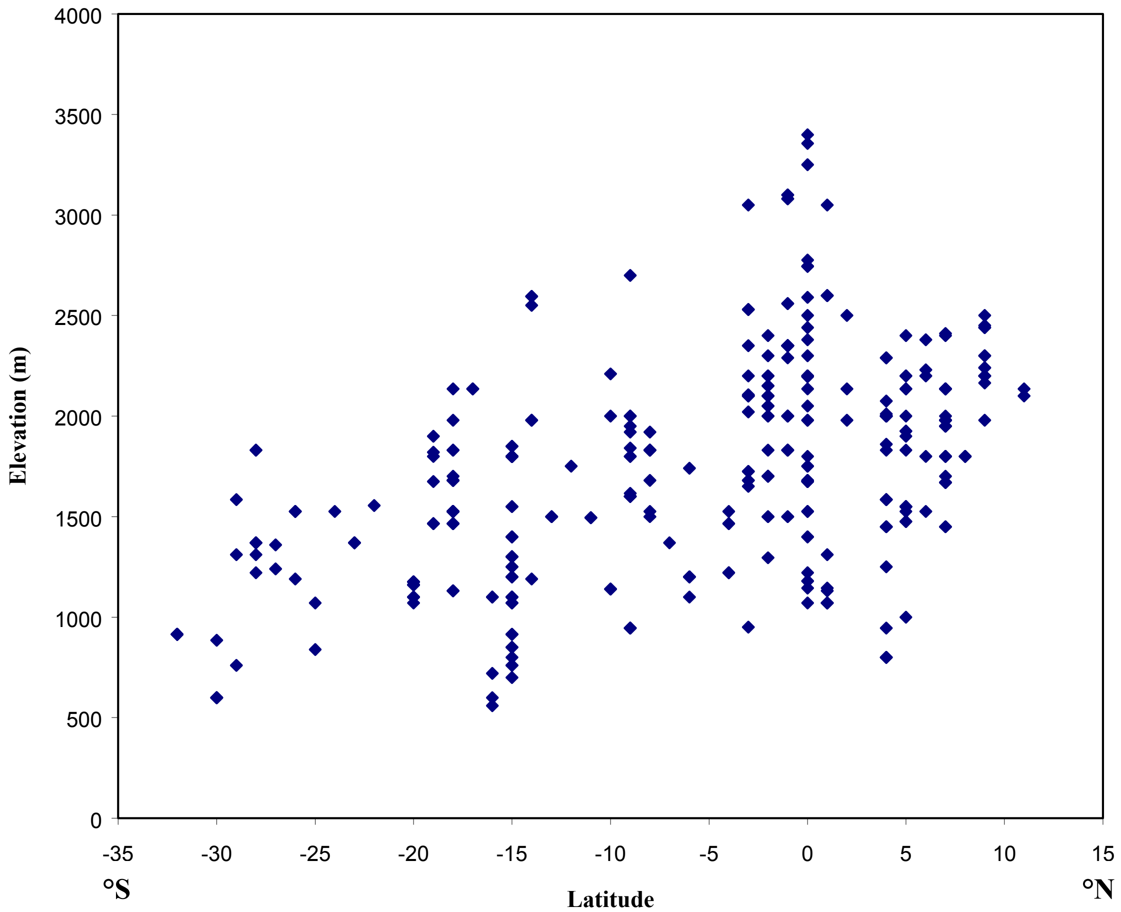


Figure 2.3 *Prunus africana* elevational range as a function of increasing latitude

In essence, *Prunus africana* is restricted to those parts of Africa that experience temperate climatic conditions and with a moisture supply (rainfall and/or cloud cover) sufficient to meet potential evapotranspiration during the growing season. It is high temperatures and/or insufficient rainfall during the warmest months of the year that limit *Prunus africana* essentially to the montane regions of Africa. The temperatures that the species is known to tolerate during the coldest months arise elsewhere in Africa (*e.g.* Kalahari Basin, Sahara Desert) (Fig. 2.2d), but this is not the case with the temperatures the species experiences during the warmest months (Fig. 2.2d), which are restricted almost entirely to the areas where *Prunus africana* occurs today.

2.1.3.2 Environmental information at locality level

Soils

Soils associated with vegetation (Afromontane Rain Forest and Undifferentiated Afromontane Forest) containing *Prunus africana* have been described from Tanzania (Pitt-Schenkel, 1938; Lundgren, 1978; Backeus, 1982), Malawi (Chapman & White, 1970), Ethiopia (Lundgren, 1971) and Sudan (Jenkin *et al.*, 1977). Information in these descriptions for the uppermost 60 cm of the soil profiles has been used for the comments which follow. The general picture is of association with fertile soils referable to the FAO-UNESCO (1977) soil mapping units of humic cambisols and humic nitosols.

Texture is generally light in the surface horizons, the soil being typically a loam or a sandy loam. Deeper horizons are often finer-textured - clay loams or even sandy clays. The soils examined by Chapman & White (1970) in Malawi are sandier than those described from other areas. Over volcanic rocks, as in Ethiopia (Lundgren, 1971), values are least acid - around pH 6.0. Elsewhere, the surface soils are rarely more strongly acidic than 5.0 and subsurface horizons rarely more strongly acidic than 4.5. The nutrient status of soils under vegetation with *Prunus africana* present is good, with base saturation values mostly in excess of 50% in the surface horizons (although markedly lower at greater depth) and reasonable supplies of nutrients.

Levels of exchangeable cations tend to be high: >4 m-mol K kg^{-1}; >60 m-mol Ca kg^{-1} and >20 m-mol Mg kg^{-1} in surface soils, but lower at depth (*ca* <3.5 m-mol K kg^{-1}, <10 m-mol Ca kg^{-1} and <5 m-mol Mg kg^{-1}). Particularly high values are reported by Lundgren (1971) for soils over volcanic materials in Ethiopia (up to 11 m-mol K kg^{-1}, as much as 250 m-mol Ca kg^{-1} and up to 40 m-mol Mg kg^{-1}). Available phosphorus usually exceeds 10 ppm in the surface horizon and values at depth are often higher. Organic carbon percentages are high (>5%), reflecting the elevation at which the species occurs. Total nitrogen percentages are also high (>0.5%) in the surface horizon.

Climate

Records of the occurrence of *Prunus africana* at known elevations within 20 km of 86 stations included in FAO (1984) allow insight into climatic conditions associated with populations of the species.

In terms of the precipitation and evapotranspiration regimes, the species occurs mainly where mean annual rainfall exceeds 900 mm. Potential evapotranspiration estimates are generally between 1100 mm and 1500 mm but as low as 900 mm in cloudy climates at high (≥2600 m) elevations. In many areas mean monthly rainfall exceeds 25 mm in every month but the species is also recorded from areas with as many as four dry (mean rainfall ≤25 mm) months, particularly towards the southern extreme of its range.

The records also allow estimation of mean monthly temperatures associated with the species, on the basis of a lapse rate of 0.6ºC per 100 m difference in height. In Fig. 2.4 the available information is summarised and presented for 1º bands of latitude. For each band, the bar shown indicates the range in temperature between the estimated lowest and highest mean monthly temperatures. The association of *Prunus africana* with cool conditions is evident, as is the similarity in temperature regime through the entire latitudinal gradient. In terms of monthly means, optimal conditions for the species appear to be temperatures of 11-19ºC and 17-23ºC in the coolest and warmest months respectively.

Monthly means of daily temperature minima and maxima indicate that the temperatures to which natural populations of *Prunus africana* may be exposed vary much more than the monthly mean temperatures suggest. Monthly means of daily temperature minima are typically between 5ºC and 10ºC while corresponding values for maxima are generally 25ºC to 30ºC. The sensitivity to severe or prolonged frost mentioned above (2.1.3.1) is again apparent. It is unusual for the mean daily minimum temperature of the coldest month to fall below 4ºC. However, there is some risk of frost even at elevations as low as 1600 m in parts of the range north of 7ºN. Here, in the December-February period, absolute minimum temperatures as low as -4ºC (Addis Ababa) have been recorded. Certain populations above 2000 m within 5º of the equator, as at Shume, Tanzania, are also subject to occasional frost. Further south, in the June-August period, frost and even snow can occur (Schulze & McGee, 1978).

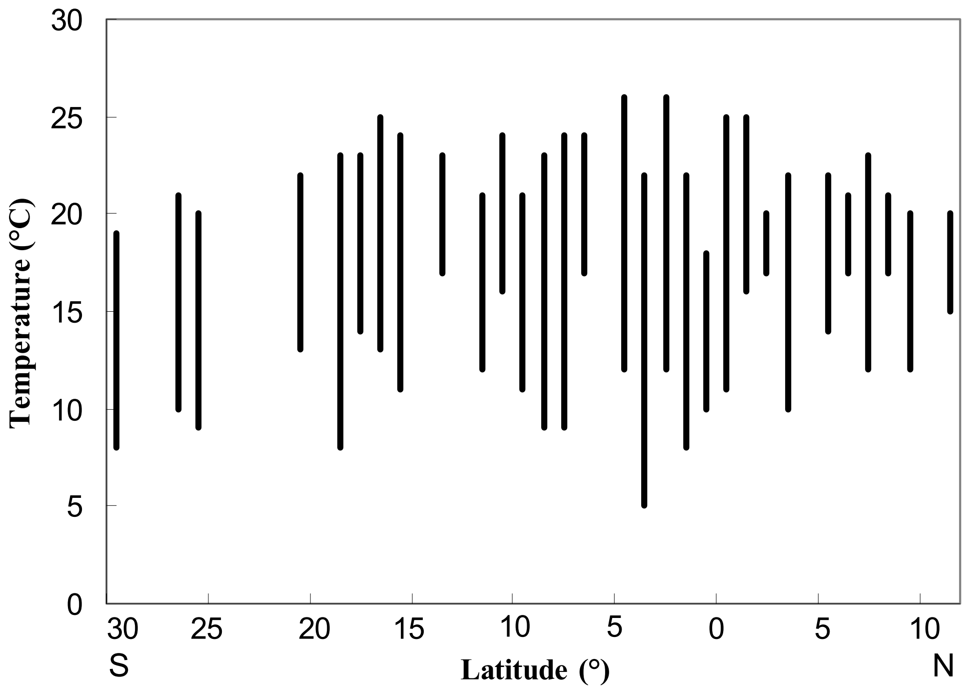


Figure 2.4 Mean monthly temperatures associated with *Prunus africana*

2.1.4 *Prunus africana* as a vegetation component

Prunus africana belongs to a group of approximately 20 tree species which typify White's (1983b) Afromontane Centre of Endemism at the continental scale. The members of this group occur in all seven of White's regional Afromontane systems on continental Africa (Table 2.1) and their presence in other phytochoria is unusual. In the particular case of *Prunus africana*, there are occurrences in forest dominated by Guineo-Congolian elements at 1000-1200 m in and around the Lake Victoria basin in Uganda and below 1000 m in southern Zaire (Kaniama - Mullenders, 1954), and as satellite populations along the Southern Migratory Track of White (1983a). Chapman & White (1970) place *Prunus africana* in the species category "eu-Afromontane genetical element" because there are no relatives in tropical African lowland forest but many in the north temperate zone. Friis (1992), however, has modified White's status to that of an Afromontane near-endemic, because of the number of occurrences in the southern part of the range in forest which is not typically Afromontane.

Prunus africana occurs both in forests transitional between lowland and Afromontane (where its occurrence tends to be sparse) and in a range of Afromontane forest types - from those dominated by a mix of broadleaved species to those dominated by conifers. In the various Afromontane forest types, the abundance of *Prunus africana* varies widely but the species is sufficiently prominent to have been used as a plant community descriptor: *Prunus* Zone of the Montane Forest Belt (Hamilton, 1974), *Pygeum* Moist Montane Forest (Langdale-Brown *et al.,* 1964; Spinage, 1972).

Table 2.1 The regional Afromontane systems of continental Africa (White, 1978)

System	Countries where *Prunus africana* occurs which are represented
West African	Cameroon, Nigeria and the offshore islands of Bioko (Equatorial Guinea) and Sao Tome
Ethiopian	Ethiopia
Kivu-Ruwenzori	Burundi, Democratic Republic of Congo, Rwanda, Tanzania and Uganda
Imatongs-Usambara	Kenya, Sudan, Tanzania and Uganda
Uluguru-Mlanje	Malawi, Tanzania and Zambia
Chimanimani	Mozambique and Zimbabwe
Drakensberg	Lesotho, South Africa and Swaziland

In White (1983b), these forest types are included in the Afromontane Rain Forest category - forest of wetter montane climates (1250-2500 mm mean annual rainfall; seven or more months with mean rainfall over 50 mm). With a similar rainfall regime but increasing elevation there is progressive change to Undifferentiated Afromontane Forest and *Prunus africana* commonly extends into this. Under increasingly drier conditions, Afromontane Rain Forest grades into Single-Dominant Afromontane Forest types. *Prunus africana* extends into the *Juniperus procera* ENDL. (Ethiopia and Malawi) and *Widdringtonia whytei* RENDLE. (Malawi) variants of these in low quantity. It also extends, again in low quantity, into Afromontane bamboo communities in Ethiopia (Lundgren, 1971), Kenya (Fries & Fries, 1948) and Tanzania (*Gereau & Kayombo 4105, K*) and into Afromontane evergreen bushland and thicket communities. Particularly in the Lake Victoria Basin, but also elsewhere, *Prunus africana* is present, but rare, in the transition between Afromontane and Guineo-Congolian or other lowland forest types.

South of the equator, *Prunus africana* has been widely reported in two other situations. The first is where, at elevations below the montane zone, the species is well-represented in rocky areas or boulder accumulations but absent from the surrounding terrain (Chapman, 1962; Chapman & White, 1970). The second is in forest associated with drainage lines - as a component of fringing forest (Zambesian riparian forest - White, 1983b) and seepage areas (Lawton, 1963) remote from any Afromontane forest communities and often at relatively low elevation. This situation appears to apply through an appreciable part of the range of the species: between the Eastern Arc Mountains and the Western Rift in Tanzania, in the southern part of the Democratic Republic of Congo and northern Zambia, and in Angola.

Fire-protection is suggested by Chapman (1962) as the explanation for populations among boulders at *ca* 900 m on the lower slopes of Mount Mlanje, Malawi. Lawton (1963) also attributes the presence of *Prunus africana* near Mpika, Zambia, to protection from fire - provided in this case by moist soil surface conditions continually maintained by seepage. The seepage areas mentioned by Lawton (1963) do not give rise to waterlogged ground with standing water, however, and the general scarcity of references to presence in swampy conditions indicates these to be unfavourable. Pitt-Schenkel (1938) states clearly that in the West Usambara Mountains, Tanzania, *Prunus africana* becomes established in valley bottoms only after the ground level has been raised by silt accumulation and build up of a layer of humus and litter.

The sensitivity to fire surmised by Chapman (1962) invites closer attention since *Prunus africana* is very characteristic of forest edges, where fires are frequent events and the thick bark (thicker than that of almost all associated Afromontane tree species - Chapman & White, 1970) imply a fair degree of fire tolerance. Nevertheless, there are very few suggestions from authors or in herbarium notes of occurrences in grassland and those reported are most likely to be of individuals left standing when land was cleared for farming.

There are several possible explanations for anomalous occurrences along drainage lines. Dowsett-Lemaire (1988) notes that some rivers flowing from Mount Mlanje pass through deep, sheltered gorges at elevations as low as 600 m which represent a downward extension of higher altitude conditions and are fringed with vegetation where Afromontane elements, including *Prunus africana*, are well-represented. In areas of more level terrain in the Zambesian region and its transition to the Guineo-Congolian region, riparian forests with characteristic Afromontane elements are suggested to be relicts of formerly more widespread and continuous communities (White, 1983a). Fragmentation of these could reflect climatic changes which confined forest to the places with the greatest availability of water, perhaps combined with human actions which cleared forest from level areas but not the steeper land along drainage lines. The survival of *Prunus africana* may be facilitated by a less extreme microclimate close to water courses than further away, as well as by protection from fire.

Profile diagrams of Afromontane Rain Forest which include *Prunus africana* (Langdale-Brown *et al.,* 1964; Lewalle, 1972; Chapman & White, 1970; Friis *et al*., 1982; Chapman, 1993-97) show the species as an upper canopy tree or emergent, reaching heights of 40 m. It can also be typically 15-20 m, in variable understorey that is sparse and mainly herbaceous in more exposed positions but with mixtures of shrubs and smaller tree species in more sheltered sites. Individuals of *Prunus africana* in vegetation transitional between the Afromontane and Guineo-Congolian phytochoria are also canopy constituents at maturity.

Inventory (Osmaston, 1959, 1960; Jenkin *et al*., 1977; Chaffey, 1979, 1980a, b, c), sample plot (Eggeling, 1947; Chapman & White, 1970) and ecological studies (Chapman *et al*., 1999) indicate the numerical contribution of *Prunus africana* to natural forest communities (Table 2.2). Most reports suggest numbers present are low and only the inventory returns furnish enough information to show a meaningful representation by size class. In Undifferentiated Afromontane Forest and Afromontane Rain Forest, numbers of *Prunus africana* individuals 30 cm dbh or larger reach 3-7 per hectare in parts of Ethiopia and Uganda and approach 2 per hectare in the Sudan Imatongs. Individual trees exceeding 120 cm dbh are present but few; most are less than 80 cm dbh.

Among the larger (>30 cm dbh) trees, *Prunus africana* accounts for 3-5% of individuals present in a number of forests assessed in Ethiopia and Sudan. For all trees $\geq$ 10 cm dbh the percentage tends to be lower due to the dilution effect (Hall, 1995) of including individuals of understorey species which never reach 30 cm dbh.

Table 2.2 *Prunus africana*: per hectare numbers or (in parentheses) tallied numbers, by diameter at breast height (dbh) class

Location	Dbh classes (cm)							Area (where given) and forest type	Reference
	≥10 <20	≥20 <30	≥30 <40	≥40 <50	≥50 <60	≥60 <70	≥70		
Cameroon: Mt Cameroon (4°00-10'N, 9°00-10'E)	0.04	0.16	0.12	0.14	0.12	0.07	0.22	'dense moist forest with crops'	ONADEF (1997)
Cameroon: Mt Cameroon (4°00-10'N, 9°00-10'E)	0.50	0.13	0.06	0.16	0.04	0.01	0.13	'farmland'	ONADEF (1997)
Cameroon: Mt Cameroon (4°00-10'N, 9°00-10'E)	0.27	0.06	0.13	0.15	0.24	0.13	0.19	'dense moist forest'	ONADEF (1997)
Equatorial Guinea (Bioko): Moca (3°16'N, 8°37'E)	(12)	(22)	(24)	(23)	(15)	(8)	(27)	No area given - 131 trees tallied (forest type not indicated)	Sunderland & Tako (1999)
Ethiopia: Tiro (8°01-15'N, 37°16'E)	1.4	1.3	1.0	1.1	0.8	0.6	1.0	Afromontane Rain Forest	Chaffey (1980c)
Ethiopia: Munessa (7°28'N, 38°53'E)	2.4	1.7	1.3	1.0	0.6	0.4	0.6	Undifferentiated Afromontane Forest	Chaffey (1980b)
Ethiopia: Shashemane (7°07'N, 38°41'E)	0.1	0.5	0.6	0.6	0.5	0.6	1.5	Undifferentiated Afromontane Forest	Chaffey (1980b)
Ethiopia: Shoa (7°00'-9°00'N, 36°00'-37°30'E)	n/a	n/a	2.0	2.1	0.9	1.1	1.0	Undifferentiated Afromontane Forest	Chaffey (1979)
South Africa: Bloukrans (33°57'S, 23°38'E; 60-240 m)	(3)	(0)	(2)	(3)	(4)	(7)	(4)	unspecified area (50-100 ha but with most *Prunus africana* individuals locally concentrated along drainage lines) of Undifferentiated Afromontane Forest	Geldenhuys (1981)

Table 2.2 (continued) *Prunus africana*: per hectare numbers or (in parentheses) tallied numbers, by diameter at breast height (dbh) class

Location	Dbh classes (cm)							Area and forest type	Reference
	≥10 <20	≥20 <30	≥30 <40	≥40 <50	≥50 <60	≥60 <70	≥70		
Sudan: Imatong Mts (4°00’N, 32°55’E)	n/a	0.13	0.40	0.20	0.53	0.33	0.57	15 ha of Undifferentiated Afromontane Forest (*Croton-Macaranga-Albizia*)	Jenkin *et al.* (1977)
Sudan: Imatong Mts (4°00’N, 32°55’E)	n/a	0.15	0.23	0.31	0.23	0.35	0.71	48 ha of Afromontane Rain Forest (*Olea-Podocarpus* closed forest)	Jenkin *et al.* (1977)
Sudan: Imatong Mts (4°00’N, 32°55’E)	n/a	0.12	0.27	0.22	0.25	0.23	0.92	60 ha of Afromontane Rain Forest (*Podocarpus-Syzygium* open forest)	Jenkin *et al.* (1977)
Uganda: Bugoma (1°15'N, 31°00'E; 1067 m)	n/a	0.12	0.12	0.01	0.02	0.05	0.02	232 ha of Drier Peripheral Evergreen Guinea-Congolian Rain Forest	Osmaston (1959)
Uganda: Kalinzu (0°20’S, 30°00’E)	n/a	n/a	0.38	0.85	0.91	0.57	0.61	21.0 ha of Afromontane Rain Forest	Osmaston (1960)
Uganda: Kalinzu (0°20’S, 30°00’E)	n/a	n/a	0.11	0.21	0.64	0.64	1.49	9.5 ha of *Parinari*-dominated Afromontane Rain Forest	Osmaston (1960)
Uganda: Kalinzu (0°20’S, 30°00’E)	n/a	n/a	0.19	0.34	0.33	0.24	0.64	88.3 ha of *Parinari*-dominated Afromontane Rain Forest	Osmaston (1960)

2.2 BIOLOGY

2.2.1 Chromosome complement

No reference has been found to any chromosome count for *Prunus africana*. However, Kalkman (1988) indicates a base number of x = 8 for those members of the Pruneae that have been examined in this regard.

2.2.2 Life cycle and phenology

2.2.2.1 Life cycle and longevity

Little information on the life cycle or longevity of *Prunus africana* has been reported. No references have been seen which suggest a juvenile phase recognisable from foliage characteristics, as is known in many tropical lowland forest trees. The species has often been recognised as a pioneer (*e.g.* White, 1983a) or early secondary (*e.g.* Geldenhuys, 1981) species. Such a status is consistent with the view of Breitenbach (1965) that it is initially fairly fast growing: mean annual height increment 0.6-0.8 m, presumably for South Africa. Further, from a more equatorial latitude in Rwanda faster early annual height growth is reported for planted seedlings (1.0-1.9 m - Mbonyimana, 1988). White (1983a) refers to the flowering of individuals 4 m tall and some collectors' notes indicate flowers were collected from trees less than 8 m in height (*e.g. Ghesquiere 3888*) suggesting that the onset of flowering may be at an age below 10 years, although commonly it appears to be later (Chapter 4). The early growth rate, early flowering and frequently reported association with disturbance (Eggeling, 1940a; Breitenbach, 1965; Geldenhuys, 1981) are consistent with White's (1983a) listing as a "nomad", a term emphasising adaptations for easily reaching (and persisting in) new forest gaps. A combination of nomadic behaviour and extended longevity explains why *Prunus africana* so often occurs as sparsely distributed large individuals in closed forest communities. The "*Pygeum* Moist Montane Forest", in which *Prunus africana* "seldom forms pure stands" even though it defines the community, is regarded as no more than a "complex mixture of juvenile stages" (Langdale-Brown *et al.,* 1964) and constitutes an ecosystem ideal for such a species. Large individuals of *Prunus africana* are not always thinly dispersed, however. Chapman & White (1970) refer to a "preponderance" of large (*ca* 1.5 m dbh), apparently ancient, individuals of *Prunus africana* retained when their understorey was replaced with a coffee plantation at Chintembwe, Malawi. Geldenhuys (1981) provides information on diameter increment by tree diameter class for trees in forest at the southern limit of the range. His observations, based on three years' monitoring, indicate progressively reducing increment as diameter increases beyond 30 cm, implying that the larger trees of his study (80-90 cm dbh) would be around 250 years old. No increment data have been seen for Malawi, where growth is likely to be faster, but it is nevertheless reasonable to estimate the longevity of *Prunus africana* as upwards of 100 years and not simply a few decades.

2.2.2.2 Flowering and fruiting seasonality

There are only a few systematic field studies of the reproductive seasonality of *Prunus africana.* Through consideration of dated records of flowering and fruiting from localities within 20 km of 57 meteorological stations included in FAO (1984), three different zones emerge for the species in general (Figs 2.5 and 2.6): a 'year-round' equatorial zone (within 5º of the equator), and two 'seasonal' zones north and south of it. The northern 'seasonal' zone (north of latitude 5ºN) is represented by Ethiopian populations. The equatorial zone includes populations in Burundi, Kenya, Rwanda and Uganda and some from the Democratic Republic of Congo and Tanzania. The southern 'seasonal' zone extends south from latitude 5ºS to South Africa and includes Malawi, Zambia, Zimbabwe and South Africa, as well as the most southern portions of the Democratic Republic of Congo and Tanzania. This synthesis suggests that there is no strong flowering seasonality in the equatorial zone, some individuals are flowering almost every month. The recent study by Munjuga *et al.* (in press) empirically supports this trend for Kenya. With few exceptions, north of 5ºN the flowering season corresponds to the November-January period, when there is least rain and when the lowest temperatures are experienced. South of 5ºS, flowering again tends to coincide with cool and dry conditions, from April to October. Possibly water stress or falling daily minimum temperatures, or both, are cues for the process.

The fruiting period seems to be the 2-3 months following flowering and is usually associated with rainfall. In the northern 'seasonal' zone, where sequences of dry months (*i.e.* 25 mm or less mean rainfall) are short (1-3 months), most reports of fruiting correspond to relatively wet months. South of 5ºS, however, where the dry season can be much longer (5-6 dry months), most records of fruiting correspond to months in the second half of the dry season or to when the rainy season is just beginning.

2.2.2.3 Flowering and fruiting frequency

Monitoring of reproductive events in forest vegetation containing *Prunus africana* has been undertaken on a short-term basis in connection with studies in Malawi (Dowsett-Lemaire, 1985), Rwanda (Sun *et al.,* 1996) and Uganda (Chapman *et al.,* 1999) in the course of bird and primate studies. Longer-term phenological monitoring specifically in the forest resource and management context was initiated in Rwanda (Godi & Zurcher, 1992) but no findings have been reported and the work has probably been discontinued. Sun *et al*. (1996) and Chapman *et al*. (1999) restrict detailed comment to a few particularly well-represented species (which do not include *Prunus africana*) and collective patterns of fruiting for all species combined. Dowsett-Lemaire (1985), however, reports that at the Nyika Plateau, Malawi (*ca* 10º30'S) individual trees of *Prunus africana* fruited in alternate years and that fruiting continued normally even in an exceptionally dry year. At Bloukrans, South Africa, the southern limit of the range (33º57'S), in sub-optimal conditions, fruiting is reported to be irregular (Geldenhuys, 1981). Referring to South Africa more generally, Breitenbach (1965) suggests full fruit-crops develop only at 2-3 year intervals. Long intervals between flowering events may help explain Sim's (1907) comment that trees of *Prunus africana,* in the Cape Province of South Africa, had been familiar to foresters for some years before they were identified botanically.

2.2.3 Reproductive biology

2.2.3.1 Pollen

The pollen is described and illustrated by Zinderen Bakker (1953-1959), and Coetzee (1967) presents a photomicrograph of a grain. The general appearance is typical of rosaceous pollen: a tricolporate sphaeroidal grain. Zinderen Bakker reports polar and equatorial diameters in the range 18-21 µm. The colpi are 3 µm wide at the equator of the grain, with the ends 5-8 µm apart over the poles. The exine is 1.5 µm thick, the nexine slightly thicker than the baculate sexine. The surface of the tectum is scabrid and minutely striate.

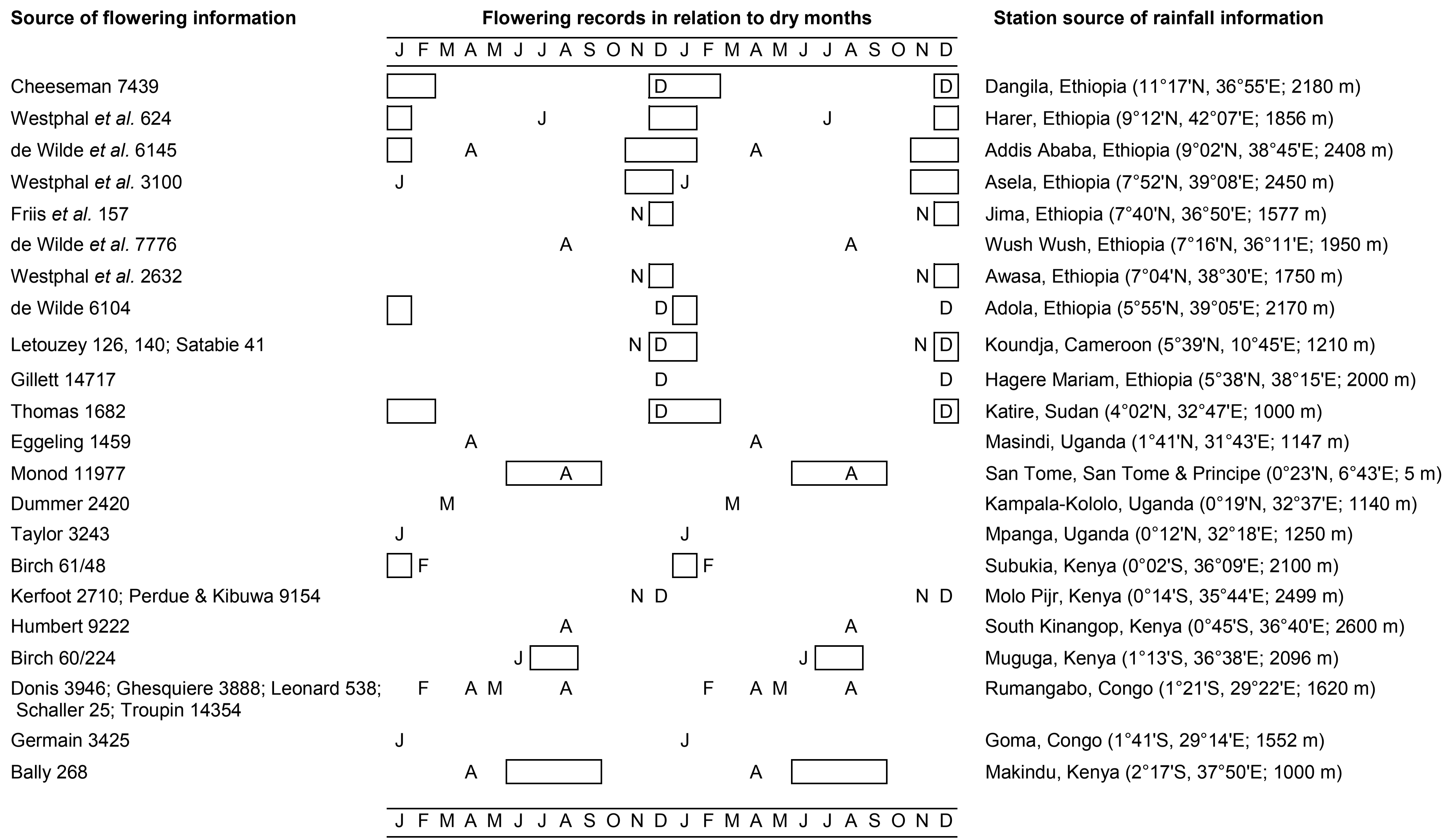
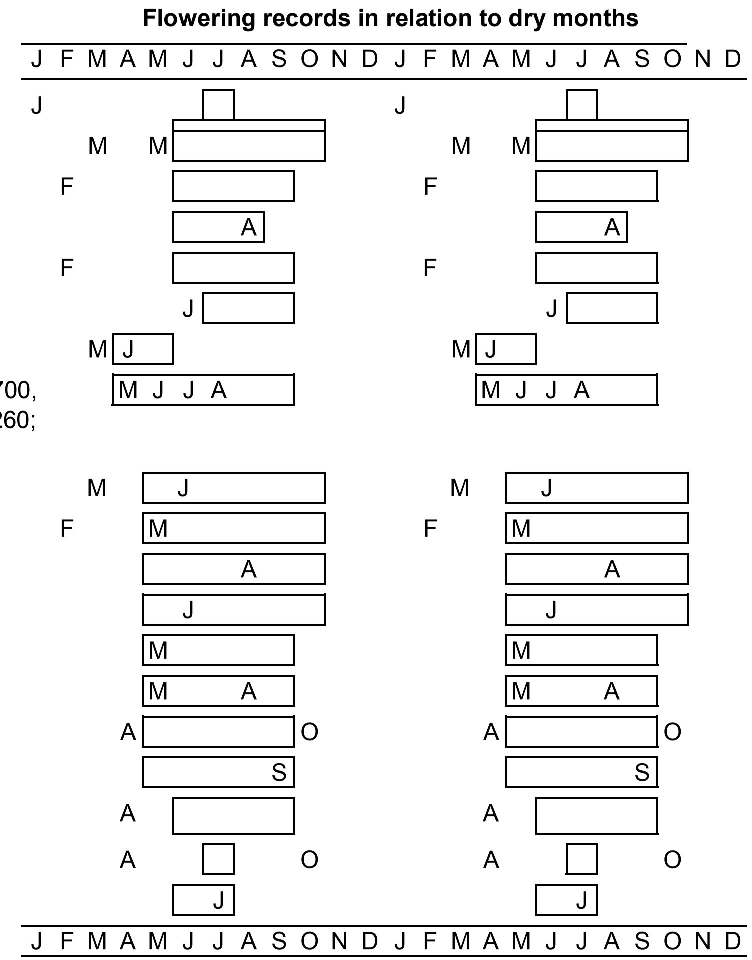


Figure 2.5 Flowering of *Prunus africana* in relation to dry months (mean rainfall ≤ 25 mm).



Source of flowering information	Station source of rainfall information
Christiaensen 1271	Mulungu Nyamunyunye, Congo (2°18'S, 28°48'E; 1703 m)
Makandy 1; Smith 3021; Tewesa 1	Arusha Airfield, Tanzania (3°20'S, 36°37'E; 1387 m)
Gillett *et al.* 17109	Voi, Kenya (3°24'S, 38°34'E; 579 m)
Michel 3574	Musasa Plateau, Burundi (3°39'S, 30°00'E; 1260 m)
Mgaza 454	Mombo, Tanzania (4°55'S, 38°14'E; 1070 m)
Schlieben 4043	Morogoro, Tanzania (6°50'S, 37°39'E; 526 m)
Hermann 2025, 2301, 2347; Perignon 74	Kaniama, Congo (7°25'S, 24°09'E; 949 m)
Gaetan Myembe 155; Linder 3835; Lovett 700, 2219; Paget Wilks 10; Parry 70; Proctor 1260; Shabani 1011	Sao Hill, Tanzania (8°20'S, 35°12'E; 1675 m)
Proctor 1883; Trapnell 1714	Mbala, Zambia (8°51'S, 31°20'E; 1673 m)
Gaetan Myembe 36; Kerfoot 3700	Mbeya Airfield, Tanzania (8°56'S, 33°28'E; 1707 m)
Trapnell 2182	Njombe, Tanzania (9°25'S, 35°45'E; 1890 m)
Milne-Redhead & Taylor 10877	Songea Town, Tanzania (10°41'S, 35°40'E; 1153 m)
Schmitz 2398, 2408	Kisanga Plateau, Congo (11°44'S, 27°25'E; 1187 m)
Brummitt *et al.* 15654; Chapman 6362	Bvumbwe, Malawi (15°55'S, 35°04'E; 1146 m)
Anon. 8502; Chase 4904; Davies 2503	Inyanga Exp Stn, Zimbabwe (18°17'S, 32°45'E; 1878 m)
Chase 924, 3946, 5068, 6198	Umtali, Zimbabwe (18°58'S, 32°40'E; 1119 m)
Swynnerton 1344	Chipinge, Zimbabwe (20°12'S, 32°37'E; 1132 m)
Goldsmith 36; Swynnerton 107	Espungabera, Mozambique (20°28'S, 32°46'E; 824 m)
Compton 32122	Mbabane, Swaziland (26°19'S, 31°08'E; 1163 m)

Figure 2.5 (continued) Flowering of *Prunus africana* in relation to dry months (mean rainfall ≤25 mm). Records are associated with a meteorological station within 20 km. Sequences of dry months are enclosed by frames and the initial letters of the months indicate when flowering was recorded. A 24-month cycle is adopted to emphasise climate seasonality and meteorological stations are listed in north-south order. [Note: Specimens not seen by the author but cited in literature sources].

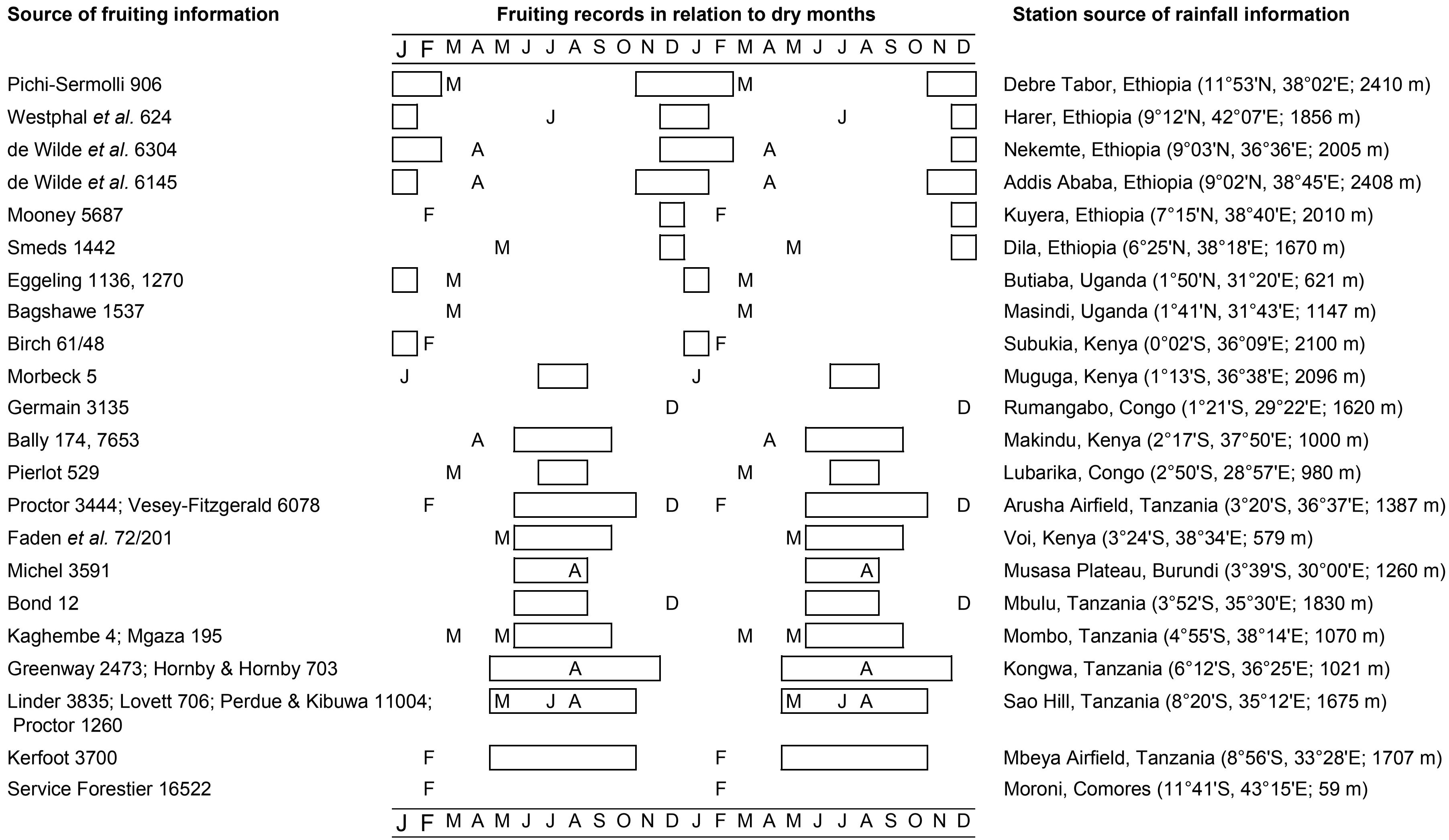


Figure 2.6 Fruiting of *Prunus africana* in relation to dry months (mean rainfall ≤25 mm).

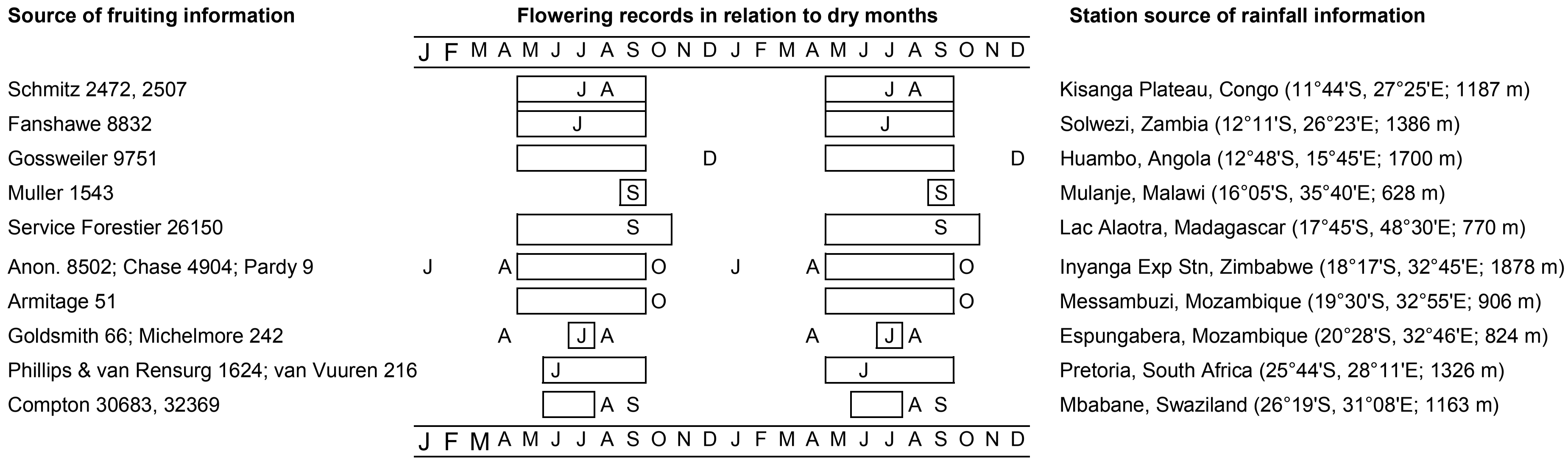


Figure 2.6 (continued) Fruiting of *Prunus africana* in relation to dry months (mean rainfall ≤ 25 mm). Records are associated with a meteorological station within 20 km. Sequences of dry months are enclosed by frames and the initial letters of the months indicate when fruiting was recorded. A 24-month cycle is adopted to emphasise climate seasonality and meteorological stations are listed in north-south order. Note: Specimens not seen by the author but cited in literature sources.

2.2.3.2 Anthesis

The opening and maturation of the flowers in the raceme follow an acropetal sequence, as shown in Mendes (1978). The flowers are protogynous. New flowers open during the morning (08.30-13.00 h) when the stigma emerges from the bud. Stigma receptivity is shown by a sticky fluid exuding immediately the flower opens and for a short period after (Munjuga *et al.*, in press).

Anther dehiscence and pollen exposure to potential vectors follow, taking place first in the outermost of the three whorls of stamens. The anthers of this whorl have withered by the time pollen is exposed in the innermost whorl, the last where dehiscence takes place. At the end of the period when viable pollen remains in the flower, petals, androecium, pistil and sepals wilt in turn (Munjuga *et al.*, in press).

2.2.3.3 Pollination and potential pollinators

In the equatorial zone, at Kiambu, Kenya (*ca* 1°10'S), the observations of Munjuga *et al.* (in press) suggest *Prunus africana* flowering, and therefore pollination, takes place continually at population level. However, different individuals flower at different times and during the study period, December 1998 - August 1999, only a few trees flowered synchronously. For individual trees, the mean duration of the flowering period was 10 days.

The flowers are apparently always perfect and there has been no suggestion that a proportion of the flowers are functionally unisexual, although this state is known in other species of *Prunus* (Kalkman, 1965). The observation that pollen grains falling to the soil surface are poorly dispersed (Hamilton, 1972) implies cross-pollination through animal vectors and that any role of wind is negligible. Munjuga *et al.* (in press) found pollen grains were sticky, taking this to indicate insects as pollinators, although also suggesting the light weight could result in some wind pollination. The wide separation of the anthers from the stigma decreases the prospect of pollen transfer within a single blossom. The presence of nectar (Munjuga *et al.*, in press) and the fragrant character of the flowers (Eggeling & Dale, 1951; Coetzee, 1967) strongly suggest insect pollination and direct observation of flower visitors supports this view. In Ethiopia and Kenya, respectively, Fichtl & Adi (1994) and Munjuga *et al.* (in press) report bee (Hymenoptera: Apidae) foraging for nectar and pollen. An intensive schedule of daytime observation (to 17.00 h) of flower visitors by Munjuga *et al.* (in press) at Kiambu, added further Hymenoptera (Anthophoridae; wasps of unspecified family), Diptera (Syrphidae), and nectar-foraging sunbirds to the list of potential pollinators. Visits were mostly from 07.00-11.00 h and 15.00-17.00 h for bees (*Apis mellifera* L., Apidae; *Xylocopa nigrita*, Anthophoridae) and mainly from 09.00-12.00 h for birds (*Nectarinia reichenowi* (FISCHER) 1884, *Nectarinia preussii* (REICHENOW) 1892). Combined with the scent, the predominantly whitish colour, the shape (dish-shaped) and the numerous well-exserted pale anthers on pale filaments will make the flowers conspicuous and accessible also to insects active at dusk. Visiting ants (Hymenoptera: Formicidae) were not thought to effect pollination (Munjuga *et al.*, in press).

Munjuga *et al.* (in press) also undertook a controlled pollination exercise. Outbreeding was found to be the dominant mechanism. Self-compatibility was confirmed but only following controlled pollen transfer, testifying to the effectiveness of mechanisms and floral structure in preventing selfing. There was no evidence of seed development without pollination.

2.2.3.4 Fruit development and seed dispersal

The reproductive process in *Prunus africana* is completed in a matter of a few months. The inflorescences arise on shoots in their second year of growth, the fruits developing behind the youngest leaves on those shoots. The fate of the flowers from anthesis to fruit maturation was monitored at Kiambu, Kenya, by Munjuga *et al.* (in press). Only 2-12 of the flowers on racemes where 15-24 flowers opened, reached the fruiting stage. No raceme eventually yielded more than four fruits and some yielded none.

Despite its wide distribution in Africa and on islands off-shore, there is little published information on the seed dispersal process. It appears that after heavy fruiting, considerable numbers of seeds fall immediately under the crown (Sunderland & Nkefor, 1997). In Cameroon, animals feeding on the fruits, and thus potential dispersal agents, include the primate *Cecopithecus preussii* and the birds *Andropagus montanus* REICHENOW 1892 and *Tauraco bannermani* (BATES) 1923.

In Kenya, Munjuga *et al.* (in press) noted greenbuls (*Andropadus gracilirostris* STRICKLAND 1884, *Andropadus latirostris* STRICKLAND 1884, *Andropadus nigriceps* (SHELLEY) 1890) and mousebirds (*Colius striatus* GMELIN 1789) as birds feeding on *Prunus africana* fruits and potentially dispersing the seeds. Three primates, *Cercopithecus mitis* WOLFF, *Cercopithecus nictitans* (L.) and *Colobus abyssinicus* (OKEN) are also known to feed on *Prunus africana* fruits and Munjuga *et al.* (in press) attribute a seed dispersal role to the first two.

2.2.4 Pests and diseases

Most of the reported insect pests of *Prunus africana* (Table 2.3) are coleopterous borers causing wood degrade. Only single reports of defoliating insects and sap-feeders (Arap Sang, 1988; Blackman & Eastop, 1994) have been seen. Pathogenic fungi (Table 2.4) have been reported from nursery and seedling studies (Breitenbach, 1965; Mwanza *et al.*, 1999).

Table 2.3 Insect pests reported on *Prunus africana*

Order and family	Species	Remarks	References
Coleoptera			
Bostrychidae	*Xylionopsis ukerewana*	wood borer; powder post beetle	Arap Sang (1988)
Bostrychidae	*Xyloperthodes clavula* LESNE	powder post beetle	Gardner (1957)
Cerambycidae	*Chlorophorus carinatus* AUR.	wood borer, particularly sapwood	Arap Sang (1988)
Cerambycidae	*Chlorophorus* sp.	wood borer	Arap Sang (1988)
Cerambycidae	*Ionthedes formosa* var. *melanaria* ACH.	Uganda (Mpanga)	Gardner (1957)
Cerambycidae	*Macrotoma dohertyi* LAM.	wood borer	Arap Sang (1988)
Cerambycidae	*Macrotoma trageramus*	wood borer	Arap Sang (1988)
Cerambycidae	*Pectotenus scalabrii* FRM.	wood borer	Arap Sang (1988)
Cerambycidae	*Phrynetopsis lovenii* AUR.	borer, initially creating galleries beneath bark, later penetrating into heartwood - Kenya (Londiani, Mt Elgon), Uganda (Mpanga, Mafuga)	Gardner (1957); Lang Brown (1964)
Cerambycidae	*Xylotrechus saltator* KLBE	in logs	Gardner (1957)
Curculionidae	*Scolytoproctus tibialis* MSHL	associated with existing tunnels in logs - Uganda	Gardner (1957)
Lyctidae	*Minthea apiculata* LESNE	associated with girdled trees - Kenya (Londiani, Nyeri)	Gardner (1957)
Meloidae	*Mylabris dicincta* BERTOL.	flower eater	Arap Sang (1988)
Passalidae	*Didimus sanzibaricus* AGR.	wood borer	Arap Sang (1988)
Platypodidae	*Doliopygus kenyaensis* SCHEDL	wood borer	Arap Sang (1988)
Platypodidae	*Platyscapus laudatus* SCHEDL	Uganda (Toro)	Gardner (1957)
Platypodidae	*Symmerus montanus*	wood borer	Arap Sang (1988)
Scolytidae	*Kissophagus fasciatus* HAG.	in dead trees - Kenya, Tanzania (West Usambara)	Gardner (1957); Arap Sang (1988)
Scolytidae	*Sphaerotrypes grandis* SCHEDL	in logs and weak trees - Uganda (Ankole, Itwara, Kalinzu)	Gardner (1957); Arap Sang (1988)
Scolytidae	*Sphaerotrypes pygeumi* SCHEDL	under bark of dead tree	Plant Protection Research Institute (1970)
Scolytidae	*Xyleborus illioidus* SCHEDL	wood borer	Arap Sang (1988)
Hemiptera			
Aphidoidea	*Aphis spiraecola* PATCH	sap feeder	Blackman & Eastop (1994)
Lepidoptera			
Geometridae	*Cleora herbuloti FLETCHER*	defoliator	Plant Protection Research Institute (1970)
Saturnidae	*Nudaurelia dione* F.	defoliator	Arap Sang (1988)

Table 2.4 Fungal pathogens reported on *Prunus africana*

Family	Species	Remarks	References
Phyllachoraceae	*Colletotrichum gloeosporioides* (PENZ.) PENZ. & SACC.	leaf spot and shot hole disease of seedlings causing premature leaf shed and leader die-back when severe - Kenya	Mwanza *et al.* (1999)
Meliolaceae	*Irene calostroma* (DESM.) V. HOEHN.	leaf mould - South Africa	Breitenbach (1965)

3 THE MANAGEMENT CONTEXT

N. Ndam, B. Ewusi, C. Asanga, John B. Hall

Most surviving Afromontane forest is in state-owned forest reserves and national parks (Hedberg & Hedberg, 1968). A large proportion of this is therefore subject to regulation and management by national forest services. Nevertheless, for Afromontane forest, and most of its component tree species, there is no tradition of management to match that for tropical lowland rain forest (Hall, 1995). In this chapter, today's setting for managing *Prunus africana* is reviewed against this background of limited experience at plant community level and also with regard to the species' ecology/biology and the infrastructures which influence harvesting practices and impacts.

3.1 MANAGEMENT AND THE AFROMONTANE FOREST ECOSYSTEM

Professional forestry management includes protection, evaluation, utilisation, ecosystem manipulation and transformation, and the creation of infrastructures to co-ordinate these activities.

Prescribed management operations concerned with protection call for minimal ecological or silvicultural knowledge and are easily undertaken by unskilled staff. For many forests, management does not involve more than boundary maintenance and prevention of fire, grazing and encroachment. As a distinctive and easily obtained (wildings) evergreen species, with a potential timber value at maturity, *Prunus africana* was formerly used in a protection capacity as a green fire break (Kigezi, Uganda - Lang Brown, 1964). On Mount Kilum/Oku, Cameroon, the species currently plays a protective role, having been planted to demarcate forest boundaries (Cunningham & Mbenkum, 1993).

Evaluation of Afromontane forest through inventory exercises has taken place in a number of areas but with emphasis principally on the existing stock of timber - as a means of judging whether investment in an exploitation operation is justified. In East Africa, in the past, *Prunus africana* was often included as a timber species which was mandatory to fell when logging licences were issued. During exploitation of forests in South Mengo, Uganda, all stems attaining *ca* 60 cm dbh were routinely felled (Sangster, 1950), while at Kalinzu, Uganda, pit-sawyers carrying out salvage felling were encouraged to exploit all individuals *ca* 90 cm dbh (Osmaston, 1960). Even forest designated as catchment forest, and primarily serving a watershed protection role, usually continues to be exploited. There is sanitary felling of "overmature" trees (Rodgers, 1993), although only trees of timber value (*Prunus africana* being one) tend to be targeted.

In practice there has been very little ecosystem manipulation because the dynamic aspects of Afromontane forest are not well understood, the commercial value of the resource has been considered relatively low, and most areas constitute difficult working terrain and are often remote. A noteworthy exception, however, is the application of the selection system of management and harvesting to the Undifferentiated Afromontane Forest of the southern Cape, South Africa (Geldenhuys, 1980, 1982). There has been more experience with transformation of the ecosystem. In areas of low erosion risk, policy has often been to replace exploited forest with plantations of exotics. Plantations of silviculturally familiar and easily managed exotic species (in particular eucalypts, cypress and pines) now occupy land that previously supported natural montane forest. Often, evaluation and harvesting have been no more than management phases leading to forest replacement with plantations of exotics.

3.2 SPECIES-FOCUSSED MANAGEMENT

The constituent species of Afromontane forest share the management neglect that has affected the ecosystem as a whole. Only for *Ocotea usambarensis* ENGL. is there a well-researched protocol (Holmes, 1995) for tending individuals that have become established spontaneously within natural populations. For a few other species, notably *Podocarpus falcatus* (THUNB.) MIRB., some recommendations have been made for increasing establishment, survival and increment with canopy opening action (Donald & Theron, 1983; Holmes, 1995). Because of the typically low stocking, *Prunus africana* has never been a priority timber species and did not merit specially tailored management practices. However, as it was a recognised timber species, it was expected to be favoured by measures aimed at promoting natural regeneration of indigenous timber trees generally (*e.g.* Osmaston, 1959, 1960 - for Uganda). In the transitional forests of the Lake Victoria basin (Chapter 2), the natural mix of species and ages was not commercially attractive. It was thought that a more valuable even-aged stand dominated by marketable timber species would develop after heavy felling (Osmaston, 1959). *Prunus africana*, favoured by the less dense post-logging canopy, was expected to contribute to the next harvest. As advance growth of *Prunus africana* reached exploitable size, it would be superseded by higher quality species, particularly mahoganies. Njunge (1996), as recently as the mid-1990s, noted that *Prunus africana* remained a preferred timber species in South Nandi forest, Kenya, and was exploited by selective felling.

In Cameroon, current, and growing, interest in *Prunus africana* as its pharmaceutical potential has been exploited is now prompting management interest in three silvicultural actions applied specially for the species. These are:

- to provide more light under seed trees to encourage the survival of seedlings
- in disturbed habitats and fallow to actively disentangle the young trees from climbers and undergrowth
- to carry out enrichment planting with both wildings and nursery-raised seedlings.

In Madagascar, encouragement of natural regeneration is the prescribed method for promoting sustainable harvesting (Walter & Rakotonirina, 1995). The ground within 10 m of each of two seed trees retained ha^{-1} must be cleared of other plants to promote regeneration of *Prunus africana*. The retention of seed trees within natural populations in Madagascar is intended at the same time to play a genetic conservation role. There is, however, an apparent conflict between the recommendation that 1-2 trees ha^{-1} be retained when the general population level is also 1-2 ha^{-1} (Walter & Rakotonirina, 1995). The importance of retaining suitable individuals specifically as seed trees has also been highlighted for Cameroon. In this case, the importance of undertaking harvesting with a procedure that will not impair the performance of seeding trees is emphasised by Stewart (1999) with the aim of protecting the genetic base.

There is little indication that for *Prunus africana* there are prospects for management schemes based on coppice rotations. Ndibi & Kay (1997) inspected cut stumps of *Prunus africana* on Mount Cameroon but found no useful tendency to produce coppice shoots as a response to felling the main stem. Dawson (1998) noted regeneration from cut trunks appeared low during an evaluation of *Prunus africana* in Madagascar. For Mount Cameroon, it has also been reported that even when shoots were produced, repeated removal of bark from the stumps of felled *Prunus africana* by bark harvesters, adversely affected shoot survival and growth (Ndam *et al.*, 1993).

3.3 *PRUNUS AFRICANA* AS A MANAGEMENT SUBJECT

3.3.1 Life cycle and increment

Seed testing indicates that *Prunus africana* has intermediate/recalcitrant seed (Chapter 4). Even in South Nandi, Kenya, where the species is well represented, no evidence of a seed bank has been found (Njunge, 1996). Although heavy seed crops are irregular, in most of the range they are not infrequent and when they occur individual trees may produce as much as 20 kg of fruit, each weighing around 0.5 g (Sunderland & Nkefor, 1997). After extraction, there are 3400-6000 seeds per kilogram, with a moisture content of 45-50%. A high proportion of fallen fruit remains close to the parent tree and germinates there, even if the shade is heavy. Nevertheless, as a light-demanding species, *Prunus africana* does not maintain a large seedling bank in the forest understorey (Ndam, 1998) and most or all such seedlings die while still small. Survival of *Prunus africana* regeneration is best in large gaps (Njunge, 1996). The concentrations of seedlings, and the ease with which they can be identified with certainty, has resulted in wide use of wildings for plantation and enrichment initiatives. Only relatively recently, as better-controlled stock quality has become especially desirable, has the emphasis moved strongly towards nursery-raised seedlings.

Detailed monitoring of increment in *Prunus africana* has not been reported but a number of references to the sizes of nursery plants, regeneration and trees of known age have been published (Table 3.1). Little information on seedling performance is available but on leaving nurseries in Cameroon, seedlings are 8-12 months old and 20-30 cm tall. This suggests that the low annual height increments measured (Ndam, 1998) in naturally regenerated seedlings in intact forest (<3 cm), fallow (*ca* 4 cm) and secondary forest (*ca* 8 cm) indicate stagnation, and that seedlings exposed to favourable conditions grow much faster.

While only limited information is available, the recorded mean annual height increment in excess of 1 m, and mean annual dbh increment >1.5 cm point to tended stands as an attractive management option. The figures provide justification for the domestication initiatives now under way (Chapter 4). Under informed and more intensive management, higher increment would probably result. If 30 cm dbh is taken as the minimum size for the commencement of bark harvesting, individual trees would reach this size at an age of *ca* 12 years; based on field experience, CERUT (1999) suggest trees should be older (15 years) but do not specify a size. Without harvesting, trees begin reproductive activity at 15-20 years old, according to Simons *et al.* (1998). Younger plants (8-9 years old) have been seen flowering among boundary-planted trees on Mount Kilum/Oku, Cameroon (C. Asanga, pers. obs.).

3.3.2 Population statistics

Natural populations of *Prunus africana* present management problems because of low and patchy stocking levels and the frequent under-representation of small individuals. All reports of stocking based on large (≥10 ha) sampled areas indicate few trees ha^{-1} that have attained exploitable size (30 cm dbh). Where such individuals are widely separated from each other harvesting time, and hence cost, increases and any supervision of the labour involved becomes more difficult. Further, during any single exploitation operation, bark should be collected from only a minority of the individuals ≥30 cm dbh (1 of every 8 for a cycle of 8 years) if a stable income based on *Prunus africana* bark is sought.

The patchy distribution of *Prunus africana* is recognised (Geldenhuys, 1981; Timberlake & Shaw, 1994; ONADEF, 1997; CERUT, 1999) but remains poorly understood. It does not appear, however, that areas where stocking is much higher (≥5 ha^{-1}) than the general level (*ca* 1-2 ha^{-1}) are sufficiently extensive to be the sole source of bark.

Table 3.1 *Prunus africana*: size, age and growth records

Location	Age	Size	Increment	Source/remarks
Kenya: S Nandi (0˚05'N, 35˚20'E; 1980 m)	1 year	30 cm tall		N. Ndam & B. Ewusi (pers. obs.) - trial plot intercropped with beans
Cameroon: Tole (4˚05'N, 9˚12'E)	5 months after outplanting	0.4-1.0 m tall		Tchoundjeu *et al.* (1999b) - nursery
Rwanda: Rutovu (2˚31'S, 29˚20'E; 2550 m)	2.5 years	1.68 m tall (mean)	0.67 m $year^{-1}$ (height)	Département de Foresterie (1991)
Rwanda: Rutovu (2˚31'S, 29˚20'E; 2550 m)	2.75 years	1.7 m tall (mean)	0.61 m $year^{-1}$ (height)	Kabera (1988)
Kenya: S Nandi (0˚05'N, 35˚20'E; 1980 m)	3 years	0.9 m tall (mean of 4)		Kigomo (1987): line planted
Kenya: Londiani (0˚10'S, 35˚35'E)	4 years	6 m tall; 10 cm dbh		N. Ndam & B. Ewusi (pers. obs.)
Rwanda: Rutovu (2˚31'S, 29˚20'E; 2550 m)	4 years	2.4 m tall (mean); 1.8 cm dbh (mean)	0.6 m $year^{-1}$ (height); 0.45 cm $year^{-1}$ (dbh)	Département de Foresterie (1991)
Rwanda: Rutovu (2˚31'S, 29˚20'E; 2550 m)	5 years	2.05-3.60 m tall	0.41-0.72 m $year^{-1}$ (height)	Département de Foresterie (1991)
Kenya: S Nandi (0˚05'N, 35˚20'E; 1980 m)	6 years	2.9 m tall (mean of 2)		Kigomo (1987): line planted
Cameroon: Mount Kilum/Oku (6˚12'N, 10˚28'E)	8-9 years	11-22 cm dbh	1.2-2.75 cm $year^{-1}$ (dbh)	C. Asanga (pers. obs.) - boundary plantings
Kenya: Kitale (1˚00'N, 35˚00'E)	8-9 years	*ca* 5 m tall; *ca* 5 cm dbh		N. Ndam & B. Ewusi (pers. obs.) - planted plot

Table 3.1 (continued) *Prunus africana*: size, age and growth records

Location	Age	Size	Increment	Source/remarks
Kenya: Londiani (0˚10'S, 35˚35'E)	10 years	*ca* 20 m tall; *ca* 25 cm dbh		N. Ndam & B. Ewusi (pers. obs.) - planted plot
South Africa: Bloukrans (33˚57'S, 23˚38'E; 60-240 m)	10 years	2 m tall to 11.3 m tall and 12.4 cm dbh		Geldenhuys (1981): transplanted nursery-raised seedlings
Rwanda: Gisovu (2˚15'S, 29˚21'E; 2500 m)	14 years	11.2 m tall (mean); 14.7 cm dbh (mean)	0.8 m $year^{-1}$ (height); 1.05 cm $year^{-1}$ (dbh)	Département de Foresterie (1991)
Cameroon: Ntingue (5˚21'N, 10˚02'E)	15 years	tallest 17 m; 7.9-42.3 cm dbh (mean = 15.8 cm dbh; n = 49)	1.1 m $year^{-1}$ (height); 0.53-2.64 cm $year^{-1}$ (dbh)	Cunningham & Mbenkum (1993) - enrichment planting
Kenya: Kopcherop (1˚02'N, 35˚19'E)	29 years	mean dbh 27 cm		N. Ndam & B. Ewusi (pers. obs.) - plantation trees
Kenya: Kakamega (0˚14'N, 34˚52'E; 1680 m)	31 years	*ca* 25 m tall; *ca* 35 cm dbh		N. Ndam & B. Ewusi (pers. obs.) - enrichment planting
Kenya: Kakamega (0˚14'N, 34˚52'E; 1680 m)	50 years	*ca* 30 m tall; *ca* 50 cm dbh		N. Ndam & B. Ewusi (pers. obs.) - enrichment planting

For Madagascar, reports of long journeys during which only isolated trees were encountered (Dawson & Rabevohitra, 1996) illustrate this problem, in this case thought to be a legacy of serious overexploitation in the past. Past yields have apparently involved most (70%) trees of 'exploitable size' on Mount Cameroon (Ndam, 1998), and will have involved widely scattered individuals as well as those concentrated in patches and at the forest margin. In the future, areas where natural populations of *Prunus africana* are subject to sustainable bark harvesting programmes will include at least a proportion of widely scattered trees.

Attention has been drawn to the "unbalanced" distribution of *Prunus africana* trees among diameter classes (Cunningham & Mbenkum, 1993; Sunderland & Tako, 1999). This is not unusual for a long-lived species associated with forest edges and disturbance, and able to reach large sizes. As with *Ocotea usambarensis* (Holmes, 1995) and *Podocarpus falcatus* (Geldenhuys, 1993), recruitment irregularities arising from year-to-year variability in fruiting contribute. The relatively rapid growth of young individuals, compared with those which are older/larger, amplifies this effect. The smaller individuals enumerated represent regeneration from only a short period (probably 20-30 years) but the larger individuals have accumulated over a much longer period, perhaps as much as 150 years. If mortality rates remain low until trees reach sizes in excess of 1 m dbh, as they do with many other large trees, large individuals are likely to be more numerous than those 10-30 cm dbh. Information on recruitment, growth and mortality is still needed to indicate whether this is the situation.

Given the nature of *Prunus africana* populations, a management option is harvesting on a forest unit basis, with the area accessible to a village being divided into units. When a unit was harvested, all *Prunus africana* individuals present which were large enough would be exploited. There would be the same number of units as years in the harvesting cycle. Units would be harvested in rotation and reharvested after the appropriate interval as the next cycle started. Units would need to be delimited on the basis of inventory information - each unit would contain a similar *Prunus africana* resource in terms of total stocking and balance between size classes. Catchment forests can be included in harvesting areas, as bark harvesting following an appropriate protocol poses no threat to catchment integrity. The species is present in many areas of catchment forest on terrain where logging is inadvisable and could offer local communities opportunities for income generation, enabling the source area of *Prunus africana* bark supply to be expanded.

3.4 MANAGEMENT AND BARK HARVESTING

3.4.1 Harvesting procedure

The two principal stages in harvesting are the removal of bark from the tree and its transport to the point where it is processed or prepared for shipping. There has been much harvesting through felling in the past and this destructive form of exploitation continues to be widely used - legally in some countries and illegally in others. There is now, however, a protocol for sustainable harvesting, developed with experience in Cameroon.

In Cameroon, without special authority being given, all felling of trees to harvest bark is illegal. Harvesting from live trees must be carried out in a non-detrimental fashion. During the wettest months harvesting is generally suspended (Macleod, 1986). The prescribed procedure is as follows (Ndam & Yogo, 1999):

- bark should be peeled from the trunk with a cutlass or a specially designed tool, to be removed in panels, beginning 1 m above the ground and ending at the first major branch. To do this, vertical incisions 1 m long are made and horizontal incisions every 0.5 m. Portions to be removed are loosened by knocking with a stake 20 cm diameter weighing *ca* 5 kg. Final separation is achieved by using the end of the cutlass.

- only trees ≥30 cm dbh can be exploited
- from trees <50 cm dbh two panels should be removed, on opposite sides of the tree and neither wider than 0.25 of the girth, care being taken not to damage the cambium
- from trees ≥50 cm dbh four panels should be removed, each no wider than 0.125 of the girth and separated from the next by an untouched section of bark of the same width, care being taken not to damage the cambium
- bark on lateral roots ≥20 cm diameter on individual trees ≥50 cm dbh, can also be harvested provided suitable additional measures to promote post-harvest regeneration are taken
- all trees with debarked roots and/or trunks should be marked
- trees should not be re-harvested for a period of 4-5 years to permit sufficient regeneration of bark.

After the prescribed period of bark regeneration, re-harvesting will remove the bark panels left untouched when the previous harvest took place. When prescribed harvesting practices are respected, trees can be reharvested after four to five years. Even after three harvests, specimens of *Prunus africana* on Mount Cameroon remain healthy (Ndam, 1998). The 4-5 years regeneration period suggested in the Cameroon protocol is the interval given by Macleod (1986) and Cunningham & Mbenkum (1993). Nevertheless, more recent thinking, also based on Cameroon experience, has extended it to 7-8 years (Simons *et al.*, 1998). The numerous reports (*e.g.* Macleod, 1986; Bobongha, 1991; Cunningham & Mbenkum, 1993) of poor post-harvest recovery, or even its failure, suggest the longer recovery period would be desirable.

In Madagascar, in contrast with Cameroon, bark harvesting is reported to be a wet season activity (Walter & Rakotonirina, 1995). Exploitation of bark in the Central-East region (the main source area) was initially carried out on a basis which provided for sustainability (Dawson, 1998). Standing trees were stripped of 50% of their bark. Currently, however, trees are felled and all the bark is peeled off in strips. In contrast with Cameroon, there is, at least in practice, no restriction of exploitation to trees which have reached a specified size - Dawson (1998) found exploited trees as small as 15 cm dbh and concluded that even trees too small to have produced seed were not spared.

In Equatorial Guinea, tree-felling to harvest bark is not illegal, but villagers are being encouraged to strip bark from standing live trees (Sunderland & Tako, 1999). Bark is removed in strips from the base of the bole to about 5 m from the ground. There are no formal protocols as there are in Cameroon, however, and one consequence is that many trees are ring-barked and even if the trees survive growth is less vigorous.

In Kenya, bark supply is a by-product of forest clearance to release land for agriculture and tea plantations. There is complete stripping of the bark after felling.

In Cameroon, after peeling, 20-30 pieces of bark each 30 cm x 1 m are tied with bush rope into bundles 50 cm diameter and 1 m long, broken sheets being bound within larger sections. Bark is sun-dried to 38.5% moisture content or less. As preparation for shipping, bark is cut into pieces 20 cm long and packed in jute sacks (*ca* 1 m x 0.65 m) unless the exporter is able to grind it into powder form. Once in powder form, it is either re-bagged (50 kg bags) and stored in wooden frames for up to two weeks, or immediately processed further to produce the bark extract.

In Madagascar, bark is carried back to harvesters' villages in bundles of pieces about 50 cm x 20 cm in size, mostly weighing 45-55 kg. The bark is then broken into small pieces, about 10 cm x 10 cm, open-air sun-dried or fire-dried, bagged and carried to a central selling point. Agents of the collectors stock the bark for subsequent transport to places where they are further dried before sale to middlemen who transport it to a processing factory at Fianarantsoa.

3.4.2 Quality control

Harvested bark varies according to its moisture content, size of bark fragments, and whether it is contaminated by other materials (soil or bark of other species). This affects how much further refinement is needed before the material is macerated or ground and enters the extraction process. In Cameroon these qualities affect the price for bark at the factory gate and are therefore an incentive to harvesters to supply a high quality product. Cunningham *et al.* (1997) present the 1994 rates for Cameroon (Table 3.2).

Table 3.2 1994 factory gate rates (in CFA kg^{-1}) for purchasing *Prunus africana* bark in Cameroon (based on Cunningham *et al.*, 1997)

Bark quality	Moisture content (%)				
	>30	25-30	20.1-24.9	12.1-20	≤12
Mediocre	104	136	160	176	200
Passable	117	153	180	198	225
Standard	130	170	200	220	250
High	143	187	220	242	275

3.4.3 Bark yields and harvesting impacts

Until now, most monitoring activity concerning *Prunus africana* bark has related to how much harvesting takes place in the countries from which bark has been exported. This has been done primarily for accounting purposes, particularly for quantifying the volume, value and importance of the trade. Use of monitoring as a tool of any sustainable management strategy has been minimal, although, especially in Cameroon, attention is turning to this.

There is variable, and to an extent conflicting, information on yield per tree and the numbers of trees being exploited. The most widely quoted figure for yield $tree^{-1}$, assuming harvesting with sustainability anticipated, is 55 kg (Macleod, 1986). N. Ndam (pers. obs.) has found considerably higher yields (85 kg $tree^{-1}$) for Mount Cameroon, while CERUT (1999) presents figures suggesting 27.8 kg $tree^{-1}$ for Muanenguba, Cameroon. Cunningham & Mbenkum (1993) report both Macleod's figure and a much lower one of 8 kg $tree^{-1}$ (also for Mount Kilum/Oku). The reality is that Macleod's (1986) figure is the one most adequately explained, as each tree harvested was tallied. Yields from felling and complete bark stripping in Madagascar have also been estimated at 50-200 kg $tree^{-1}$, depending on the size (Walter & Rakotonirina, 1995). It is apparent that sustainably harvesting 55 kg on three or more occasions at intervals of eight years would generate a higher long-term yield.

Except for Mount Kilum/Oku (7717 trees in 10 months - Macleod, 1986), there is much uncertainty about estimates of the numbers of trees harvested to secure an accumulated total yield from an area. If the assumption is made that harvesting was carried out with sustainability of the resource intended (only gathering bark from one-fifth to one-eighth of the mature individuals present each year), estimated numbers harvested per year are suspiciously high:

- Mount Kilum/Oku: bark yield per tree and tree numbers, cited by Cunningham & Mbenkum (1993) are 8 kg and 75 000, respectively
- Muanenguba: bark yield per tree and tree numbers, cited by CERUT (1999), 27.8 kg and 17 280 respectively

- recorded Cameroon mean annual harvest (1986-1991) reported as 1923 t from an estimated 6300 ha, and assuming a mean bark yield per tree of 55 kg (Cunningham & Mbenkum, 1993). This equates to 34 650 trees exploited.

Thus, Acworth & Ewusi (*s.d.*) estimate the total population of *Prunus africana* trees ≥30 cm dbh on Mount Cameroon (in *ca* 46 600 ha of forest) at 37 000! It seems probable that much of the bark volume entering international trade entails destructive harvesting or excessive bark removal from individual trees.

Given an Afromontane forest area of 20 000-40 000 ha, and assuming:

- an overall stocking level of 2 individuals ha^{-1} ≥30 cm dbh
- a yield per tree exploited of 55 kg
- no post-harvesting mortality
- an 8-year harvesting cycle

a sustainable annual bark harvest of 275 t (20 000 ha) to 550 t (40 000 ha) should be feasible. Compared with these projections, a contrast with past experience can be noted. In excess of 600 t bark was collected from Mount Kilum/Oku in 1985. As the forest area was estimated (Macleod, 1986) at 6900 ha, plus 2400 ha of tree savanna and scrub, either exploitation was not sustainable or the general stocking level was far higher than 2 ha^{-1}. For Mount Cameroon, Acworth & Ewusi (*s.d.*) concluded on the basis of a recent inventory that harvesting was at an unsustainable level. For Cameroon generally, Cunningham & Mbenkum (1993) reach the same conclusion.

In terms of sustainable exploitation of wild *Prunus africana* bark, the major limiting factors are: illegal harvesting, unsustainable quotas and unsustainable harvesting methods. Only Cameroon officially prescribes a sustainable method for harvesting the bark. In all cases, illegal harvesting and unsustainable quotas are as yet unresolved problems. The former is due in part to the fact that even where prescribed methods of harvesting exist, they are difficult to enforce. Sustainable quotas are a function of supply and demand, and depend on the supply being well documented through inventories, improved understanding of post-exploitation responses in harvested individuals and the demand being well-monitored.

3.5 THE INSTITUTIONAL SETTING FOR MANAGEMENT

3.5.1 Traditional and professional management infrastructure

In Kenya, there is a national *Prunus* Working Group, whose permanent members include the Kenya Forestry Research Institute, Kenya Wildlife Services, International Centre for Research in Agroforestry, Kenya Forestry Department, and National Museums of Kenya. This group agrees and acts on priority actions with respect to the management and cultivation of *Prunus africana* in Kenya. Its current plan of action includes activities on seed and seedling collection, provenance trials, reproductive ecology, current abundance and distribution surveys (in natural stands and plantations), market studies and phytochemical research. The group is mandated to propose policy recommendations. In Madagascar, the Ministry of Waters and Forests arranged discussions on *Prunus africana* among a range of stakeholders. As a result a *Prunus africana* commission was set up in 1999. This body is to co-ordinate the activities of ministries, educational establishments and national centres, non-governmental organisations and bark exporters. All these interest groups are represented on the Commission.

Broad categories of land tenure and resource use influence *Prunus africana* management options and where management responsibilities rest. In Cameroon, stricter national regulations apply to permanent forests (gazetted state forests and national parks) than to communal forest. Nevertheless, use of communal forest is also regulated, in this case by traditional laws. The management of permanent forests depends on the conditions of access and exploitation spelled out in their original charters. In communal forest members of the local community can freely exploit natural resources (including *Prunus africana* bark) for traditional uses, in accordance with customary rights of use and access. However, they cannot exploit *Prunus africana* for commercial uses (for trade or sale elsewhere) without acquiring a special permit. A third category in Cameroon is 'open access' land, where it is difficult to determine who controls what. It is here that conflict and competition arise between different groups of users and where much of the illegal and destructive harvesting of *Prunus africana* takes place. Neither the local people nor the state are able or willing to exert much control over open access land.

Forest tenure and access categories similar to those in Cameroon exist elsewhere in Africa. In Kenya, there are State Forests (national parks, forests and plantations on state owned lands), Local Authority Forests (forests held in trust for local communities and controlled by local administrators), and Private Forests. The Forestry Department is in charge of managing State Forests and Government plantations only. Forests associated with National Parks are managed by the Kenya Wildlife Service. At present, all commercial exploitation of *Prunus africana* bark takes place in Local Authority Forests that are being cleared for farming, or in State Forest areas that have been de-gazetted for resettlement or for other development activities. In such areas, access to *Prunus africana* resources is regulated by Local Administrative Officers and by local traditional leaders.

3.5.2 Community responsibilities

Historically, traditional management of natural populations of *Prunus africana* involved simply controlling access and use by villagers to communal forests. What they exploited, and how much, was in essence judiciously allocated by village elders, not formally managed. The need to manage both natural populations and eventually plantations of *Prunus africana* developed from commercial timber exploitation. The resulting management practices follow industrial and governmental standards and guidelines common to the exploitation of indigenous timber trees in general. New management and harvesting practices have had to be developed and implemented for commercial exploitation of bark. We focus here on those developed and used in countries where *Prunus africana* bark is exploited commercially.

In Cameroon, villagers are legally involved in the commercial harvesting of bark, and benefits accruing from such involvement serve as an incentive for sustainable harvesting. Certain communities even harvest under Plantecam's licence. A pilot study involving 37 villages around the mountain was carried out by Plantecam, Ministry for the Environment and Forestry, and Mount Cameroon Project staff, to determine where community participation in *Prunus africana* management was likely to succeed. The Mount Cameroon Project continued this effort, gathering the perceptions of major stakeholders and identifying and mapping conflicts, eventually brokering an agreement between two villages, Bokwango and Mapanja, on the eastern slopes of the mountain. Village harvesters' unions were formed and under this agreement the unions worked under Plantecam's licence in the forests around their villages and supplied directly to their factory. The results included a drastic reduction in illegal exploitation, improved relationships between the young and elders in the villages, increased economic benefits to the village and better control and monitoring of harvesting activity. In Kenya, village leaders, along with Local Administrators, issue authorisations and attestations that bark has been legally harvested.

3.6 COMPENSATORY PLANTING

Cunningham & Mbenkum (1993), Sunderland & Nkefor (1997) and Simons *et al*. (1998) all advocate *Prunus africana* planting programmes. In these instances, action is urged in response to perceived depletion of populations and to create opportunities for wider use of superior genotypes. The broad management picture also indicates that a shift in emphasis from wild *Prunus africana* populations to planted stands is desirable. These stands would be established with the aims of replacing recent, and continuing, losses from natural populations and introducing a simpler management situation in which growth would be faster and more uniform.

References to planted stands of *Prunus africana* have often been made and have a long history (Chapter 4). After over 80 years of planting experience (Simons *et al*., 1998) the total amount of planting is small. In fact, the largest national estimate, of 628 ha (Simons *et al.*, 1998), is at variance with another estimate for the same country, Kenya (153 ha - Marshall & Jenkins, 1994). Outside Kenya, it is probable that pure stands of *Prunus africana* have a combined area of less than 50 ha and are individually small and young. Most are in Cameroon, for where Ndam (1998) refers to 8.8 ha established (on Mount Cameroon) by the Cameroon Development Corporation, including the 2 ha plantation (800 individuals at 5 m x 5 m spacing) noted by Cunningham & Mbenkum (1993). High numbers of trees are harvested annually and there are suspicions of high post-harvest mortality (*e.g.* Macleod, 1986; Bobongha, 1991; Mbai, 1998). Published annual planting targets of 5 ha (2000 trees) for Plantecam, whose annual bark quota was set at 300 t (implying at least 3500 trees were exploited) in 1996, would not compensate for losses on the scale (80%) estimated by Bobongha (1991) for Mount Kilum/Oku. Effectiveness would be reduced by inevitable mortality among the planted individuals and there would be no progress towards replacing the losses from Cameroon's *Prunus africana* stocks during the last 30 years. Similar reservations apply to enrichment planting efforts to date. The largest reported, 60 ha of forest enriched at Menoua, Cameroon (Cunningham & Mbenkum, 1993), would amount to some 6000-20 000 plants introduced. Without careful tending, high early mortality could be expected and, as the initiative was not sustained as an annual operation, its impact would be limited. Trade records (Cunningham & Mbenkum, 1993) suggest that in most years from 1985 to 1992 at least 400 t (7000 trees exploited) bark was harvested in this part of Cameroon.

Against a background of low impact from conventional planting and enrichment, obstacles to efficient management of natural stands (patchiness and low total stocking) and doubts over current harvesting procedures (supervision difficulties, mortality and weakened post-harvest health), alternative options are of management interest.

One option is on-farm cultivation. Initiatives in this area are reported in Chapter 4. A further option is for accelerated bark/active ingredient production on short/very short rotations. Cunningham & Mbenkum (1993) present a suggestion for a 12-year rotation of *Prunus africana* grown at 2.7 m x 2.7 m spacing. At age 12 years it is assumed the trees would be around 15 cm dbh and that *ca* 21 kg of bark could be recovered from each, by total stripping. Cunningham & Mbenkum estimate that, by establishing 68.4 ha of *Prunus africana* plantation every year for 12 years, it would be possible to achieve an annual production of 1900 t of bark on a sustainable basis. These authors also draw attention to a more innovative suggestion made in 1991 by A. Hamilton (World Wide Fund for Nature). Hamilton proposed farmer cultivation of *Prunus africana* on a 2-3 years rotation. At the end of the rotation, the active ingredients of interest to the pharmaceutical sector would be extracted from the foliage and shoots as well as the bark. We have seen no references to further development of this idea.

4 DOMESTICATION

A.J. Simons, Z. Tchoundjeu, M. Munjuga, J. Were, I. Dawson, S. Ruigu, A. Lengkeek, H. Jaenicke

The case for domesticating *Prunus africana* rests on the high current levels of demand for its products (primarily bark, but also timber), levels that cannot be met long-term from wild populations. The current annual amount of *Prunus africana* bark traded internationally is approximately 3500 t (Cunningham *et al.*, 1997). This demand is predicted to double, or even triple, within a decade due to ageing populations and growing confidence in herbal remedies in the major consumer markets - Europe and North America (J.-F. Colas, pers. comm.; A.B. Cunningham, pers. comm.). This translates into a projected demand of 7000-11 000 t of bark entering the trade annually. The traditional demand for bark within Africa, based on household surveys (Cunningham *et al.*, 1997) is estimated to be as much as 500 t $year^{-1}$.

With natural bark stocks dwindling in Cameroon and Madagascar, the major suppliers to the international trade, to continue harvesting from wild populations at existing rates will not be sustainable. Furthermore, much of the present supply of bark is drawn from wild populations using techniques that usually kill the tree (felling and/or complete stripping). However, given the vested interest of farmers in the crops they grow on-farm, cultivation of *Prunus africana* potentially promises a sustained product supply. Progress in developing a sustainable exploitation technique based on cyclical removal of bark panels (Chapter 3) will reinforce planting action by farmers. Domestication of *Prunus africana* thus has an important role in ensuring its sustainable and beneficial exploitation while significantly reducing the threat of depletion and extinction of wild populations. Here we review progress to date with domestication in terms of propagation and planting.

4.1 PROPAGATION

A constraint to the domestication of *Prunus africana* is the availability of viable seed in sufficient quantities. Jaenicke *et al.* (in press) report good seed production at intervals of two or three years. Farmers recognise these limitations and are increasing prices for the seed they sell. Dawson & Fondoun (1996) documented a farmer selling seed for US\$8 kg^{-1} in Cameroon.

4.1.1 Germination and seedling production

Exploratory studies of *Prunus africana* germination success under a range of controlled laboratory or nursery conditions have been reported from South Africa (Geldenhuys, 1981), Cameroon (Sunderland & Nkefor, 1997), Madagascar (Rajaonarivony, 1997; Anon., 1999) and Kenya (Schaefer, 1990; Were & Munjuga, 1998). From these studies it has become clear that seed must be from fruit collected at the correct stage of maturation and depulped prior to sowing or storage. For large quantities of seed, depulping can be done with a coffee pulper and high resultant seed purity (98%) is possible (Albrecht, 1993). For successful extended storage appropriate conditions of temperature must be provided (Schaeffer, 1990; Albrecht, 1993), and Jaenicke *et al.* (in press) suggest seed moisture content in storage should be around 15%. Doubts over whether *Prunus africana* seed is strictly recalcitrant, as widely assumed, have been expressed (Were & Munjuga, 1998) and the occurrence of germination inhibitors in the pericarp of fresh seeds has been suggested (Geldenhuys, 1981). Nevertheless, for practical purposes the seed is considered recalcitrant and unless carefully stored only a negligible proportion remains viable after as short a period as three weeks (Sunderland & Nkefor, 1997).

Were & Munjuga (1998) compared the germination of Kenyan (Kibujoi) seed from green, purple/green and purple fruits, with and without pulp in each case. The highest initial germination (72%) was attained with seed dried to 15% moisture content extracted from purple (ripe) fruit and this treatment also led to the highest viability after storage at 5°C for one year, although reduced by then to approximately half the initial viability. Sunderland & Nkefor (1997) report declining germination (from 70% to 0%) for Cameroon (Mount Cameroon) seed, apparently collected off the ground, without pericarp over an 18-week period of storage at 4°C. More successful storage is recorded for Kenya where, over a 75-day period, 39-74% of depulped seed germinated after 5 months stored at 3°C (Schaeffer, 1990) and 12-38% of depulped seed germinated after one year stored at 5°C (Were & Munjuga, 1998).

Some attention has been paid to germination light regime (Sunderland & Nkefor, 1997) and substrate (Schaeffer, 1990), and acid and water immersion as pretreatments (Geldenhuys, 1981). The effects of pretreatment and exposure to different light intensities respectively were far outweighed by the effect of depulping. Although Sunderland & Nkefor (1997) noted no germination in exposure to full light, this effect could not be separated from an associated effect of desiccation. A positive view of shade for regeneration is also implied by Geldenhuys (1981) and shared by Kigomo (1987) who, at South Nandi, Kenya, noted increasing regeneration of *Prunus africana* (and other species considered shade-bearing) as light penetrating to the ground diminished.

In South Africa (Bloukrans River Gorge), germination percentages as high as 90% have been reported for depulped fresh seed, although germination starts only after about 50 days (Geldenhuys, 1981). Geldenhuys found 80% of viable depulped seeds germinated within about 75 days of sowing; for seeds sown with pericarps the period was extended to about 90 days. For Kenya, after 5 months storage, Schaeffer (1990) reports a value of around 40% germination over 75 days. Studies in Madagascar have found similar levels of germination (52-94%) from freshly extracted seed (Rajaonarivony, 1997; Anon, 1999).

In terms of seedling growth, light was observed to be a significant factor in Cameroon: under 70% shade, seedlings became weak and pale whereas at 40% shade normal internode length was found (Sunderland & Nkefor, 1997). One consequence of greater shading was that specimens were more susceptible to pest and disease attack.

4.1.2 Vegetative propagation

Vegetative propagation through cuttings from juvenile plants of *Prunus africana* has been achieved with varying degrees of success in Kenya, Madagascar and Cameroon (Ndeti, 1999; Tchoundjeu *et al.*, 1999a, 1999b). Rooting success in an experiment at Mbalmayo, Cameroon, was higher (84%) with a sawdust medium than with sand (68%) or a 1:1 mix of the two (78%). Kenyan work (Ndeti, 1999) found that success rates could be raised with indole butyric acid application. In Cameroon, clonal trials were initiated in 1998 to compare the growth of trees developed from rooted cuttings and trees developed directly from seed.

Air-layering of *Prunus africana* is also possible and experimental work in Kenya has indicated that success is influenced by substrate although not by the application of indole butyric acid. In Cameroon, with a peat-based substrate, 80% of air-layered shoots 1-2 cm diameter on mature trees had produced roots after five weeks and most survived after transfer to the nursery as independent plants (Jaenicke *et al.*, in press).

4.2 PLANTING

Simons *et al.* (1998) identify a planted block of *Prunus africana* 0.4 ha in extent, at Ngong, Kenya, as the first attempt at its cultivation. This stand was planted in 1913 as a timber stand. Over the following 79 years a further 64 stands were established in Kenya, increasing the area planted with *Prunus africana* to 628 ha. The last of these plantings (16.2 ha) was carried out in the Nyeri Hill Forest in 1992. Interest has been revived with the recent publicity given to the species and in 1997 a new management trial was established at Muguga using wildings from South Nandi. Outside Kenya planting was on a much more limited scale until the impact of heavy exploitation for bark was appreciated in the 1980s. This prompted on-farm planting in Cameroon (Cunningham & Mbenkum, 1993; Sunderland & Nkefor, 1997). Geldenhuys (1981) reports casual planting in the Bloukrans River Gorge area of Cape Province, South Africa, in 1969, and Lang Brown (1964) mentions fire-breaks of *Prunus africana* planted during the 1941-1954 period in the Mafuga Central Forest Reserve, Uganda. In Rwanda, arboretum plots of *Prunus africana* were established at Ruhande in 1953 and 1979 (Département de Foresterie, 1987), and research plots at Gisovu, Rangiro and Rutovu between 1970 and 1985 (Kabera, 1988; Mbonyimana, 1988).

The suitability for *Prunus africana* to be grown in plantations in Kenya was not matched in Cameroon, apparently because the sites chosen were outside the ecological range - being at low altitude (450 m and lower) where the young trees proved vulnerable to attack from a cerambycid borer (Cunningham, 1995). Elsewhere in Cameroon some direct attempts are being made to replant *Prunus africana* in heavily exploited forest, and parallel action has been initiated on Bioko, Equatorial Guinea (Sunderland & Tako, 1999). Macleod (1986) reported that 7000 *Prunus africana* seedlings available for use at Mount Oku had been "established" in the Forestry Department nursery at Kumbo and CERUT (1999) notes that 2500 seedlings were "raised" at Mangem for use on Mount Muanenguba. It is clear, however, that much of this activity involves re-locating wildings to areas needing enrichment after a period (typically one year) in the nursery rather than plants raised from seed under nursery conditions. In masting years wildings become available in great quantity but in the natural course of events very few survive longer than a few months (Sunderland & Nkefor, 1997; Ndam, 1998; Sunderland & Tako, 1999). Given the problems of seed storage, use of wildings in this way is currently an attractive option although enabling little control of vigour or quality. Moreover, the stock is rather susceptible to water stress. Simons *et al.* (1998) suggest that the water stress problem can be mitigated by incorporating soil gathered from around forest trees into nursery substrates.

Cameroon on-farm planting initiatives have been more effective: an estimated 3250 farmers were involved in planting *Prunus africana* seedlings according to Cunningham (1995). Simons *et al.* (1998) identify the main constraints to expansion of this on-farm tree planting as the irregular seed availability, long-term seed storage difficulties and the relatively late age (15-20 years) at which seed production begins. The only published information available which indicates tree performance after planting on-farm is for the Likombe farms where mean height after two years growth was 2.3 m (Marcelin, 1998).

More recent plantings have been in the form of progeny evaluation trials, complementing the molecular studies examining genetic and chemical variations through the geographical range (Chapter 7). Currently *Prunus africana* is being evaluated on-station at locations in Uganda, Kenya and Cameroon. Wildings were used to establish a trial at Kabale (2100 m), Uganda, including 40 Kenyan and 40 Ugandan (Bwindi) *Prunus africana* individuals. This trial showed that trees three years old had good survival rates and a mean annual height increment of 0.6 m, matching rates observed in Rwanda in similar circumstances (Kabera, 1988). The plants of Kenyan origin were taller after four years than those from Uganda.

Seedling stock was used for the progeny trial (Kibujoi provenance) started in 1998 at Kakamega, Kenya (Simons *et al.*, 1998), and in a trial started in the previous year to compare three Cameroon provenances (Mount Cameroon, Mount Kilum, Mendankwe) of *Prunus africana* at Saxenhof, Buea, in Cameroon (Marcelin, 1998). At Kakamega, mean height was 1.13 m after 15 months growth and the tallest tree in the trial was 3.38 m in height. Mean height values among the 20 genetic families represented ranged from 0.92 m to 1.43 m at this stage. In the Saxenhof trial, after 14 months, mean height was 1.21 m and there were significant differences in height and diameter between progenies (Marcelin, 1998). Wide variation in survival was noted amongst the 20 families represented (Marcelin, 1998).

Plate 1.

Plate 2.

Plate 3.

Plate 4.

Plate 1. *Prunus africana* regeneration on the forest floor showing disease on leaf, Kenya [Ian Dawson]. Plate 2. Red petioles and flowers and rust dots. Plate 3. Old versus new growth, showing fruiting and flower buds, central Kenya [Moses Munjuga]. Plate 4. Sorted unripe and ripe fruit awaiting extraction, ICRAF laboratory [Anthony Njenga].

Plate 5.

Plate 6.

Plate 7.

Plate 8.

Plate 5. Young (5 year old) *Prunus africana* tree, Embu, Kenya. Plate 6. *Prunus africana* tree, stripped and being felled, Madagascar [Ian Dawson]. Plate 7. Habit of tree in open. Plate 8. Traditional healer stripping bark from the trunk of a mature tree, Cameroon.

Plate 10.

Plate 9.

Plate 12.

Plate 11.

Plate 9. *Prunus africana* logs awaiting transportation to sawmill, western Kenya [Tony Simons]. Plate 10. Bark collector from the forest in Madagascar carrying bark with a balancing rod [Ian Dawson]. Plate 11. Large scale bark drying in Madagascar [Ian Dawson]. Plate 12. *Prunus* bark being dried on a shade over a fire, before being carried out of the forest, Madagascar [Ian Dawson].

Plate 13.

Plate 14.

Plate 15.

Plate 13. *Prunus africana* bark being chipped, Madagascar [Ian Dawson]. Plate 14. Villagers with bagged and drying *Prunus* bark, Madagascar [Ian Dawson]. Plate 15. Commercially produced pharmaceutical products [Emma Youde].

5 PHARMACEUTICAL PRODUCTS

E.M. O'Brien

The bark, leaves and fruit of *Prunus africana* are part of the pharmacopoeia of wild medicinals used by traditional healers in Africa. Commercial use of *Prunus africana* by the pharmaceutical industry began in the 1970s with the manufacture and marketing of the bark extract as an effective treatment for Benign Prostatic Hyperplasia (BPH). Only 200 tonnes of bark were harvested in 1980 (Cunningham & Mbenkum, 1993). By 1997, the commercial demand had risen to around 3500 t yr^{-1} (Dawson, 1997, Cunningham *et al.,* 1997). After presenting information on the traditional uses of *Prunus africana*, this chapter focuses on the extract - how it is made and what is known about its chemical composition and pharmacological properties, as well as its efficacy in treating BPH and other disorders.

5.1 TRADITIONAL MEDICINE

The use of *Prunus africana* as a traditional or 'witchcraft medicine' (*Gerstner 6700*) has been documented since the mid-nineteenth century (Watt & Breyer-Brandwijk, 1962; Burkill, 1997). Relevant comments include:

- "*the bark is pounded in water and the resultant red liquid is drunken to relieve stomach-ache"*" (Kokwaro, 1976);
- "*leaves are used as wound-dressings in Ethiopia*" (Getahun, 1975);
- "*The leaves as well as the kernels of the fruit are similar in taste to those of bitter almonds!! only still richer (with regard to the) substance, and a decoction of the leaves, mixed with milk provides a substitute for almond-milk*" (translation from Latin of comments by the first collector of the species; *Welwitsch 465*; May 1857, Angola);
- "*infusions of leaves are drunken to improve the appetite*" (Kokwaro, 1976) or "*employed as an inhalent for fever*" (*Gane 43*; August 1952, Tanzania);
- "*the fruit [although suspected of being poisonous] is reported to be eaten"* (*Adamson 4356*, Kenya);
- "*bark is also an important component of the Bubi primary health care system*" (Sunderland & Obama, 1999; Bioko);
- "*an infusion of the bark is used to treat chest infections or as a tonic*" (Sunderland & Nkefor 1997; Cameroon); and,
- for livestock, "*medicine extracted from bark - used as a purgative for cattle by Nandi"* (*Moon 1256*; May 1923, Kenya).

Although trees of all ages can be exploited for their leaves and fruits, only adult trees are sources of bark. Cunningham *et al*. (1997) estimated that 500 t of bark was harvested annually in Africa for traditional medicinal purposes.

In addition to its medicinal uses, the wood of *Prunus africana* is traditionally used for making tools, such as axe handles and hoes (*Chapman 1369, Gaetan Myembe 155*), and for poles for shelter and house construction (*Eggeling 3685*). For these activities, saplings and very young trees, or the small branches of adult trees tend to be used. Without modern powered equipment, it is difficult to fell adult trees or to work the wood (see Chapter 6). Nevertheless, in Uganda the trunk of mature *Prunus* *africana* trees is traditionally used to make 'beer boats', brewing troughs 40-50 cm wide and as much as 2 m or more long, hollowed from a single length of trunk (Cunningham, 1996).

5.2 THE EXTRACT

Around 1965, J. Debat began developing and eventually patented (Debat, 1974) the preparation and use of non-crystalline and purified crystalline extracts of *Prunus africana* plant material as the active ingredient in the medical treatment of glandular disorders such as Benign Prostatic Hyperplasia (BPH). Although the bark is the plant material commonly extracted, all parts of the plant have been shown to have similar chemical, pharmacological and therapeutic value. Other patented uses for the extracts include: as a medical treatment for other disorders of senescence (Lacolle, 1988) and for hirsutism (Tolino *et al.,* 1996); and as a dietary supplement (Perez, 1996).

5.2.1 Production

5.2.1.1 Collection and preparation for extraction

The supply chain for *Prunus africana* bark is straightforward: harvest, break into pieces, dry, bag, transport to shipping points or processing plants and transform into a fine powder. All but the last two steps are done either entirely by harvesters (e.g. Cameroon) or by both harvesters and middlemen (e.g. Kenya, Uganda and Madagascar) (Cunningham & Mbenkum, 1993; Walter & Rakotonirina, 1995; Cunningham *et al.*, 1997; Sunderland & Tako, 1999). After bark is stripped from the tree, it is carried out of the forest, in metre long bundles each weighing about 50-70 kg, to the point of sale (e.g. village). The bark strips are then broken into small pieces roughly 10 cm x 10 cm in size. These are spread out on the ground and either open-air sun-dried or fire-dried. The dried bark chips are then bagged and weighed, either before (e.g. in Cameroon) or after (e.g. in Madagascar, Kenya, Uganda) being sold to middlemen.

For extraction purposes, the dried bark must have less than 10% moisture content. The higher the moisture content of the bark, the cheaper the sale price, since further drying by middlemen, exporter or extractor will be necessary. This, coupled with agricultural demands, probably contributes to the tendency for bark to be harvested primarily during dry or low rainfall periods (Cunningham & Mbenkum, 1993; Walter & Rakotonirina, 1995). There is a 50% reduction in weight when fresh bark is dried (Walter & Rakotonirina, 1995). Following transportation and sale to exporters or extraction plants, the dried bark is pulverised to a fine powder (Sunderland & Tako, 1999).

5.2.1.2 The extraction process

Extracts from powdered dried plant material (bark, leaves, fruit, etc.) are prepared in two phases (Debat, 1974). Phase one produces a non-crystalline extract, a red transparent paste with a yield of as much as 20% with respect to the weight of the initial plant material. Yields for extracts vary depending upon the solvent used, which in the above case is a methanol-water mixture (80:20). Other solvents include distilled water, methanol, chloroform, methylene chloride, benzene, cyclohexane, petroleum ether, diethyl ether, acetone, methylethylketone and mixtures thereof. The weakest yields obtain with extractions using distilled water or a water-methanol mixture (80:20) as the solvent, and are not recommended (Debat, 1974). The most commonly used extraction solvent for chemical analyses is chloroform (Bombardelli & Morazzoni, 1997), with a yield of 0.5%. In all cases, extraction is characterised by a 1 part plant material and 2 parts liquid solvent (e.g. 1 kg dried bark powder to at least 2 litres of solvent), extracted three times; extracts filtered and evaporated under vacuum at 30°C.

Phase two uses the non-crystalline extract to produce a fine white crystalline extract. Depending upon the eluting agent, the yield ranges from *ca* 5% to 0.05% with respect to the weight of the initial dry plant powder. Following one of two methods (Debat, 1974), the non-crystallised extract is chromatographed on a silica column using cyclohexane, methylene chloride, benzene or mixtures thereof as the eluting agent. One method produces a crystalline form of the 'total' extract; the other a highly purified 'sterolic' extract. Extractions effected on the dried and pulverised branches, leaves, fruits and inner bark of *Prunus africana* gave results similar to those for the outer bark (Debat, 1974).

Both the non-crystalline and crystalline extracts can be used for medicinal purposes (Debat, 1974; Lacolle, 1988). They are suitable for a variety of pharmaceutical forms, such as tablets, cachets, capsules (common form), dragees, liquid compositions for subcutaneous, intramuscular or intravenous injection, or hypodermic pastilles or pellets. Before manufacturing the capsule form, the extract is standardised to 12-13% phytosterols (Mediherb, 1991). According to Simons *et al.* (1998), 5 g of extract is enough to produce 100 50-mg capsules of *Prunus africana* extract. *Prunus africana* extract is also blended with other extracts known to be beneficial in the treatment of BPH (Perez, 1996), such as saw palmetto (*Serenoa repens*) (Lowe & Ku, 1996), and sold in capsule form.

5.2.2 The pharmaceutical context

Benign prostatic hyperplasia (BPH) is a disease of old age that afflicts males, causing painful swelling of the prostate gland, skin irritation and impeded and frequent urinary flow. The cause of BPH is still unknown, but appears to be an age-dependent alteration of the androgen-oestrogen balance, associated, for example, with testosterone being reduced into dihydrotestosterone (DHT) by the enzyme 5-alpha-reductase (Lobaccaro *et al.*, 1998). The affliction and its cure, using conventional medical practices, can negatively affect other aspects of life, especially sexual activity and fertility. There are no significant side effects from using *Prunus africana* extracts in the treatment of BPH (Wasson & Watts, 1998; Holm & Meyhoff, 1997).

5.2.2.1 Chemical compounds

Prunus africana extracts are lipophilic ($C_{12\text{-}24}$) and sterolic and can be analysed in either their crystalline or non-crystalline form (Debat, 1974; Bombardelli & Morazzoni, 1997). The active compounds directly involved in the relief of BPH have not been identified and synthesised.

Identified chemical constituents (Catalano *et al.*, 1984; Bombardelli & Morazzoni, 1997) include:

- fatty acids: (62.3%),
- sterols: ß-sitosterol (10.7%), ß-sitosterol 3-O-glucoside, ß-sitostenone, (2.0%),
- pentacyclic triterpenoids: ursolic acid (2.89%), 2"-hydroxyursolic acid (0.50%), oleanolic acid (0.66%), crataegolic acid and friedelin (1.39%), and epimaslinic acid (0.82%),
- linear alcohols (n-tetracosanol, 0.48%; and n-docosanol, 0.39%) and their esters with *trans*ferulic acid.

Recently, two new compounds have been identified: 24-*O-trans*-ferulyl-2", 3"-dihydroxy-urs-12-en-28-oic acid (Fourneau *et al.*, 1996), and 4-*O*-ß-D-glucopyranosyl-(7,8)-dimethoxyisolariciresinol (Scarpato *et al.*, 1998).

Most data on the chemical compounds in *Prunus africana* extract are based on analysing extracts of the trunk bark. Similar findings should be obtained for extracts made from any part of a plant (Debat, 1974; Lacolle, 1988). However, both quantitative and qualitative differences in chemical compounds have been shown to exist between geographically disparate populations. In mainland African populations from Cameroon and the Democratic Republic of Congo, levels of several compounds were different from levels found in the bark of Madagascan populations. Levels of ursoilic acid and ß-sitosterol 3-O-glucoside were higher while levels of 3-O-acetyl aleanolic acid were lower (Martinelli *et al.*, 1986).

5.2.2.2 Pharmacology

Prior to 1984, the therapeutic effects of *Prunus africana* were attributed to n-docosanol (Thiebolt *et al.*, 1977), and to ß-sitosterol and its glucoside (Longo and Tira, 1981; Barth, 1981). The former is now considered unlikely given the low amount of n-docosanol and large amounts of sterols and triterpenes (Catalano *et al.,* 1984). Instead, it now appears that 'the extract of *Prunus africana* (*Pygeum africanum*) bark may be regarded as a sort of natural pharmacological combination in which the different components exert a synergistic action, counteracting some of the biochemical and functional changes that characterise BPH' (Scarpa *et al.,* 1989). Pharmacologically active compounds which interfere with the development of BPH include: phytosterols, pentacyclic triterpenes and ferulic esters of long chain fatty alcohols. Phytosterols, for example, appear to be inhibitors of 5-alpha-reductase activity and of prostaglandin synthesis in prostatic tissue, as well as contributors in counteracting the inflammation common with BPH (Bauer, 1986; Marcolli *et al.,* 1986; Holms & Meyhoff, 1997; Wasson & Watts, 1998). The latter applies as well to the pentacyclic triterpenes in *Prunus africana* extract, which apparently inhibit the activity of glucosyl-transferase. Ferulic esters appear to lower cholesterol in blood, which is relevant since cholesterol and its metabolic by-products are also suspected of being contributors to the development of BPH (Catalano *et al.,*1984; Bombardelli & Morazzoni, 1997). Ferulic esters also increase the secretion of adrenal androgens (in rats).

In vitro studies suggest that *Prunus africana* extract inhibits 3T3 fibroblasts and basic fibroblasts (parent cells producing fibres for repair and growth of connective tissue), and epidermal growth factors in rodents (mice/rats), without being toxic to the cells (Yablonsky *et al.*, 1997). Growth factors seem to play a role in the development of BPH, in particular b-FGF which is higher than normal in BPH tissue and suggests that one of *Prunus africana*'s therapeutic properties is the inhibition of fibroblast growth (Levine *et al.*, 1992). The production of 5-lipoxygenase metabolites in human cells is also inhibited by the extract. In which case, the extract may be counteracting infiltration into the prostate of inflammatory cells involved in the development of BPH. It also slightly inhibits 5-alpha-reductase in human prostate (Rhodes *et al.*, 1993), as well as aromatase activities (Hartman *et al.*, 1996).

The earliest *in vivo* studies showed that *Prunus africana* extract stimulated secretions of the prostate in normal rats and prevented hyperplasia in rats after being injected with human prostate tissue. Similar results occurred with men without BPH, but suffering from insufficient prostate secretion (Clavert *et al.*, 1986). Taken orally by rats, *Prunus africana* extract not only stimulated secretory processes in the prostate, but in the cells of the bulbourethral gland (Latalski *et al.*, 1979). It also stimulated secretions in seminal vesicles in castrated rats while being an antagonist of testerone in these organs. In castrated adrenalectomised rats the extract had an opposite effect, increasing testosterone activity, as well as the content of gonadotropins in the pituitary. Thiebolt *et al.* (1977) concluded that *Prunus africana* extract is involved with the adrenal cortex and pituitary gland. *Prunus africana* exhibits anti-inflammatory and anti-oedema activity in rats and reduced vascular permeability due to histamine (Marcoli *et al.*, 1986). Lastly, the extract exhibited a modulating activity on age-related hypercontractility of the bladder in rats, and reduced bladder hyperactivity in guinea pigs (Thiebolt *et al.*, 1977).

5.2.3 Therapy

Prunus africana extract is an effective and well-tolerated drug for the treatment of symptoms associated with mild and moderate BPH (Andro & Riffaud, 1995; Bombardelli & Morazzoni, 1997). Although the bark and other parts of the tree have been reported to be poisonous, all studies to date, whether on rats, mice, guinea pigs, dogs or humans, indicate the extract is well-tolerated (Table 5.1)

(Andro & Riffaud, 1995; Scarpato *et al*., 1998). Only in a few cases, were there reports of mild gastrointestinal reactions to the extract.

The usefulness of *Prunus africana* extract in the treatment of BPH has been demonstrated in a variety of open and double-blind placebo-controlled clinical trials. In the most significant studies, the results ranged from good to excellent with regard to tolerability, for dosages ranging from 75 to 200 mg daily and treatment periods ranging from 6 weeks to 3 months (Table 5.1). Chatelain *et al.* (1999) compared once- and twice-daily dosage forms of *Prunus africana* (*Pygeum africanum*) extract and found them to be equally effective and safe. In most cases, urine flow increased while frequency decreased and in some cases irritative symptoms and prostate size decreased, especially with higher dosages (Bartlet *et al.,* 1990). Alleviation of sexual disorders associated with BPH or chronic prostatis was also observed in patients taking 200 mg daily of the extract for 60 days (Carani *et al.*, 1991).

In the treatment of both bacterial and non-bacterial chronic prostatis and of genital infection, the extract proved successful, whether taken alone or in association with antibiotics (Menchini-Fabris *et al.*, 1988). For patients suffering from low prostatic acid phosphatase activity, the extract successfully increased enzyme activity and protein secretion (Lucchetta *et al.*, 1984).

Table 5.1 Clinical and tolerance trials of *Prunus africana* extract carried out on BPH patients (extracted from Bombardelli & Morazzoni, 1997)

Authors	Number of patients	Dosage (mg day^{-1}, p.o.)	Period of treatment (days)	Improvement in urological symptomatology[#]	Tolerability
Durval, 1970	23	100	30-120	Residual urine (95), daytime frequency (95), nocturnal frequency (91)	Excellent
Gallizia & Gallizia, 1970	19	100	40	Residual urine (37), daytime and nocturnal frequency (74)	Excellent
Thomas & Rouffilange, 1970	33	75	50	Dysuria (60), daytime and nocturnal frequency (57), stream (69)	Excellent
Viollet, 1970	20	75-100	1-2 months	Dysuria, nocturia in 2/3 cases	Good
Wemeau *et al*., 1970	28	100	6 weeks	Daytime and nocturnal frequency	Excellent
Pansadoro & Benincasa, 1972	35	75	90	Residual urine (85), nocturia (94), urgency (80)	Excellent
Hallemans, 1973	50	75	90	Residual urine (73), daytime and nocturnal frequency (58), stream (42)	Good
Colpi & Farina, 1976	42	150	45	Maximum flow (67), residual urine (55), daytime frequency (45), nocturnal frequency (74), hesitancy (48)	Excellent
Zurita *et al*., 1984	30	100	90	Maximum flow, daytime and nocturnal frequency, reduction of prostate size	Excellent
Anonymous, 1985	159	100	6 weeks	Daytime frequency (37), nocturnal frequency (61)	Excellent
Rigatti *et al*., 1985	41	100-200	2 months	Dose-related differences: residual urine -35**, -57**, nocturia -40**, -61**, prostate size -15**, -23**	

Table 5.1 (continued) Clinical and tolerance trials of *Prunus africana* extract carried out on BPH patients (extracted from Bombardelli & Morazzoni, 1997)

Authors	**Number of patients**	**Dosage (mg day^{-1}, p.o.)**	**Period of treatment (days)**	**Improvement in urological symptomatology[#]**	**Tolerability**
Arena *et al*., 1987	22	200	90	Daytime and nocturnal frequency (77), urgency (46)	Excellent
De Paula *et al*., 1987	40	100-200	68-76	Dose-related differences: dysuria -24, -56**, daytime frequency -54, -64**, nocturia -32, -58**, hesitancy -33*	Excellent
Fava *et al*., 1987	38	200	60	Maximum flow +28**, dysuria -53**, daytime and nocturnal frequency -59**, hesitancy -60**	Very good
Mattei & Acconcia, 1988	30	200	NR	Maximum flow +10**, mean flow +16**, flow time -15*, dysuria -39**, daytime frequency -39**, nocturnal frequency -37**, hesitancy -36**	Excellent
Carani *et al*., 1991	18	200	60	Dysuria -57**, nocturia -39*, dribbling frequency (33), periuretral edema -53*	Excellent
[+]Bongi, 1972	50	75	60	Residual urine -29, daytime frequency (100), nocturia -59. Global evaluation: good or very good in 88% of patients.	Excellent
[+]Maver *et al*., 1972	60	100	60	Maximum flow (57), residual urine (23), daytime frequency (50), nocturia (47), hesitancy (53)	Excellent
[+]Dufour *et al*., 1983	120	100	6 weeks	Nocturia (79), hesitancy (55), incomplete emptying (66)	
[+]Blitz *et al*., 1985	57	100	6 weeks	Nocturia, urgency and hesitancy (77), nocturnal frequency (61)	
[+]Rizzo *et al*., 1985	40	200	60	Maximum flow +55**, mean flow +61**, daytime frequency -59*, nocturia -86**, dysuria -73**	Excellent

Table 5.1 (continued) Clinical and tolerance trials of *Prunus africana* extract carried out on BPH patients (extracted from Bombardelli & Morazzoni, 1997)

Authors	Number of patients	Dosage (mg day^{-1}, p.o.)	Period of treatment (days)	Improvement in urological symptomatology[#]	Tolerability
[+]Frasseto *et al*., 1986	20	200	60	Daytime frequency -56*, nocturia -57**, weak stream -48*	Excellent
[+]Ranno *et al*., 1986	39	200	2 months	Maximum flow +91**, mean flow +133**, daytime frequency -49**, nocturnal frequency -56**, dysuria -46**, prostate volume -11**	Excellent
[+]Bassi *et al*., 1987	40	100	60	Maximum flow, daytime frequency (65), nocturnal frequency (75), dysuria (61), urgency (80)	Excellent
[+]Barlet *et al*., 1990	263	100	60	Maximum flow +17***, voided volume +12***, residual urine -24***, daytime frequency -19, nocturnal frequency -31. Significant improvement in 66% of cases.	Very good

[#]: % of cases (in brackets) or % difference vs baseline. * $P<0.05$, ** $P<0.01$, *** $P<0.001$ vs baseline, NR not reported.

[+]Double-blind, placebo-controlled clinical trials.

5.2.4 Other pharmaceutical uses

Lacolle (1988) and Debat Laboratoire identified and patented *Prunus africana* extract as an anti-ischaemic and antiamnesic medication, based on experiments with rats. In this case, the total extract was used, the dried plant material being from any part of the plant or mixtures thereof. The extract, administered in doses of 100 mg kg^{-1} body weight, significantly protected against amnesia due to hypoxia. Age-related changes in the brain and pituitary were also found to be associated with increases in 5-alpha-reductase, but involve a mechanism other than finasterides (inhibitors of 5-alpha-reductase).

Another major affliction of ageing is bladder dysfunction secondary to BPH. As BPH slowly progresses, the bladder changes from a state of compensation to decompensation that results in severe and irreversible changes in bladder function - partial outlet obstruction followed by major cellular changes in the bladder - progressive denervation, mitochondrial dysfunction and disturbances of calcium storage and release from the sarcoplasmic reticulum. Pretreatment in rabbits with *Prunus africana* (*Pygeum africanum*) extract significantly reduced the severity of both the contractile and metabolic dysfunctions caused by partial outlet obstruction (Levin *et al.*, 1997). This may in part explain the clinical efficacy of the extract in the treatment of BPH.

Sexual disorders, such as loss of fertility, sometimes occur during and after standard medical treatment for BPH. They do not occur following treatment with finasterides (Iguer Ouada & Verstegen, 1997). Breeding dogs treated with finasteride experienced a marked decrease in both prostate size and secretion within 5 to 15 weeks of treatment (dosage 1 mg kg^{-1} body weight). Production of spermatozoa also decreased, but reversed to normal within 6 to 8 weeks of treatment. Matings at 20-22 weeks were fertile.

Symptomatic hirsutism affects women and is a skin disease associated with increased activity of 5-alpha-reductase. For idiopathic hirsutism and hirsutism in women with polycystic ovary syndrome, treatment using finasteride (daily dose of 5 mg for 6 months) is very effective, producing a greater than 50% reduction for all patients, with no apparent side effects (Tolino *et al.*, 1996).

6 TIMBER

John B. Hall

The numerous literature references to the timber of *Prunus africana* through the twentieth century tend to relate to the working properties and end uses. Although there are a number of reports on the outcome of strength tests, most of these derive from the assessment of wood from Kenya around 1950 (Wimbush, 1950). There has been no quantitative evaluation of the wood since the report of Brehme *et al*. (1963-1966). Photographs of the wood as seen with a lens (Stone, 1924; Forest Products Research Laboratory, 1953; Goldsmith & Carter, 1981) and with a transmission microscope (Miles, 1978) have been published.

6.1 DESCRIPTION

Freshly cut, the sapwood is not clearly differentiated from the heartwood but the latter turns from pale pink (Brehme *et al*., 1963-1966) or light red (Vernede, 1955) to dark red with exposure and becomes more easily distinguished. After seasoning, the heartwood colour is less intense (Brehme *et al*., 1963-1966). The sapwood remains pale in colour: it is usually described as pale pink although Vernede (1955) reports ‘yellowish’. The timber has medium to fine texture and even, somewhat interlocked, grain (Bryce, 1967; Goldsmith & Carter, 1981). McCoy-Hill (1957) describes it as diffuse porous. The clarity of growth rings to the naked eye is variable, from vague (Stone, 1924 - South Africa) to visible as alternating dark and light bands (Bryce, 1967 - Tanzania).

On the basis of features visible with the aid of a hand lens, Goldsmith & Carter (1981) draw attention to numerous rays and many small- to medium-sized vessels occurring singly or in radial groups associated with parenchyma (Figure 6.1). Brehme *et al.* (1963-1966) note 7-20 vessels mm^{-2} (of medium size: 0.1-0.2 mm tangential diameter). Brazier & Franklin (1961) report minute (<3 µm) pitting and spiral thickening of the vessel walls (Figure 6.2). Simple perforation plates, and often - especially in the heartwood - dark deposits (Figure 6.1), are present within the vessels. Forest Products Research Laboratory (1952) refer to gum deposits; Brehme *et al*. (1963-1966) term these deposits resin. Traumatic vertical intercellular canals, interpreted as being formed after injury to the tree, were noted by Brazier & Franklin (1961).

There are 25-80 rays per 5 mm, of a pinkish/reddish tinge. The ray tissue is heterogeneous, with most of each ray revealed as multiseriate in tangential section (Figure 6.2) and of isodiametric or upright cells. Inspection of tangential surfaces shows the rays are 12-70 cells tall and red in colour.

McCoy-Hill (1957) refers to sparse, pink, vasicentric parenchyma, but Brazier & Franklin (1961) note presence in both paratracheal (although to only a limited extent) and apotracheal states (Figure 6.1). In the latter case, occurrence is mostly in groups, but occasionally as single apotracheal strands.

Brazier & Franklin (1961) note that inorganic crystalline inclusions (druses) are present within some, presumably parenchymatous, cells.

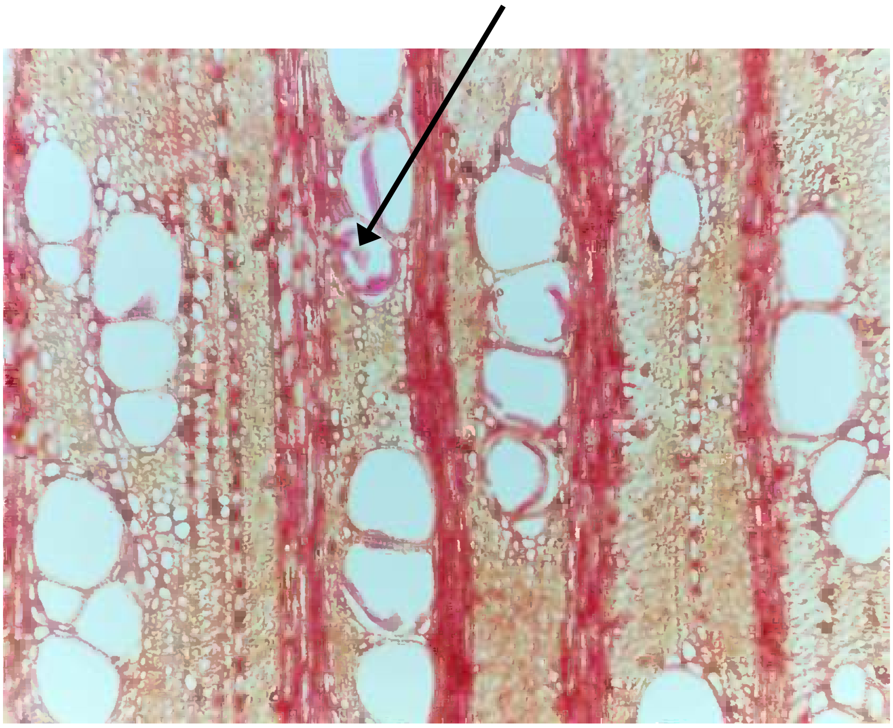


Figure 6.1 *Prunus africana*: transverse section of wood from a Kenyan source (wood sample collection, School of Agricultural and Forest Sciences, University of Wales, Bangor). Note the radial groups of vessels, some paratracheal parenchyma and (arrowed) gum deposit in vessel. (x 50) (Emma Youde).

Figure 6.2 *Prunus africana*: tangential longitudinal section of wood from a Kenyan source (wood sample collection, School of Agricultural and Forest Sciences, University of Wales, Bangor). Note the multiseriate ray tissue and minute wall pitting of the arrowed vessel. (x 250) (Emma Youde).

6.2 PHYSICAL AND STRENGTH CHARACTERISTICS

The timber is heavy, hard and tough, being of above-average strength (Bryce, 1967). Values for strength parameters, based on clear samples, are indicated in Table 6.1.

Table 6.1 Reported strength properties of *Prunus africana* timber

Parameter	Value	Sources	Comments
Density (kg m^{-3})	785 1090	Tack (1958) Goldsmith & Carter (1981)	air-dry (*ca* 11-12% moisture content)
Nominal specific gravity	0.70	Lavers (1983)	
Modulus of rupture (N mm^{-2})	95-122*	Anon. (1954); Tack (1958)	
Modulus of elasticity (kN mm^{-2})	11.3*	Tack (1958)	
Energy consumed in bending to maximum load (mm N mm^{-3})	0.132*	Lavers (1983)	
Energy consumed in bending to total fracture (mm N mm^{-3})	0.279*	Tack (1958)	
Maximum compression strength parallel to grain (N mm^{-2})	50.3-62.7*	Wimbush (1950); Anon. (1954); Tack (1958)	
Maximum shear parallel to grain (N mm^{-2})	14.5-16.3*	Tack (1958); Bryce (1967)	
Hardness on side grain (kN)	3.8 8.3	Anon. (1954) Tack (1958)	Janka side hardness
Hardness on end grain (kN)	4.0 9.4	Anon. (1954) Tack (1958)	resistance to indentation
Resistance to splitting - radial plane (N mm^{-1} width)	12.1* 22.9*	Tack (1958) Bryce (1967)	
Resistance to splitting - tangential plane (N mm^{-1} width)	15.7	Tack (1958)	

*values for 2 cm x 2 cm samples converted (Chudnoff, 1980) from data for 2 inch x 2 inch samples

6.3 SEASONING, PRESERVATION AND WORKING PROPERTIES

Opinion generally rates *Prunus africana* timber as refractory and unstable, and difficult to season. Large sizes are liable to split during drying, while flat-sawn stock in small sizes is liable to distortion (McCoy-Hill, 1957). To counter checking, McCoy-Hill (1957) suggests painting end surfaces with a solution preventing evaporation. Goldsmith & Carter (1981) recommend careful stacking and seasoning under cover to minimise degrade during air-drying, which is a slow process and takes as long as nine months for boards 2.5 cm thick separated with 6-8 mm stickers (Bryce, 1967). Pieces 10 cm x 10 cm or 10 cm x 20 cm are reported by Dale (1936) as drying in kilns most satisfactorily and Chudnoff (1980) gives kiln-drying schedules for these sizes.

The schedules (Table 6.2) start with material with a moisture content in excess of 40% subject to a drying temperature of 40.5°C and a low saturation deficit. Once the moisture content falls to 40% the kiln setting is adjusted to increase the saturation deficit and further adjustments are made for every 5% fall in moisture content to a final value of 11-12%. Initially only the saturation deficit is modified but once the moisture content falls to 30% temperature increases are also effected. Bryce (1967), although suggesting which of several drying schedules should apply (a milder schedule than those of Chudnoff), questions whether the cost of kiln drying *Prunus africana* is justified by the value of the end product. Volume shrinkage from green to oven-dry is reported by Brehme *et al.* (1963-1966) as 4.5% and by Goldsmith & Carter (1981) as 9.1%.

Table 6.2 Kiln-drying schedules recommended for *Prunus africana* timber

Moisture content (%) of timber	**Drying temperature (°C)**	**Saturation deficit (kPa)**		
		Stock 10 cm x 10 cm cross-section (Chudnoff, 1980)	Stock 10 cm x 20 cm cross-section (Chudnoff, 1980)	Stock 10 cm thick (Bryce, 1967*)
green	40.5	1.0	0.9	0.3
60	40.5-43.5	1.0	0.9	0.7
40	43.5	1.3	1.0	1.2
35	43.5	2.3	1.9	1.7
30	46.0-48.9	4.6	3.4	2.7
25	51.5-54.4	10.5	9.4	3.8
20	60.0	17.2	17.2	8.0
15	65.5-71.1	26.0	26.0	11.9

*Entries in the tables published by Bryce (1967) apply for boards only 4 cm thick. In the table above adjustments have been made, as recommended by Bryce, to specify a milder schedule for a thickness comparable with those used by Chudnoff.

Reports on durability are very variable - possibly there is geographic variation in durability through the range. Some (*e.g.* Vernede, 1955; Goldsmith & Carter, 1981) rate the timber as durable. Others (*e.g.* McCoy-Hill, 1957; Dale & Greenway, 1961) are in conflict with this, particularly those referring to its short service life in contact with the ground (only 1-2 years - Bryce, 1967). Reports of resistance to borers apparently refer to the heartwood (Bryce, 1967). Exposed sapwood is rapidly attacked by insects, limiting use in the ground as house poles (Eggeling, 1940b). Susceptibility of the sapwood to powder-post beetle attack is noted by Chudnoff (1980). In the sea, however, even the heartwood is degraded swiftly (in less than six months) by marine borers (Bryce, 1967). Several authors (Logan, 1946; Brehme *et al.*, 1963-1966; Goldsmith & Carter, 1981) report resistance to termites and Goldsmith & Carter also report resistance to fungal attack. Attempts to improve durability by treatment with preservatives have met with little success - even under a pressure of 1.24 MPa maintained for 6 h (Bryce, 1967).

The wood is considered rather difficult to work. But if material is seasoned successfully, it saws easily and cleanly and works fairly well with hand and machine tools (Chudnoff, 1980). Goldsmith & Carter (1981) qualify this, however, noting that the wood picks up with machine planing. Hand planing produces a very smooth, lustrous surface. The wood polishes and takes paint and varnish well and stains evenly (Dale & Greenway, 1961; Bryce, 1967). It is amenable to moulding and turning although it blunts cutting edges (Bryce, 1967). Nailing is difficult because of the wood's hardness, and nailing near edges leads to splitting - pre-boring has been advised (Goldsmith & Carter, 1981).

6.4 USES AS TIMBER

The high wearing qualities and resilience of *Prunus africana* timber and its resistance to abrasion make it suitable for heavy flooring and construction, where durability is not a limitation, and for interior use for window and door frames and furniture (Chudnoff, 1980; Goldsmith & Carter, 1981). In East Africa it has proved satisfactory and popular in the past for lorry bodywork and as bridge decking, and for railway sleepers on less heavily used sections of track (McCoy-Hill, 1957; Bryce, 1967).

7 CONSERVATION

I. Dawson, J. Were, A. Lengkeek

The successful conservation of any resource species demands awareness of its biology and ecology, and how provision can be made for its sustainable utilisation. A useful approach to understanding the most important considerations and how they combine to make conservation efforts successful or inadequate is by recognising determinants. Here, in our treatment of the conservation of *Prunus africana*, we are concerned with two categories of determinant. The biological/ecological determinants are primarily characteristics of the species, while the strategic determinants are consequences of the way stakeholders use it as a resource. Biological/ecological determinants are reviewed below under Conservation status (7.1) and strategic determinants under Conservation provision and action (7.2). In a further section of this chapter (7.3) we offer suggestions for future conservation emphasis and initiatives.

7.1 CONSERVATION STATUS

The overall distribution pattern, population levels and forest utilisation and clearance trends are the main biological/ecological determinants which have a bearing on the conservation status of *Prunus africana*.

7.1.1 Distribution and variation

7.1.1.1 General distribution

The full distribution picture for the species illustrates well White's (1978) delimitation of African mountain systems and associates *Prunus africana* with each one of them (Chapter 2). This testifies to the successful establishment of *Prunus africana* throughout these tropical ecosystems. In addition, the physical intervals separating the systems could restrict genetic exchange between. Particularly well-defined intervals surround the West African, Ethiopian, Chimanimani and Drakensberg systems. The Madagascar system is also discrete. The remaining systems (Kivu-Ruwenzori, Usambara-Imatong, Uluguru-Mlanje) are less sharply separated from each other. The mapped locations of *Prunus africana* outside the regional mountain systems (in Angola, Democratic Republic of Congo and Zambia) are satellite occurrences (defined by White, 1978, as being at least 50 km from the nearest Afromontane vegetation), possibly marking a migratory track and thus often believed relictual (White, 1981).

7.1.1.2 Morphological variation

Prunus africana is remarkably constant in the features evident in herbarium material. Thus, within 10 years of its scientific recognition, in 1864, collections from Cameroon (the type material), Malawi and Angola were referred to it (under the synonym *Pygeum africanum*) without serious reservation. In 1952, however, a second African species of *Pygeum* was described (Hauman, 1952a): *Pygeum crassifolium*. The material which Hauman referred to his new species differed in having more fleshy leaves, and was from Mikeno and Ruwenzori (Democratic Republic of Congo) and Ukinga (Tanzania). Later workers (Graham, 1960; Mendes, 1978) have rejected Hauman's case and treated the degree of fleshiness as a variable feature within a single entity, *Prunus africana*. For present purposes, Graham's (1960) broader circumscription is followed and *Prunus crassifolia* is considered synonymous with *Prunus africana*. The presence of the variation highlighted by Hauman (1952a) nevertheless invites further investigation to clarify if the basis is genotypic. Variation within the species has also been noted in Madagascan material, prompting a suggestion by Leroy (1978) that there were three species of *Pygeum*, one endemic, on the island. We have not been able to trace either names or descriptions to amplify Leroy's claim but while it is dismissed as erroneous by Ph. Morat (pers. comm., April 2000), Muséum Nationale d'Histoire Naturelle, Paris, it suggests phenotypic variability was noted by Leroy. There is indirect support for variation within *Prunus africana* in the recognition of 'white-barked' and 'red-barked' forms by local people in Madagascar (Walter & Rakotonirina, 1995), and in Cameroon (Authors, pers. obs.).

7.1.1.3 Evidence of genetic variation

Comparative studies of bark chemistry (Martinelli *et al.*, 1986) and DNA (Barker *et al.*, 1994; Dawson & Powell, 1999) have confirmed that the populations of the west African and Madagascar mountain systems are very distinct from one another. Less attention has so far been given to characterising populations from elsewhere. All three studies also revealed modest, but nevertheless discernible, differences between populations from the Kivu-Ruwenzori system and those examined from west Africa. In DNA terms, one population from the Usambara-Imatong system (Mount Kenya) and one from the Ethiopian system proved fairly similar, but different from those of West Africa/Kivu-Ruwenzori (Dawson & Powell, 1999), and one from the Drakensberg system (Bloukrans) was also well-differentiated from these (Barker *et al.,* 1994). In a very recent DNA-based study (Mwangi, 2000), large genetic differences were observed among Kenyan populations, with stands around Mount Kenya being highly differentiated from a western Kenya (South Nandi) population. The latter was more similar to stands from West Africa/Kivu-Ruwenzori. Distinction among populations in Kenya was considerably greater than among populations in either Cameroon or Madagascar (Dawson & Powell, 1999). Nevertheless, information from much of the range, specifically the populations of the Uluguru-Mlanje and Chimanimani systems, the satellite populations and the isolated island populations of Bioko, San Tome (since originating in the Tertiary era) and the Comores (since originating in the Quaternary era) is not available. Further, because of its extreme isolation, the Bloukrans population may not adequately represent the populations of the Drakensberg system as a whole. While the understanding of genetic variation in *Prunus africana* among regional mountain systems is incomplete, what is known suggests that if any were completely eliminated there would be a significant depletion of the species' gene pool.

Little appears to have been published in terms of relating variations between populations to product quality, which would be relevant for identifying conservation priorities in the pharmaceutical context. The major contribution to the differentiation of bark extracts from Madagascan populations from those derived from mainland African material was the high 3-*0*-acetyl oleanolic acid content of the former (Martinelli *et al.*, 1986). The oleanolic acids are among what Simons *et al.* (1998) describe as a 'cocktail' of compounds acting synergistically to promote the desired effect of medicine based on *Prunus africana* bark extract. Walter & Rakotonirina (1995) report that in bark extract from Madagascar a second element of the cocktail, ß-sitosterol, is present in higher concentrations than in extract from Cameroon bark.

7.1.1.4 Association with atypical climatic conditions

Additional inferences about intraspecific variation in *Prunus africana* can be drawn from ecological information implying occurrence under extreme or unusual conditions. Satellite occurrences in Angola, the Democratic Republic of Congo and Zambia are members of tree communities composed primarily of lowland Guineo-Congolian species (Angola - White & Werger, 1978; Democratic Republic of Congo - Mullenders, 1954; Zambia - Trapnell, 1953). The population at Kaniama, Democratic Republic of Congo, enjoys relatively warm conditions and in every month the mean of the daily temperature minima exceeds 15ºC. At this location, corresponding maxima are unusually high for *Prunus africana* - *ca* 31ºC in August, and always >27ºC. A similar temperature regime applies to those Uganda populations in and bordering the

Lake Victoria basin and in the interval between the Kivu-Ruwenzori and Usambara-Imatong mountain systems, although these are not sufficiently isolated to qualify as satellites in White's terminology. These populations are also in essentially Guineo-Congolian forest communities (Eggeling, 1947; Wood, 1960).

7.1.1.5 Reports of rarity

Published reports of rarity in countries where little or no bark is being harvested today also have relevance to the present conservation status of the species. In several southern African countries within the range *Prunus africana* is regarded as rather rare. In fact, the earliest comment relating directly to conservation status describes *Prunus africana* as a rarity in the Bloukrans Pass Forest, South Africa, in 1926: "About 20 trees have been located" (Phillips, 1931). This small population still survived half a century later, containing 20 individuals ≥10 cm dbh (Geldenhuys, 1981), and provided Barker *et al.* (1994) with the DNA for the southern limit of the range. The Bloukrans population of *Prunus africana* remains the only one where direct estimates of the numbers of individuals in a population have been published. Palmer & Pitman (1972) note that *Prunus africana* occurs widely in South Africa but never abundantly, often as a constituent of communities other than Afromontane forest (Geldenhuys, 1981). Geldenhuys (1981) concluded that as a consequence of increasing aridity through the Holocene period the Bloukrans population was now outside the natural climatic range of the species. Only the warmer Bloukrans microsites with enhanced moisture supply favoured successful regeneration and persistence. Given the relatively low mean annual rainfall (<1000 mm) now prevailing, it is likely that similar changes have affected a number of the other South African populations of *Prunus africana*. Further north, in Zimbabwe, *Prunus africana* has been reported as rare (Anon., 1994) and its exclusion from Gomes e Sousa (1966-1967) underlines its rarity in Mozambique, where its presence was not confirmed until a collection was made in 1935 (*Gilliland 1868*).

7.1.2 Population levels

The structure of populations of *Prunus africana* and the dynamics of recruitment into them have implications for their viability under harvesting or management actions. For areas of forest large enough to be significant for management, *Prunus africana* contributes less than 5% of the individuals ≥20 cm dbh, around 5-10 ha^{-1} at most (Chapter 2). Concentrations of approximately 2 ha^{-1} are more typical. The higher stocking levels apparently relate to elevation/temperature and forest disturbance. On Mount Cameroon, Cameroon, below 1600 m, where mean temperature is likely to rise above 20°C from January to April, concentrations are <2 ha^{-1} (Anon. *s.d.*). From 1600 m to 2000 m (upper limit for enumeration reported), levels rose above 2 ha^{-1}. Disturbance favours the species according to Geldenhuys (1981) who, among a number of authors, associates it with forest edges and good illumination, and to Eben Ebai *et al.* (1992) who localise the main concentrations at the 1600-2000 m level of Mount Cameroon to forest margin situations.

Information on the reproductive biology of *Prunus africana* (Munjuga *et al.*, in press) complements the population picture, providing indications of how genetic diversity within natural populations is maintained, and possible changes that may arise when they are exploited. Munjuga *et al*. (in press) conclude that the species is predominantly outcrossing. Reports of high post-harvest mortality with *Prunus africana* (Ewusi *et al.*, 1992; Ewusi *et al.*, 1997) raise concerns about whether effective population sizes survive in natural stands exploited for bark in accordance with current routines. It is probable that their viability as effective conservation stands is impaired.

Even with populations that have not been reduced by harvesting and where normal gene exchange between individuals remains possible, recruitment of *Prunus africana* into the productive size classes is limited. Supra-annual fruiting (Dowsett-Lemaire, 1985) and masting behaviour (Sunderland & Tako, 1999), the rapid loss of seed viability and high seedling mortality contribute to this situation. As a result, in many populations there is under-representation of individuals <20 cm dbh (Chaffey, 1980b; Cunningham & Mbenkum, 1993; Sunderland & Tako, 1999).

7.1.3 Forest clearance and *Prunus africana* harvesting impacts

In most of the countries in its natural range, extensive replacement of montane forest by other ecosystems has implications for *Prunus africana* populations, since changes involve retreat of forest boundaries. Local clearance of forest may be substantial, and rapid, as at Mount Kilum/Oku, Cameroon. Here, in a major *Prunus africana* harvesting area, there was an estimated forest area reduction of 20% - from 8700 ha in 1983, to 7000 ha in 1986 (Macleod, 1986). Additional montane forest clearance in Cameroon has taken place with the collapse of the coffee market and creation of crop fields through clearing forest as an alternative source of income (Cunningham & Mbenkum, 1993). In the Virunga Mountains, Rwanda, all the forest described as *Prunus* forest has been converted to agricultural land (Sayer *et al.*, 1992). In Kenya, exported *Prunus africana* bark was legally stripped from many trees felled when forest was deproclaimed to release land to farmers and to allow tea estate expansion (Cunningham *et al.*, 1997).

Considering the range of the species overall, the destruction of montane forest is probably the major factor affecting its conservation status. However, where populations are contributing bark to the international market there are additional concerns at the level of the populations being exploited. Trees are often felled or severely damaged as bark is removed and there is now concern for the long term sustainability of harvesting programmes. The resource base is most exploited in Cameroon (Cunningham & Mbenkum, 1993) and Madagascar (Walter & Rakotonirina, 1995) but exploitation is beginning (*ca* 300 t $year^{-1}$) in Kenya (Cunningham *et al.*, 1997) and Equatorial Guinea (Bioko - Sunderland & Tako, 1999).

Commercial exploitation of *Prunus africana* began in 1972 (Muanenguba, Cameroon - CERUT, 1999). Doubts about the viability of the resource under the harvesting regime in force were not voiced, however, until 1986 (Macleod, 1986). Through the 1972-1994 period, conservation prospects for *Prunus africana* as a resource were weakened by ineffective legislation, limitations of silvicultural and ecological knowledge and harvesting practices at variance with such prescriptions as existed. Ndibi & Kay (1997) noted ambiguities in license conditions and shortcomings in the practical administration of regulations, and imply that unwarranted silvicultural assumptions were made about capacity for regeneration from cut stumps. There appears to have been no realistic strategy to take population structure or stocking levels into account when harvesting intensity was set, presumably because information on these parameters was not collected. As these information gaps have been filled in recent years, a consensus has been reached that the species has been overexploited.

Recommendations of refinements to harvesting protocols have been made in efforts to reduce adverse effects. In Cameroon, there has been stress on bark panel removal rather than tree felling. Cunningham *et al.* (1997) suggest this approach was favoured for sustainable resource exploitation from 1972 until 1987, when the Plantecam harvesting monopoly was broken and additional entrepreneurs harvested with less rigour. Comments on the amount of bark entering the market in Cameroon during the period that followed attest to increasingly intensive exploitation nationally (Cunningham & Mbenkum, 1993; Cunningham *et al.*, 1997; Simons *et al.*, 1998). As a measure to reduce its destructive impact, harvesting by felling was eventually banned formally in 1993 (Ndibi & Kay, 1997). How effective the ban has been remains in doubt: Mbai (1998) identifies felling and complete bark stripping as a continuing problem. More positive actions are also meant to take place. In Cameroon, enrichment planting to replace exploited trees was advocated for Mount Kilum/Oku (Macleod, 1986). The annual *Prunus africana* plantation targets of 3 ha, set in 1986, and 5 ha set in 1992 (Ndibi & Kay, 1997) were an appropriate declaration of intent although far too small to have meaningful impact. The success of panel harvesting remains uncertain, in the absence of data from monitored demonstration stands. Crown health assessments on Bioko (Sunderland & Tako, 1999) and in Cameroon (CERUT, 1999) indicate considerable mortality and loss of vigour among harvested individuals but abuse of panel removal guidelines may be a major contributory factor. The interval scheduled between harvests has been increased from the original 4-5 years (Macleod, 1986) to 7-8 years (Simons *et al.*, 1998).

Additional ecological impacts of *Prunus africana* harvesting are indirect, but threaten ecosystem integrity overall. In Cameroon, the Fon of Banso considered that commercial harvesting of *Prunus africana* bark had stimulated forest clearance by changing local perceptions of forest use, from being a community resource to an asset to be exploited for personal gain (Cunningham & Mbenkum, 1993). Opening new access routes into forest also influences forest use. In 1997, new *Prunus africana* harvesting access routes into the forest of Pico Basile on Bioko gave bush meat hunters easier access to the habitat of the threatened endemic monkey *Cercopithecus preussi* (MATSCHIE, 1898) subsp. *insularis* THOMAS, 1910 - Preuss' guenon (Bioko Primate Protection Programme, 1999; Sunderland & Tako, 1999).

7.2 CONSERVATION PROVISION AND ACTION

Conservation policy and regulation and the nature of community involvement with the use and exploitation of the species are the major strategic determinants of *Prunus africana* conservation.

7.2.1 Conservation policy and regulation

7.2.1.1 The national level

As the export of its bark and bark extract has developed into a significant source of foreign exchange, source countries have introduced various legislative measures and guidelines specific to *Prunus africana*. In both Cameroon and Madagascar, there are regulations applying to the harvesting of *Prunus africana* bark (Chapter 8) reflected in management plans developed in collaboration with industry (Walter & Rakotonirina, 1995; Ndibi & Kay, 1997). Between these two countries regulations differ widely, with the Madagascar framework much less stringent than that of Cameroon, despite recent revision (Directeur des Eaux et Fôrets, 1997).

The significant aspect of the existing regulations and quotas for sustainable harvesting, as far as the conservation of the species is concerned, is that harvesting regulations are not fully effective in any area where *Prunus africana* is currently exploited. The poverty of bark collectors, lack of resources for monitoring at an institutional level and lack of political capacity/inclination to enforce the regulations make short-term gain at the expense of sustainability an attractive option for an impoverished bark collector (Mbenkum & Fisiy, 1992; Cunningham *et al.*, 1997; Ndibi & Kay, 1997). Consequences in Cameroon have included an explosion of destructive illegal exploitation, by cutting down trees, when harvesting licenses were awarded to 50 entrepreneurs in 1987. Further large scale illegal harvesting took place in Cameroon when, to fulfil a large order for bark export to Italy, export licenses were awarded to three entrepreneurs in 1993 (Cunningham *et al.*, 1997). The direct result of this was that, from June 1994 to February 1996, at least 900 t of bark were harvested illegally around Mount Cameroon. A more recent step taken in Cameroon has been a sharp reduction of the annual quota for bark collection from Mount Cameroon. However, it has been suggested (J. Acworth, pers. comm.) that this could result in increased illegal exploitation or a shift in exploitation to other regions or countries, rather than more sustainable exploitation.

In Madagascar, bark can be harvested legally by felling and stripping trees (Walter & Rakotonirina, 1995). However, the prescription that two seed trees per hectare should be left in the exploitation area is widely disregarded. Bark is also harvested illegally in protected areas, despite exploitation of forest products being subject to additional regulations and higher levels of monitoring activities. Thus, in Mantadia National Park, collectors illegally cut down approximately 200 trees of *Prunus africana* between December 1995 and March 1996, before the authorities were alerted (Dawson & Rabevohitra, 1996). This cutting probably constituted a considerable proportion of the mature trees within the relatively small Park area of 10 000 ha (I.K. Dawson, pers. obs.). Macleod (1986) refers to illegal exploitation in the Mount Kilum/Oku Forest Reserve, Cameroon.

Sunderland & Tako (1999) summarise the conservation position with respect to the specific provisions for *Prunus africana* in the 1997 Appendix to Equatorial Guinea's forestry law. The law requires that *Prunus africana* be sustainably managed. To support its implementation a national bark harvest quota (500 t $year^{-1}$) was set. However, the quota has not been based on data on the abundance of *Prunus africana* and no minimum tree size for exploitation has been specified. Sunderland & Tako (1999) present evidence that bark is collected from trees <20 cm dbh. Further, the current regulations and practice do not stipulate the use of tools whose design minimises cambial damage during bark removal. Much of the post-harvesting mortality noted at Pico de Basilé is attributed to cambial damage due to use of improper tools. On the positive side, Sunderland & Tako (1999) record that harvesting after felling was successfully halted through a Forest Department initiative to reduce long-term impact on the resource base.

7.2.1.2 International action to support *Prunus africana* conservation

The conservation of *Prunus africana* has attracted considerable international attention in recent years. Its addition to Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has been one result. This action was a response to concern over the erosion of the Cameroon and Madagascar gene pools through exploitation of natural populations. Indications that exploitation of natural populations was also taking place in the absence of protective measures in Kenya, Uganda and the Democratic Republic of Congo strengthened the case for regulating trade involving the species. CITES is discussed further in Chapter 8.

Complementary measures seek to improve conservation prospects by increasing awareness of threats to the viability of populations, which are especially severe in certain areas, and perceived declines in the abundance of the species range-wide. *Prunus africana* is listed in the Tree Conservation Database of the World Conservation Monitoring Centre (World Conservation Monitoring Centre, 1999) as a vulnerable species, considered to have suffered a population reduction of at least 20% over the last three generations following a decline in area of occupancy, extent of occurrence and/or quality of habitat and exploitation.

Further international action has been taken under FAO auspices, through the FAO Panel of Experts on Forest Genetic Resources. By the eighth session of the Panel in June 1993 (FAO, 1994) *Prunus africana* had been widely publicised as a valuable source of pharmaceutical products. Concerns over sustainability were being voiced (Cunningham & Mbenkum, 1993) and the Panel reinforced these by placing the species on the conservation priority list. The Panel stressed the need for information on variation, biology and population status as of high priority, and indicated an equally urgent need for *in situ* conservation action, and for provenance and progeny testing to start. For the next session of the Panel, which took place in 1995 (FAO, 1996), *Prunus africana* remained a priority species for FAO conservation attention despite the full Africa list being revised (to reflect responsibilities shifting from FAO to national and regional level) and reduced from about 80 indigenous species to only 13. *Ex situ* conservation action became an additional high priority with *Prunus africana* and action to improve seed supply was recommended.

7.2.2 Community involvement in *Prunus africana* conservation

Local communities are an important determinant in conservation strategies because villagers are frequently employed by industry 'middle-men' as harvesters. Thus, local communities can be direct beneficiaries from the sustainable utilisation of the species. On Mount Cameroon in 1997, the company handling and exporting bark (Plantecam) signed special agreements with two villages, Mapanja and Bokwango, for the sustainable management and production of *Prunus africana* (Chapter 8).

However, although the community management of stands appears an attractive conservation approach, it has limitations. One is that catering for attitudes towards forest resource use which differ among communities, even within a region, as around Mount Cameroon (Watts & Akogo, 1994), adds complexity to the process. Delayed action while a lengthy consultation exercise is conducted may weaken the eventual conservation impact. A second potential difficulty is that community approaches to conservation can be very sensitive to changes in external factors as when, in 1999, Plantecam suspended the special agreements with Mapanja and Bokwango mentioned above, as a reaction to being given a much-reduced quota for bark harvesting on Mount Cameroon (N. Ndam, pers. comm.). Community-industry agreements, which have taken years to develop, are unable to accommodate such rapid fluctuations in the local demand for *Prunus africana*. Finally, community management approaches are clearly not appropriate in areas where tree tenure has not been defined, or community management of forest resources is not recognised constitutionally, as is the case in Kenya (Emerton, 1997).

A further aspect relating local communities to the conservation of *Prunus africana* is that the economic value to them determines the extent to which relatively remote populations are protected from harvesting. Although the collection of bark provides a relatively small return to harvesters compared with that of the companies selling the extracted product to Europe for further processing (Simons *et al.*, 1998), the (often extreme) poverty of collectors determines the considerable efforts they will undertake to harvest trees. In Madagascar, for example, villagers are willing to walk long distances (for several days) into forest to harvest bark (Walter & Rakotonirina, 1995). Only extremely remote populations are unlikely to be targeted by harvesters.

7.3 CONSERVATION OPTIONS

7.3.1. Forest approaches

Prunus africana is not normally a keystone species of the ecosystems in which it occurs and, while often more common in patches or marginal belts than elsewhere, it is not an ecological dominant (Chapter 2: 2.2.2.1). In the context of high general exploitation of highland forest in Africa, feasible and relevant *in-situ* management strategies will be ones which focus on general conservation of representative forest blocks where it is a constituent species. The low population levels, even where well-represented, combined with both its tendency to be concentrated towards forest edges and its irregular regeneration behaviour, complicate targeting *Prunus africana* in conventional forest management. A need for management appropriate for forest edge situations, ensuring good illumination while avoiding excessive, desiccating exposure, and including protection of young plants from typical boundary hazards, particularly wildfire, is indicated. Long forest edges per unit area of interior forest will make irregular forest-grassland interfaces, and forest islands within grassland possible conservation environments for *Prunus africana*. In the event of specific interventions being needed to promote the recovery of exploited *Prunus africana* populations, opening of the canopy around, and clearing the undergrowth beneath, seed-bearing trees should maximise recruitment (Ndam, 1998).

The conservation of *Prunus africana* in countries where the species is exploited commercially will only be effective where exploitation is adequately monitored, the local community is sympathetic to sustainable harvesting principles, or where trees are too inaccessible to harvest. In this context, Dawson & Powell (1999) have identified natural stands on Mount Cameroon and Mount Kilum/Oku, in Cameroon, and populations at Mantadia and Antsevabe in Madagascar, as meriting conservation effort. However, Dawson & Powell (1999) point out that the Antsevabe population is not within a protected forest area, which will limit what is feasible.

Traditional community beliefs connected with forest management offer a further basis for conservation. They may be significant and secure reservoirs of germplasm and genetic diversity. On Bioko, Sunderland & Tako (1999) noted that *Prunus africana* trees were not harvested from sacred groves around the village of Moca, even though villagers exploited bark elsewhere. In Greater Meru District, Kenya, over 250 sacred groves of forest survive in otherwise cleared land, many containing *Prunus africana* (Ameru Traditional Doctors of African Medicine, pers. comm.). The utility of these groves for conservation purposes depends on their size and proximity to each other, but remnant *Prunus africana* trees in open farmland can maintain some gene flow between groves (A. Lengkeek, pers. obs.), possibly sufficient to keep populations viable.

7.3.2 Approaches through planting

Planting is one of the few viable conservation options for thinly dispersed heavily exploited Afromontane species. The demonstration over more than 80 years that planted stands of *Prunus africana* can be established with little difficulty emphasises their potential role in the conservation of the species. As the seed of *Prunus africana* is intermediate in nature (Chapter 4), plantings depend on fresh seed. Early plantings used available seed without consideration of any genetic implications and, often, wildings were also used. Today, we recognise the importance of the origin and genetic diversity of planting material, whether for enrichment planting, plantations or farmers fields. There are now, in addition, techniques enabling short-term seed storage across seasons (Chapter 4). This makes it possible to meet needs for germplasm of known origin and quality for the drive towards improved performance in reforestation and on-farm cultivation projects. In fact, the first provenance and progeny trials of *Prunus africana* have already been initiated in Kenya and Cameroon. In Kenya, a progeny trial of a single provenance from Kobujoi, South Nandi Forest, western Kenya, was established locally by ICRAF in 1998. The seed source was well-documented and collected from a large number of trees, to ensure a wide genetic base, in line with standard collection protocols (Dawson & Were, 1997). In Cameroon, a mixed provenance trial was begun in 1977 at Buea under the auspices of l'Institut de Recherche Agricole pour le Développement (IRAD) and ICRAF (Z. Tchoundjeu, pers. comm.). The seed used was collected from Mount Cameroon, Mount Kilum/Oku and Mendankwe, near Bamenda.

Where natural forests contract due to agricultural encroachment, agro-ecosystems assume increasing importance as reservoirs of biodiversity. The cultivation of *Prunus africana* on-farm, taking pressure off the natural resource base, illustrates this concept. On-farm planting, using germplasm of known origin and genetic base, can be an important supplement to enrichment and plantation action, as well as increasing local community awareness and interest in the sustainable management of the species. For *Prunus africana* in Cameroon, there has already been planting by approximately 3250 small-scale farmers (Cunningham *et al.,* 1997). The early efforts of the Mount Kilum/Oku Forest Project in collecting seed and promoting planting was a major catalyst for this success (Cunningham & Mbenkum, 1993).

8 POLICY AND REGULATORY FRAMEWORKS

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Until recently, the only regulations protecting *Prunus africana* were general forestry regulations. Given the potential for unsustainable and deleterious bark harvesting practices (Chapter 3), new laws, regulatory bodies and management practices containing specific reference to *Prunus africana* have become necessary. We review here the rules and regulations that have been introduced by the international community and/or by countries exporting the bark.

8.1 INTERNATIONAL PROVISIONS

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) helps regulate the sustainable exploitation of natural products in source countries, their export, and their entry into external markets (CITES, 1999). CITES regulations have applied to international trade in *Prunus africana* since 16 February 1995, when *Prunus africana* was officially added to Appendix II of the Convention. This action was proposed by Kenya and was ratified by the Secretariat at the 9th Conference of CITES in November 1994, taking effect three months later in accordance with CITES procedure.

CITES Appendix II status means that *Prunus africana* is not necessarily threatened with extinction, but may become so unless trade involving this species is subjected to strict regulation. Prior granting and presentation of an export permit is now required for *Prunus africana* products to be traded on the international market. The permit can be granted only after being approved by both the designated Scientific Authority and the designated Management Authority in the country from which *Prunus africana* is being exported. Furthermore, the import of any natural product of *Prunus africana* requires the prior presentation of either an export permit or a re-export certificate. The export permits apply to the import of dried bark or the extract into countries where the marketed end product is produced. Re-export certificates apply if dried bark is imported into a country which undertakes extraction but exports the bark extract abroad for further processing into the marketed product. Re-export certificates apply to the situation whereby dried *Prunus africana* bark has been harvested from Cameroon, transported to Madagascar for extraction and subsequent re-export of the extract to France for further processing. In such cases the Management Authority in the country of re-export confirms before issuing the re-export certificate that the material was originally imported in accordance with CITES provisions.

CITES requirements pertain to all individual specimens of *Prunus africana* and to all international trade involving any part(s) or derivative(s) of the plant other than seeds and pollen, seedlings and tissue obtained *in vitro*, and cut flowers from artificially propagated individuals. CITES regulations do not apply to the exploitation, trade or use of *Prunus africana* products that is entirely within a nation's boundaries.

Most *Prunus africana* source countries have Management Authorities and Scientific Authorities (Cunningham *et al.*, 1997). However their operation and mandate are not always in compliance with the CITES convention. For example, the Kenya Wildlife Service, which is under the Office of the President, is both the Management Authority and the Scientific Authority for plants and animals in Kenya. The Kenya Wildlife Service is independent of the Kenyan Ministry responsible for natural resources in general, and the Department of Forestry in particular. To be in compliance, the Scientific Authority and Management Authority must be independent of each other. This is the case in other source countries, such as Madagascar, Tanzania, Uganda and

Democratic Republic of Congo (formerly Zaire). However, the effectiveness of these authorities in controlling the *Prunus africana* trade is not clearly known. Also in some of these countries, such as Tanzania and Uganda, the emphasis of the Scientific Authority tends to be oriented to animal wildlife. In Cameroon there is still no Scientific Authority for plants.

The current and forecasted markets for the natural products and derivatives of *Prunus africana* are European countries, Canada and the United States of America. Being parties to CITES, these countries are obliged to honour CITES provisions regulating the import of natural products. In addition, their national regulatory bodies, such as the Food and Drug Administrations of both Canada and USA, can further influence the supply-demand by limiting how imported natural products can be used and sold. In France, for example, the bark extract of *Prunus africana* can be sold as a medicine. In the USA, it can only be sold as a herbal dietary supplement. In the United Kingdom, it cannot be sold for use as a medicine or dietary supplement.

8.2 NATIONAL PROVISIONS

Since commercial pharmaceutical use of *Prunus africana* extract first began in the 1980s, the harvesting and demand for *Prunus africana* has greatly increased, usually with little or no government control. With the exception of Cameroon and Madagascar, there appears to be little documentation to guide the exploitation of *Prunus africana* bark in source countries.

8.2.1. Harvesting regulation

Three countries (Cameroon, Equatorial Guinea and Madagascar) have passed national legislation in which there is specific reference to the exploitation of *Prunus africana*. Kenya regulates exploitation under the general forestry and exporting legislation and Marshall & Jenkins (1994) indicated a royalty fee of Kshs 725 m^{-3} applying to harvested timber.

8.2.1.1 Cameroon

In Cameroon there are two Government institutions responsible for developing guidelines on access to wildlife resources and forest research. These are, respectively, the Ministry of Environment and Forestry (MINEF) and the Ministry of Scientific Research. Within the former a section concerned with non-timber forest products, including *Prunus africana* products, has recently been created.

Since 1974, the legal and policy frameworks in Cameroon for regulating the harvesting and export of *Prunus africana* bark, and how local communities benefit from its exploitation, have been in constant flux (Table 8.1).

While the procedure for exploiting *Prunus africana* remains basically the same as in the 1981 Forestry Law, the 1994 Law (94/01) introduced two major changes for all ‘special’ forest products. First, the applicant must be granted approval for forest exploitation activities (Section 41 of the law) from the Prime Minister’s office, and then seek permission from MINEF, creating a two-tiered system of control.

Second, the Provincial Chief of Forests must provide a technical report which specifies the species and quantities to be exploited, the area in which exploitation will take place, and the harvesting modalities to be used (Article 59(2b) of decree of application). Based on this, and in accordance with the recommendations of the Ministry technical commission, a special permit can be issued.

Table 8.1 Cameroon legal measures relevant to the case of *Prunus africana*

Decree No.74/357, 17 April, 1974 - Sections 74, 97 98 - Regulates the exploitation of medicinal plants.
Law No. 81-13, 27 November 1981 - Specifies Forest, Wildlife and Fisheries Regulations.
Decree No. 83-169, 12 April 1983 - Specifies Forestry Regulations.
Arrete No.48/A/MINAGRI/DF, 28 February 1991 - Banned the exploitation of *Prunus africana* in Cameroon (exempting Plantecam).
Arrete No. 48/MINAGRI/DF, 14 February 1992 - Lifted the ban on *Prunus africana* exploitation.
Decision No. 0045/MINEF/DF, 11 January 1993 - Banned felling in the exploitation of *Prunus africana*.
Law No. 94/01, 20 January 1994 - Specifies Forestry, Wildlife and Fisheries Regulations which cover *Prunus africana*.
Decree No. 15/ 531/PM of 23 August 1995 - Specifies Forestry Regulations.

Holders of such special permits are responsible for obtaining Forestry Service specifications which detail the conditions for exploiting and transporting natural products, and the terms and conditions for paying taxes. Following the presentation of a copy of the permit and the receipt or payment of taxes, the Provincial Chief of Forests can authorise a start to exploitation.

The 1994 Law (94/01) requires that the following guidelines are given to any person or company interested in the exploitation of *Prunus africana* bark:

- Stamped application to the Ministry in charge of forests specifying:
  - Full name, nationality, occupation and place of residence (for individuals)
  - Name, Articles of Association, Head Office, Registered Capital and its distribution, and name of the Director or Manager (for companies).
- The capital invested (Attestation).
- The applicant's Investment Plan and the financing guarantee (means of transportation envisaged, existing storage facilities and other facilities to be set up, measures taken to process part of the products locally).
- List of species and quantities to be exploited, as well as the location.
- A signed undertaking that the applicant understands and will abide by the regulations and will co-operate with the Forestry Service.

A Ministerial Committee sits at least twice a year to grant exploitation permits for *Prunus africana* and other medicinal/non-timber forest products. After permits are issued they remain valid for one year, but are renewable pending production of the following:

- A stamped application.
- A copy of the previous permit.
- Receipts testifying to the payment of the registration fee and the selling price of the product.
- Copies of certificates of origin if the holder exports the product.
- A detailed report of the activities of the previous seasons, specifying the quantities of products exported or produced locally.

The law of 1994 (Republic of Cameroon, 1994) refined the previous procedure by requiring the Provincial Chief of Forestry to attach a technical report specifying the methods for harvesting and the quantity of each species to be exploited.

8.1.1.2 Equatorial Guinea

Sunderland & Tako (1999) specify a legal measure in which *Prunus africana* is named as a species for which the legislation is intended to regulate exploitation. This is Article 62 of the 1997 Appendix to the 1995 forestry law (Reglamento de Aplicacion de la Ley Sobre el Uso y Manejo de los Bosques EQG/96/002). The Article links commercial timber and non-timber forest product exploitation with provision for sustainable management.

8.1.1.3 Kenya

There are no laws in operation in Kenya which refer specifically to *Prunus africana* products.

8.1.1.4 Madagascar

In Madagascar, the current regulations for exploiting *Prunus africana* bark do not preclude felling the tree and stripping it of all bark. However, to promote regeneration, two trees per hectare must be left standing and the ground cleared of other plants within 10 m of each tree. However, no cutting within 10 m of a watercourse is permitted. The duration of the permit is specified, but no limit is set for the number of trees to be exploited or the amount of bark that can be harvested (Walter & Rakotonirina, 1995).

8.2.2 Added value incentives

Present policies in both Cameroon and Madagascar favour the transformation of bark locally before exportation. In Madagascar a recent Ministerial Service Note (No. 031/99-MEF/MI of 04/03/99) states that exploiters should satisfy the needs of the only transformation company in the country before any exportation occurs.

In Kenya, Jonathan Leakey Limited is (June 2000) the sole exporter of *Prunus africana* bark. Bark is purchased after successful liaison with local administrative authorities, chiefs and land owners and then an authorisation letter is obtained from the nearest Forestry Service to permit transport of the product to Mombasa, the point of export. Export permits are obtained from the Kenya Wildlife Service, each for 50 t.

Cameroon's revised (1994) forestry law includes provision for benefit-sharing and participatory management. This provision led to the signing, backed by the South West Forestry Service and the Mount Cameroon Project, of contractual agreements between Plantecam and the villages of Mapanja (July 1997) and Bokwango (September 1997) for the harvest and supply of *Prunus* bark under Plantecam's license. The Village Traditional Council served as the main negotiating and administrative body for this agreement. A Village Development Fund was established by each village to manage finances resulting from the agreement; a Monitoring Committee and a

Harvesters' Union were also established. Under the terms of the agreement, only members of the Harvesters' Union could harvest bark. Plantecam bought the bark for the price paid elsewhere to middlemen with special permits (209 CFA kg^{-1}), who used to pay villagers only about 100 CFA kg^{-1} (1$US = 695 CFA, May 1999). Union members (about 60) now received a higher price for their effort.

Article 2(D) of the same contractual agreement provided for a maximum monthly tonnage of 10 t to be supplied by the Harvesters' Union to Plantecam. Each villager could harvest a maximum of 30 kg a day. Actual weights were measured at Plantecam. Proceeds from 2 kg of the 30 kg were contributed to the Village Development Fund and proceeds from 1 kg to the Union's Fund. Each member retained the remaining 27 kg income (*ca* 209 CFA kg^{-1}, less 10 CFA kg^{-1} for transportation from their village to the company's factory at Mutengene, and 10% of the total weight as exportation tax). After all deductions had been made, each bark harvester collecting 30 kg received a wage of about 5000 CFA. As a result of payments by bark harvesters into the Village Development Fund in Mapanja, the Fund held about one million CFA just 5 months after it was set up. In addition to the monetary benefits accruing to the village, bark harvesters have been trained to harvest the bark sustainably. In conjunction with staff from Plantecam, MINEF, MCP, and other villagers, bark harvesters were responsible for monitoring exploitation.

9 SECURING THE *PRUNUS* RESOURCE

John B. Hall and Fergus L. Sinclair

This monograph represents the first attempt to systematically retrieve and collate existing information on all aspects of *Prunus africana*. We have produced and interpreted a comprehensive distribution map for the species and have been able to revise and amplify understanding of its ecology. Against this background it has been possible to examine the conservation status more closely than could be done previously, and to evaluate management practices and consider conservation and management needs in policy and trade terms.

Our review indicates that *Prunus africana* is a long-lived, medium- to large-sized, outbreeding, early successional Afromontane tree. The species is noteworthy for its morphological uniformity despite a discontinuous distribution and the long distance (5000 km) between the populations at the northern and southern limits. It has succeeded in reaching and persisting in all of Africa's mountain systems and several off-shore islands, including Madagascar. Near-total absence from the lower-lying, warmer areas around the mountain systems separates the populations associated with each of these. Where comparisons have been made between populations from different mountain systems, it has been shown that they are genetically distinct. Overall estimates of stocking indicate that *Prunus africana* contributes only a minority of trees in the communities where it is found, and seedlings are often under-represented. However, the species is more common at and near forest margins. Trees apparently tend to flower in alternate years and there is much year-to-year variation in fruiting intensity at the stand level.

Silvicultural familiarity with *Prunus africana* as a minor timber species has gradually accumulated over almost 100 years. The relocation of wildings, especially for enrichment purposes, and the planting of stock raised from seed have proved practicable. However, vigorous planting programmes have not developed - partly because attention was diverted to other species and partly because of complications with irregular seed supply and seed storage difficulties - even though with fresh seed the germination percentage is high and the nursery phase can be completed within one year.

Management has been particularly concerned with devising and introducing procedures for collecting bark with minimal adverse long-term impact on the tree, and monitoring the implementation of these procedures. Recommended practice results in two panels of bark each 20-25 cm wide, and as much as 3 m or more long, being removed. Each leaves a scar some 1 m^2 in area on the bole and individual trees are subjected to this impact at intervals of approximately eight years. However, lasting post-harvest damage to trees, and even deaths, remain a management concern - both where the recommended harvesting practice is being implemented and where it is not. Pressure to maintain supplies for export has also led to continuing exploitation without either close monitoring of harvesting impacts or area yield limits informed by reliable population statistics. This makes the regulation of bark harvesting to ensure individual *Prunus africana* populations remain viable, a central management objective.

Concern over the sustainability of exploitation of natural populations has been expressed by conservationists for over ten years and this review echoes these concerns. Initial unease arose from the impact of unsustainable exploitation on the integrity of forest with high general biodiversity value, particularly in terms of avifauna. When closer attention was given to the *Prunus africana* bark trade, international measures intended to encourage regulation of exploitation were instituted by including the species in CITES Appendix II. Further conservation publicity has reinforced this action: designation as a vulnerable species by the

World Conservation Monitoring Centre and as a conservation priority by the FAO Panel of Experts on Forest Genetic Resources. The FAO Panel's approach has particular value in its broader view of the *Prunus africana* conservation problem. The Panel advocates efforts to extend knowledge and intensify conservation action within and beyond the natural forest populations and specifically urges formal germplasm comparisons through trials and steps to improve seed supplies. The picture emerging from this monograph allows consideration of opportunities and options for securing and improving the *Prunus africana* resource, addressing the FAO Panel's key points in the process.

To reduce and eventually eliminate the over-exploitation of *Prunus africana*, management changes are essential. Currently, most exploitation is not planned following effective inventory appropriate for the patchy distribution of the species. Annual harvest areas and bark quotas should be set only after an effective inventory. Unless and until new research justifies changes, areas and quotas would be determined by the numbers of individuals ≥30 cm dbh and implementation of an inter-harvest interval of eight years. To confirm acceptable post-harvest recovery of trees exploited according to the protocol currently recommended, tree health monitoring should be undertaken in selected major production areas. The monitoring should be organised as a statistically robust survey which will indicate if tree size affects recovery, and with individual trees reassessed periodically to detect any delayed or progressive deterioration in condition.

Lowering or halting over-exploitation will reduce commercial supplies of bark if additional sources of pharmaceutical raw material do not enter the trade. A shortage of supply would not be in the interest of countries currently contributing supplies to the market. A shortfall could lead to an irreversible shift in favour of alternative plant sources, such as saw palmetto (*Serenoa repens*). As many populations of *Prunus africana* have not yet been exploited for pharmaceutical purposes, there is untapped potential - although whether its product quality is satisfactory awaits confirmation. Such widening of the natural forest supply base will need to be implemented with appropriate provisions for sustainable management - thorough prior inventory and according to comprehensive and specific harvesting protocols. As new source areas are located, populations of *Prunus africana* set aside in an inviolate state for conservation and baseline research purposes should also be identified.

Planted stands are a further option as an additional source of *Prunus africana* products. Forest services traditionally favoured planting the species in pure stands but this never achieved the scale applied to key exotic species such as cypresses, eucalypts and pines. Plantings of *Prunus africana*, despite the long planting history, cover a very small area. The numbers of planted trees that have reached exploitable size are trivial and are not in themselves sufficient in any locality to justify bark harvesting. Today, tree planting centres much less on the forestry services, particularly when trees are grown for non-timber products. On-farm planting of *Prunus africana*, well-established in Cameroon and being initiated in Kenya and Madagascar, illustrates this change. It is an attractive mechanism for strengthening the resource base of the species and vigorous and successful promotion of on-farm planting could secure its future. Relatively few farmers control large land holdings. The need is, therefore, to persuade large numbers of those who farm small areas in suitable mountain environments to each plant one or a few *Prunus africana* trees, perhaps along farm boundaries.

The scale of such activity needs to be emphasised so that the task of the extension services or other promoters is appreciated. On the basis of experience with small-scale tree growing by individuals, losses of as much as 70% of trees planted are likely. To bring one million trees to the age of 12 to 15 years when bark can be harvested, would call for the involvement of around 1.1 million farmers each planting three trees. The farmer would then face a choice of complete stripping of bark and replacing the tree or removing bark panels at an age of about 15 years in the first of a series of harvests from the same tree. In the latter case, there would be two further intermediate harvests at eight-year intervals, and a rotation-end harvest at 40 years when the tree was completely stripped and the timber also exploited. Current factory and market arrangements are tailored to bark as the raw material for pharmaceutical processing. This means a lag (12-15 years) for the farmer between planting and benefit. For the species it means continuing reliance on natural forest sources until significant amounts of bark from planted trees are available. Complete stripping and replacement of one million trees at 12 years would entail a 12 year lag and then a contribution of some 1700 t year^{-1} of bark to the market. The rotation ending with the timber harvest would take 40 years to assume full effect and then contribute, for every million trees, around 7500 t year^{-1} to the market. With boundary planting, prospects of a long lag period being acceptable are better than if farmers were expected to allocate land to blocks of trees. In the context of these lag periods, examination of the suggestion that harvesting of foliage and shoots from young trees grown by farmers as a short-term perennial crop, as an alternative to bark harvesting, emerges as a research priority.

With an expansion of the planted *Prunus africana* resource, product quality and genotype considerations will assume greater importance and progress is being achieved with these aspects of the species. However, the overall picture of genetic variation through the range remains incomplete, particularly outside Cameroon, Kenya and Madagascar. Nor do findings made public to date allow populations to be compared with respect to product quality. There has been a general neglect of studies of *Prunus africana* which take full account of its wide and disconnected distribution. With the information provided in this monograph such studies can be planned more easily than in the past. A particular need can be highlighted for a unified survey of genetic variation and product quality which includes populations representing all the mountain systems in the range and satellites along the Congo/Zambezi rivers divide and in the Lake Victoria basin. Island populations, at least for Bioko and Madagascar, should also be represented. More detailed understanding of the pattern of genetic variation through the range and relative product quality from different areas will have tree improvement implications. It would also provide a framework for a programme of trials to optimise site x genotype matches for high productivity and quality. In addition, a clearer genetic picture might prove highly relevant to the research question of how the species achieved its present range, and would complement the research needed into its relationship with other members of the genus.

Interest in *Prunus africana* arises largely because it supplies an export product demanded in increasing quantity. Conservation concerns, management refinements and promoting planting are all consequences of this situation. Infrastructure is vital if benefits from management and planting measures are to flow to local communities and have national relevance. Equally, there are national responsibilities to address the conservation concerns as required under CITES, and infrastructure is needed to ensure this. There should be a national *Prunus africana* forum in each country from which the bark is harvested and exported. Kenya has already taken this step, setting up a *Prunus africana* Working Group. In this group, national CITES scientific and management authorities, the forest services, and independent professional institutions participate. Other supplier countries need such groups. In the Kenya group, industry and local communities are not included. However, their representation would enable co-ordination through the complete process from inventory and exploitation to export or in-country processing. The working groups would bring together the expertise competent to advise Government and other stakeholders on the strategy for maintaining and reinvigorating the *Prunus africana* resource. An important role would be to devise and institute monitoring programmes operating through such tools as Criteria & Indicators schemes applied to the *Prunus africana* populations being exploited. It would be consistent with the CITES status of the species if certification was issued for bark harvested in accordance with recommended policies and protocols. Just as higher rates have been paid in Cameroon for better quality bark, a higher rate could be set as an incentive to suppliers for bark certified as originating from sustainably harvested populations.

An additional level of infrastructure is needed to co-ordinate collaboration between the different supplying countries and between these and the countries producing and marketing the finished products. A relevant international organisation would be best placed to set up an international *Prunus africana* Accord to which the countries concerned subscribed. Acting on behalf of all these countries by taking forward an agreed collective position with regard to trade in *Prunus africana* products, the international organisation would be in a position to lobby for expansion of the consumer market where it is restricted by unwarranted regulations. As a step towards such action, the countries involved should adopt the same provisions for implementing the CITES regulations applying to the species, reinforcing this action by specifying standard conditions for certification of production through sustainable forest management. The international group would also be an appropriate forum for exploring the potential for processing and preparation of the finished pharmaceutical items to be transferred to countries where the bark is harvested.

9.1 RECOMMENDATIONS

Recommendations for action to maintain *Prunus africana* as a resource and harvest it sustainably are given below under five headings, starting with national and international policy initiatives and ending with the principal research required to plug knowledge gaps. The sequence of recommendations within each section reflects their priority and the sections themselves are presented in an overall order of priority.

Policy and markets

1. At national level a planting programme implemented according to a defined and specific national strategy is needed for each country providing bark for the pharmaceutical sector. National *Prunus africana* Working Groups, or their equivalent, in which Government, industry and local communities participate, should develop strategies. Review and revision of bark harvesting quotas should be the responsibility of the National *Prunus africana* Working Group, or its equivalent. There should be certification (green-labelling) of bark from populations shown by monitoring to have been harvested strictly in accordance with the prevailing recommendations.

2. At international level there is currently insufficient co-ordination of effort between source countries or between these countries and the user industries in America, Australasia, Europe and the Far East. There is need for an International *Prunus africana* Accord involving all supplying countries and the industries receiving material for processing. To initiate the process and bring the Accord into operation, a relevant international body/organisation such as the Food and Agricultural Organisation of the United Nations (FAO) or International Plant Genetic Resources Institute (IPGRI) should liaise with the parties concerned. There should be provision for additional suppliers and users to join the Accord subject to meeting relevant conditions. The Accord should specify, in advance for five year periods, balanced national harvest and supply quotas, to be met without contravening CITES regulations and should incorporate provision for certification.

3. The market demand for *Prunus africana* extract is likely to be maintained and could increase significantly. Clinical trials indicate the extract to be both efficacious and virtually non-toxic for treating benign prostatic hyperplasia. There would be a much-increased market if products based on the extract were approved for prescription as medicines by the Federal Drug Administration (USA) and as dietary supplements and medicinally in the United Kingdom. An appropriate international organisation, acting

on behalf of the parties to the International *Prunus africana* Accord, should lobby for the relevant approvals to be given, ensuring benefits are clearly directed towards the people of the exporting countries.

4. Very little value is added to *Prunus africana* products by the limited processing carried out within Africa/Madagascar. The feasibility of more, or all, processing being routinely undertaken in the source countries, with more economic benefit accruing to stakeholders there, should be evaluated.

Inventory

5. Population structure and status of exploited populations of *Prunus africana* should be clarified through inventory and reflected in exploitation schedules. Because *Prunus africana* tends to occur in groups or patches, between which its occurrence is relatively sparse, conventional systematic inventory methods are not appropriate and Adaptive Cluster Sampling, recently implemented in Cameroon (Mount Cameroon), is more suitable and cost-effective. Inventory could be funded and facilitated by national forestry services, conservation INGOs or funded by companies exploiting the resource, in which case they would need to be independently administered. There is a key role for national forestry services in ensuring that inventories of exploited populations are conducted to an acceptable standard.

Harvesting

6. Because the basis for setting bark harvesting quotas for *Prunus africana* is weak, unsustainable quotas may be contributing to tree mortality. As a matter of urgency, monitoring of post-harvest tree health under formal, statistically robust, survey protocols, is needed. Monitoring should be annual and on-going through at least three harvesting cycles. Interim revised bark harvesting quotas for *Prunus africana* at individual tree and population levels should be determined following two years of formally monitoring post-harvest tree health. Bark harvesting quotas should be reviewed, and if appropriate revised, in the light of the post-harvesting health survey findings, two years after monitoring commences and thereafter at five-year intervals.

7. Exploitation of natural populations should be on the basis of land units containing equal amounts of resource and opened for harvesting in rotation. After harvesting, a unit would not be re-opened until an appropriate interval, provisionally eight years, had elapsed.

8. To add rigour to monitoring activities concerned with *Prunus africana* (particularly population status and tree health), provision should be made for use of the Criteria & Indicators approach. Lists of criteria, indicators and verifiers for such purposes should be prepared under the auspices of National *Prunus africana* Working Groups, or their equivalent.

9. *Prunus africana* harvesting is compatible with maintaining watershed functions and so may be a suitable activity even on gradients within protected catchments where logging is unacceptable. Opportunities for utlilising such sites as sources of *Prunus africana* bark should be considered.

Cultivation and conservation

10. *Prunus africana* in natural populations is a difficult species to manage successfully - being sparsely distributed and with many populations in remote localities inaccessible

by road. There is need for more on-farm planting and planted stands to simplify, and reduce the cost of, management activity and enable more effective supervision of labour.

11. In countries currently supplying bark to the pharmaceutical sector, natural stocks of *Prunus africana* are dwindling. Here, much increased levels of planting activity, using nursery material raised from seed of known origin, are needed urgently.

12. The major focus of planting activity should be on trees grown singly or in relatively small numbers on-farm by farmers willing to integrate *Prunus africana* into their farming system. In line with this, studies are needed investigating potential on-farm planting niches and farmer preferences.

13. Priority geographic areas containing unexploited populations of *Prunus africana* need to be identified for special conservation effort. Such areas should serve as sources of germplasm for complementary 'conservation through cultivation' measures by communities in the vicinity.

14. Management action with the aim of safeguarding natural populations as gene pools should be based on strategies suited to the interface situation of the forest edge. Interventions to increase the number of seedlings which survive (canopy thinning, removal of smothering undergrowth, controlled burning of contiguous grassland), should be considered.

Research

15. Parts of *Prunus africana* other than the bark are used in traditional medicine. However, there is very little documentation on these as sources of extract for the pharmaceutical products currently marketed. Relatively short-lived and readily replaced organs, such as leaves, are thus a possible alternative source of extract of acceptable quality. If this were confirmed, harvesting could start when plants are much younger, and take place more frequently, and the risk of persisting post-harvest damage would be lowered. Further investigation of the feasibility of short-rotation options for growing *Prunus africana* are desirable, particularly those aimed at extracting the active ingredients from shoot and leaf material as a possible source of early revenue for a farmer.

16. There is insufficient experience of the species in terms of how it responds to bark harvesting. There is need for systematic study of the impact on tree health of different bark removal intensities in relation to tree size, the season when harvesting is carried out and the interval elapsing between successive harvests.

17. Considerable genetic variation between countries has been demonstrated. There is need to extend investigation of this variation to the other countries where there are natural populations of *Prunus africana* and to take it into account in developing an international conservation strategy for the species.

18. Within-country genetic variation appears to be important and needs to be systematically investigated and characterised in all countries where bark is harvested as raw material for the pharmaceutical sector.

As the concerns that led to its CITES listing have made clear, *Prunus africana* has been very heavily exploited in parts of its range even threatening local extinction in some places. Active management is now required and appears to be gaining ground in some of the major producing countries. The challenge is now to create circumstances under which more of the value of the *Prunus africana* trade accrues locally and nationally within source countries. This will involve major thrusts towards sustainable harvesting of wild populations and planting of trees on-farm, facilitated by national and international structures.

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APPENDIX 1 TAXONOMY AND DESCRIPTION

John B. Hall

NOMENCLATURE

Collectors' notes, and a few years later the scientific description under the name *Pygeum africanum* by Joseph Hooker in 1864 (Hooker, 1864), appear to be the first recorded references to the species (Table A1). Simons *et al.* (1998), however, make a passing, unsourced reference to 18th century European awareness of indigenous medicinal use to treat bladder conditions in Natal, South Africa.

Hooker's description was based on the specimen collected on Mount Cameroon by Gustav Mann in December 1862 but he also determined that material from Malawi, actually collected earlier (April and October 1859) by John Kirk, was of the same species. In fact, neither Mann nor Kirk collected the oldest botanical material. Credit for this belongs to Friederich Welwitsch who worked in Angola, and collected specimens in May 1857. Because of delays in Welwitsch's collection reaching Europe, it had not been available when Hooker drew up his description but its identity quickly became evident when it reached the Kew herbarium and it is listed under *Pygeum africanum* in the Flora of Tropical Africa (Oliver, 1871).

Until 1952 it was accepted that no other indigenous African plant belonged to the same genus. In that year, however, Hauman (1952a) described a second African *Pygeum*, *Pygeum crassifolium*, for certain plants collected from Mikeno and Ruwenzori (Democratic Republic of Congo), and from Kyimbila (Tanzania) which he considered were specifically different from *Pygeum africanum*. Graham (1960), in the treatment of the Rosaceae for the Flora of Tropical East Africa re-examined the material on which Lucien Hauman based the second species and concluded that the case for retaining it as distinct was weak.

Hooker (1864) had referred Mann's plant to Carl Friedrich von Gaertner's genus *Pygeum* and this placement was accepted for the next 100 years. However, Kalkman (1965) undertook a taxonomic revision of the Old World species of *Pygeum* and concluded that separation from the longer-established, Linnean, genus *Prunus* could not be justified. Therefore, in accordance with the international conventions governing plant nomenclature, the name *Pygeum africanum* was superseded by *Prunus africana* (HOOK. f.) KALKMAN. Kalkman did not treat *Pygeum crassifolium* as conspecific with *Pygeum africanum* and therefore published a new combination for this, too - *Prunus crassifolia* (HAUMAN) KALKMAN.

For this monograph, Graham's (1960) wider circumscription of a single indigenous tropical African species has been adopted but with the name updated to *Prunus africana*. The derivation of the generic name is that *Prunus* was the ancient Roman name for the plum. The specific epithet signifies the African origin of the species. The family position taken here is that the genus *Prunus* is in the Rosaceae although in some accounts (*e.g.* Troupin, 1982) the sub-tribe Amygdaloideae (= Prunoideae) which contains *Prunus* is elevated to the rank of family as the Amygdalaceae.

Table A1. *Prunus africana*: chronology of nomenclature, synonymy and significant collections

Year	Name	Remarks
1857 (May)		Earliest recorded voucher specimen: *Welwitsch 465* from Pungo Andongo, Angola
1859 (Apr & Oct)		Kirk's specimens from Malawi (*Kirk s.n.*) from Mungazi (April) and Chiradzulu (October)
1862 (Dec)		Type specimen collected by Gustav Mann (*Mann 1207*) on Mount Cameroon
1864	*Pygeum africanum* HOOKER f.	Original description (Hooker, 1864) based on *Mann 1207*
1952	*Pygeum crassifolium* HAUMAN	Name applied by Lucien Hauman to particular Congo and Tanzania specimens he considered specifically distinct from those he referred to *Pygeum africanum*
1960	*Pygeum crassifolium* HAUMAN	Reduced to synonymy under *Pygeum africanum* by Graham (1960)
1965	*Prunus africana* (HOOK. f.) KALKMAN *Prunus crassifolia* (HAUMAN) KALKMAN	New combinations applied by Kalkman (1965) to tropical African material previously named *Pygeum* when he reduced this genus to synonymy under *Prunus*

DESCRIPTION

Seedling

Hauman (1952b) provided a very brief description of the *Prunus africana* seedlings collected in the Kivu-Ruwenzori area but a much more detailed account of seedlings (in Cameroon) has since been provided by Fraser *et al.* (1998). The latter forms the basis of the description which follows here.

The two accounts differ in conclusion about the form of germination - Hauman describes this as hypogeal but Fraser *et al.* imply there is elongation of the hypocotyl and that it is epigeal and cryptocotylar.

The epicotyl is 3-16 cm long. The leaves are glabrous, simple and sometimes reduced to cataphylls at some lower nodes. The first two to six leaves are opposite, those of the lowermost pair consistently so. Subsequently phyllotaxy is spiral. Ptyxis is conduplicate and expanding or newly expanded leaves are lighter-coloured, somewhat yellowish and commonly flushed with red. With time the leaves darken and this coloration is largely obscured.

A glabrous, thin or fleshy, more or less apiculate, triangular stipule 1-1.5 mm long is present on each side of the leaf axil but is eventually shed. The petioles are long (20-25 mm on leaves up to 11 cm long; up to 35 mm on those which are larger) but slender (1 mm thick) and diverge from the stem at a wide angle (45-80°). Each is fairly straight and channelled adaxially. Often a pinkish coloration is evident.

In the first two leaves, the lamina is 2-7 cm long and relatively broad (ovate in outline) compared with the usually longer, narrowly ovate or lanceolate lamina of the leaves developed later. These later leaves display the features typical of mature plants. The base of the lamina is acute to rounded, and often asymmetric, and the apex is acute to acuminate. The margin of the lamina is often undulating and usually serrate, each serration being oblique and terminating in a dark, glandular point. The gland at the apex of the lowest marginal tooth on each side is larger.

The venation is pinnate and brochidodromous. The midrib is narrow, straight and usually impressed above but prominent beneath. The secondary nerves diverge alternately from the midrib at a wide angle (45-80°) and are more prominent on the abaxial than on the adaxial leaf surface. There are 8-12 pairs. Each secondary nerve is straight near the midrib but curves towards the apex and connects with the superadjacent nerve at some distance from the leaf margin. A reticulum of minor veins is connected to the secondary nerves. Branch nerves from the reticulum extend to the apices of the marginal teeth.

Mature tree

Habit, size and form

Prunus africana is generally described as a tree but Graham (1960), Mendes (1978) and Beentje (1994) indicate that it may not be larger than a large shrub from 3 m to 5 m tall in "lava forest". Typically it is described as reaching 25 m in height. Taller trees are not unusual in tropical East Africa (36 m - Graham, 1960), Ethiopia (40 m - Hedberg, 1990) and Chapman & White (1970) report individuals 30 m tall from Malawi. Diameter typically reaches 0.9 m to 1 m in large old trees in Kenya (Dale, 1936) and South Africa (Palmer & Pitman, 1972) but individuals as large as 1.5 m dbh are recorded from Malawi by Chapman & White (1970).

In *Prunus africana* trees in forest conditions, the bole is slim, straight and cylindrical and may be free of branches for 20 m or more, two-thirds of the total tree height (Letouzey, 1978). References to buttresses vary from absent (Friis, 1992 - Ethiopia), through occasional small buttresses (Hamilton, 1981 - Uganda) to the presence of about four prominent buttresses 8-10 cm thick, rising 1 m up the bole and spreading outwards 1 m and bifurcating near the soil surface (Letouzey, 1978 - Cameroon). The crown is spreading, with a few large ascending tortuous branches (Letouzey, 1978). Graham (1960) describes the branches as somewhat pendulous, seemingly a reference to the more distal shoots, or branches in the crowns of trees that have grown in relatively open conditions and developed a short bole and where low branches have persisted to form a deep crown. For South African trees, Palmer & Pitman (1972) describe the branches as brown and the twigs as knobbly. Graham (1960), for East Africa, and Letouzey (1978), for Cameroon, describe the branchlets as smooth and shiny, brown to reddish-brown, and bearing lenticels 1-2 mm long with raised margins. Hauman (1952b), describing plants in the Kivu-Ruwenzori mountain system, notes that the leafy shoots are slender, smooth or slightly wrinkled, 1-2 mm in diameter and dark purple in colour. Caducous, linear stipules, 1.5-2.0 mm long are present (Mendes, 1978).

Bark

The bark is usually described as dark brown to blackish but Graham (1960) notes that it may be grey. In young trees, there are prominent longitudinal fissures but on older individuals, where the bark is *ca* 15 mm thick, there tend to be coarse exfoliating scales often *ca* 5 cm x 5 cm or larger (to 10 cm wide and 15 cm long - Hamilton, 1981). Beneath the bark is a whitish or very pale pink phellogen (Eggeling & Dale, 1951). The blaze is soft and fibrous beneath the bark, pale red to red-brown in colour but darkening with exposure and smelling strongly of cyanide. A clear sap, which becomes faintly turbid with exposure (Eggeling & Dale, 1951), is exuded in some quantity from the cambial region (Letouzey, 1978), particularly from young trees.

Foliage

Prunus africana is evergreen. The leaves are simple and alternate (Fig. A1), internodes being 2-2.5 cm long (Hauman, 1952b). The leaf is typically glabrous and subcoriaceous to coriaceous in texture, although grading in some locations at high elevation into the more fleshy forms that Hauman distinguished as *Pygeum crassifolium* (*Prunus crassifolia*). The surfaces contrast in appearance, being a shiny deep green above and duller and paler below (Palmer & Pitman, 1972) and, particularly in young leaves (Letouzey, 1978), the midrib is often reddish above.

There is a distinctive long (1-2 cm), usually reddish, channelled petiole and an elliptic-oblong or ovate lamina, 3-6 cm broad and 6-15 cm long. Referring to East Africa, Graham (1960) states that the lamina is usually three times as long as broad but Hamilton (1981) notes that short, relatively broad, more ovate leaves seem typical at high altitudes. Specimens regarded as *P. crassifolia* by Hauman (1952b) had relatively small leaves (5-8 cm long and 3-4 cm broad). The lamina base and apex are both rather variable. The base may be rounded or cuneate and Letouzey (1978) from Cameroon material, notes that the base may be unequal. The apex is variously described as rounded, obtuse, subacuminate or long drawn-out. Letouzey (1978) draws attention to the glandular nature of the tip. The margin of the lamina is usually crenate-serrate, with shallow incisions barely 1 mm deep at intervals of 5-8 mm, or less commonly at intervals of 2-3 mm (Hauman, 1952b). Less commonly the leaves are subentire. Caducous dark, conical, apical glands are present on the teeth between the incisions, the lowest gland on each side being more prominent than those above (Mendes, 1978) and sometimes being located at the distal end of the petiole (Letouzey, 1978).

The pinnate venation is more clearly visible on the abaxial surface where there are 5-12 pairs of slightly prominent secondary nerves diverging widely from the prominent midrib (Hauman, 1952b; Letouzey, 1978). At about two-thirds of the distance between the midrib and the margin the secondary nerves bifurcate (Letouzey, 1978). In specimens regarded by Hauman (1952b) as *Prunus crassifolium*, the secondary and tertiary venation were more prominent on the abaxial surface and occasional caducous hairs were noted on the nerves of young leaves.

When bruised the leaves, like the blaze, smell of cyanide (Palmer & Pitman, 1972).

Inflorescence and flowers

The inflorescences are simple, slender axillary racemes 2-8 cm long (Fig. A1), which arise singly from cataphylls or leaf axils on the previous year's shoots (Graham, 1960; Mendes, 1978). Occasionally the inflorescence rachis is branched (Hauman, 1952b) and if subtending leaves or cataphylls are congested the inflorescence may appear to be 2- to 5-fasciculate (Letouzey, 1978). The peduncle is 0.5-2 cm long and the inflorescences may be congested or open, and pendulous or erect and spreading (Graham, 1960). The cataphylls are caducous and shiny brown, *ca* 3 mm long and tridentate with two deltoid outer teeth 1 mm long representing stipules and a narrower central tooth representing a reduced leaf (Letouzey, 1978). After abscission a distinctive projecting semi-circular rim remains on the shoot below the point of attachment of the inflorescence.

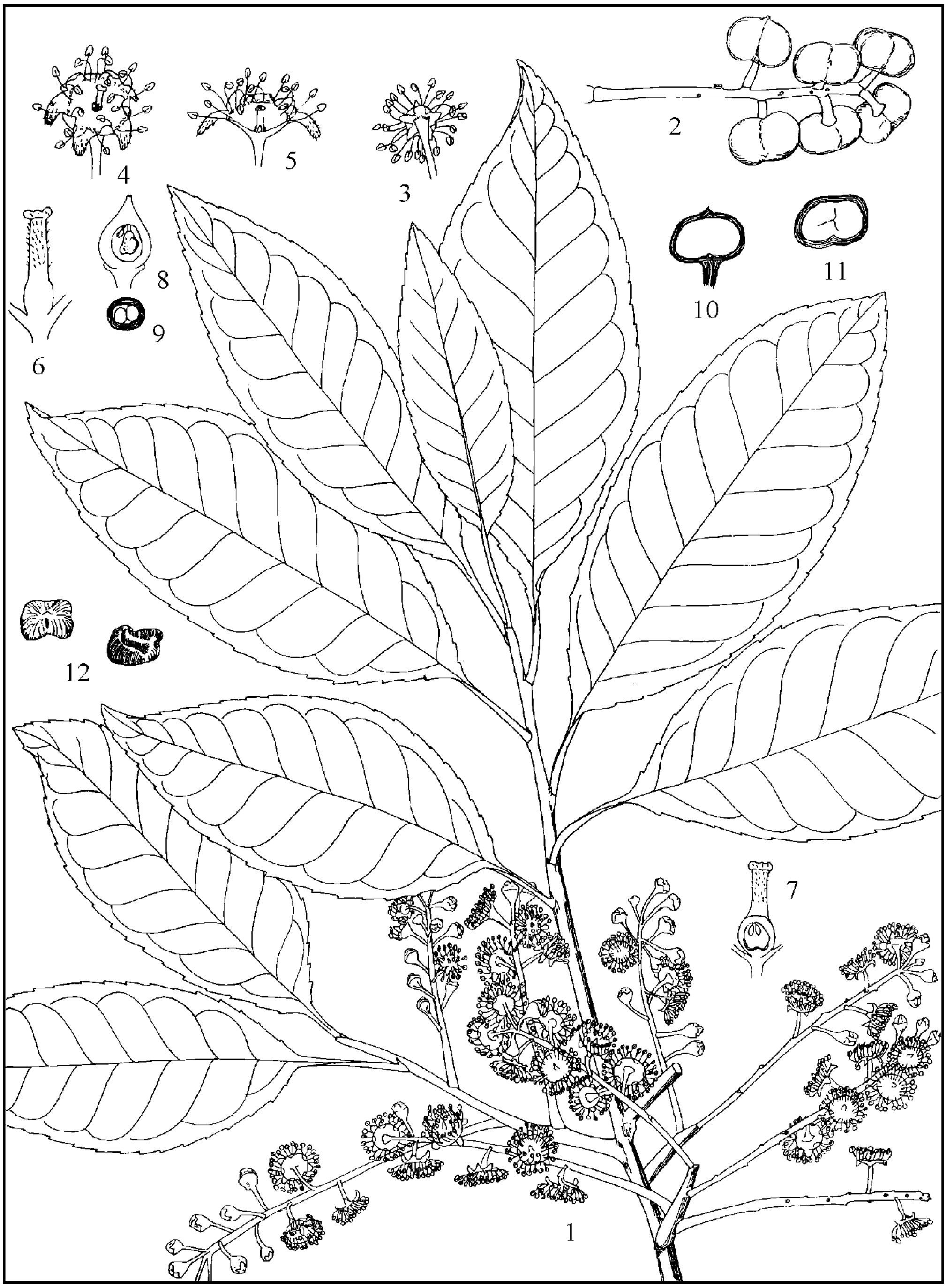


Figure A1 *Prunus africana* (after Sim, 1907). 1: flowering branch (x 0.5); 2: fruit (x 0.5); 3, 4, 5: flowers (x 1); 6: pistil (x 4); 7: section of pistil (x 4); 8: section of young fruit (x 1.5); 9: transverse section of ovary (x 4); 10, 11: sections of fruit (x 0.5); 12: seeds (x 0.5), showing upper and under sides of seeds, with twisted cotyledons and lateral hilum.

In each raceme there are 5-15 flowers according to most descriptions but a larger number (10-20) is given by Letouzey (1978) for Cameroon. Intervals of 1-3 mm separate the attachments of the pedicels to the rachis (Hauman, 1952b). At the base of each pedicel is a small, much-reduced and early caducous triangular bract which, like the cataphylls, leaves a semi-circular rim on abscission (Letouzey, 1978). Pedicels are ebracteolate, 3-11 mm (usually 5-7 mm) in length, rigid and spreading at a wide angle and slender 0.5-0.8 mm (Hauman, 1952b; Graham, 1960; Letouzey, 1978).

The flowers are hermaphrodite, more or less actinomorphic, and predominantly pentamerous - although Mendes (1978) refers to tetramerous and hexamerous forms. The calyx tube is 3-8 mm in diameter at the mouth and 1.5-4 mm deep (Hauman, 1952b; Graham, 1960), somewhat fleshy and glabrous outside but often villous within (Graham, 1960). The calyx lobes are triangular, 1-1.5 mm long and ciliate at the apex. The petals are creamy-white in colour, linear or spathulate and 2-2.5 mm long and 0.5-1.5 mm wide, becoming reflexed (Hauman, 1952b). The abaxial surface is pubescent to villous, especially towards the margin, and less often the adaxial surface is also hairy (Mendes, 1978). Kalkman (1965) has noted supernumerary sepals and missing petals as floral irregularities.

The androecium is of three ill-defined whorls of exserted stamens (25-35 in total), with glabrous white filaments 1.5-2 mm long and didymous ovoid to globose anthers 0.5-1 mm long (Hauman, 1952b; Mendes, 1978). The unilocular ovary is ovoid (slightly zygomorphic according to Letouzey, 1978), sparsely villous and 3-5.5 mm long, including the stout style (1.5-2 mm), the distal portion of which is distinctly villous and protrudes from the calyx tube and contains two pendulous ovules (Hauman, 1952b). The yellowish stigmatic disc covers the somewhat expanded tip of the style and has been variously described as peltate (Mendes, 1978), obscurely 2- or 3-lobed (Graham, 1960) and horseshoe-shaped (Letouzey, 1978).

Fruit

The fruit is a dry, usually glabrous, transversely ellipsoid (5-10 mm long; 6-15 mm wide) and slightly bilobed drupe, with a thin mesocarp and a woody endocarp (Hauman, 1952b; Mendes, 1978). At the distal end, the hardened remains of the style persist as a cusp (Graham, 1960). When ripe the colour is dark reddish brown to purple or blackish. The drupe contains one seed.

SYSTEMATIC ANATOMY

Apart from a brief comment on leaf structure, essentially leaf thickness, made to support the case for recognising *Prunus crassifolia* as a separate species (Hauman, 1952a), there appears to be no information on the anatomy of *Prunus africana*.

Hauman (1952a) reported the following thicknesses: complete leaf - 180-450 µm; upper epidermis - 22-37 µm; palisade layer - 50-210 µm; spongy mesophyll - 90-175 µm; lower epidermis - 15-22 µm. Hauman also notes the presence of calcium oxalate crystals in the palisade and spongy mesophyll layers.

APPENDIX 2 VERNACULAR NAMES

E. M. O'Brien

Throughout its range, *Prunus africana* is known as Red Stinkwood or Bitter Almond (*Chase 7853*). The following is a list of local vernacular names drawn from the literature and from data on herbarium specimens. It is unlikely to be exhaustive. Because vernacular names can apply to other, sometimes extremely dissimilar plant species (*Clements 745*), caution is advised when identifying *Prunus africana* based solely on a local name.

Country	Common Name (Language)	Source
Angola	munjimbe-ndende (Kimbundu)	
Cameroon	iluo/elouo (Kom), vla/eublaa (LamOku), alumty (Bamenda), wotangue (Bakweri), kirah (LamNso/Banso), sebeh (Fulfulde)	Cunningham & Mbenkum (1993)
Burundi	umuremera (Kirundi)	*Lewalle 1499*
Equatorial Guinea (Bioko)	bihasa (Bubi)	Sunderland & Tako (1999)
Ethiopia	aquoma (Zeghie), tekurancet, tkorincet, tugoringetz (Amhara), mukoraja (Harar), bouraio, homi, omi (Galla), michiccio (Sidamo), caro (Mao)	Cufodontis (1954)
Kenya	mueri/muiri (Kikuyu), mutimuiru (Kamba)	*Cooper 78, Dale 294, Honore 661, White 1065*
	mueria/mweria (Meru)	*White 1223,*
	mueritsa/mwiritsa (Luhyia)	*Machin 792*
	tenduet/tendwet/tenduwet (Nandi/Klipsgis/Kalenjin/Dorombo)	*Kerfoot 2710*; J. Leakey, pers. comm.
	mutimuilu (Kamba), Omoiri (Kisii), kanukwa (Tugen), tendwet (Kalenjin), Ol-Koijuk (maasai), kiburabura (Kiswahili), kumuturi (Bukusu),	Schaefer C. (1992); National Research Council (1991).
Madagascar	saripaiso/Sary (Province de Majunga), tsipesopeso (Moramanga), paisoala (Betsileo), menalaingo (Vatomandry), sofintsohihy (Brickaville, amparafaravola, Vohimena), tsintsefintsohihy or kotofihy--kotofihy vavy for white bark, kotofihy lahy for red bark (Ambatondrazaka)	Walter & Rakotonirina (1995)
Malawi	musyuluti (Chisukwa)	*Chapman 209*
	mpeuma (?)	*Clements 745*
	kamfundu (N), mulesanyondo (N)	*Adlard 206*
	mgumcear (Chewa), mseure (Yaro?)	*Burtt-Davy 1426*

Country	Common Name (Language)	Source
Rwanda	igegeyo (Kinyaruanda)	*Troupin 11557*
	umuhumba, umwumba (Kinya-rwanda)	*Bamps 3218*, Hauman (1952)
	Umujuga	*Bouxin 1578*
	Umusasa	*Bouxin 959*
	umwumba, tshikongokongo (Kaniama)	*Runyinya 475*, Hauman (1952)
South Africa	bitteramandel, rooistinkhout, nuwehout, motodol, umDumezulu, mgoturie,umKhakhazi, !Nkokhokho/umKokoke, umLalume (Zulu); xalote,	*Scheepers 959,* Sim (1921), Moll (1981), Bews (1921)
Tanzania	igambo (Kisafua)	*Kerfoot 4234*
	isaza (Kisafwa)	*Kerfoot 2996*
	mufubia (Kisuisa?)	*Gane 43*
	Muri	*Swynnerton n/a*
	olgofuk (Kiarusha), mkondekonde (Meru)	*Bancroft 49*
	olkonjuk(?) (Masai)	*Makandy 1*
	mkomahoya (Sambaa), Mwiluti (Hehe), Ol-konjuku (Masaai), Mpembati (Kinga), Mfipa(Fipa)	Beentje (1994)
Uganda	mugote (Lunyankole)	*Eggeling 3775*
	omumba (Luchiga)	*Eggeling 3685*, Cunningham (1996)
Zaire	mumba (Kiyunde) muhumba (Kinyaruanda).	*Michelson 416, Germain 3135, 3425 & 3501*
	tshikongokongo (Kaniama)	*Herman 2347,* Hauman (1952)
Zimbabwe	mototo	*Gilliland 1903*
	muototo	*Gilliland 964*
	Red stinkwood, Bitter Almond	*Chase 7853*

APPENDIX 3 DETAILS OF SPECIMENS CITED IN TEXT AND OTHER APPENDICES

Collector	Number	Date of Collection	Country and locality	Herbarium
Adamson	4356	n/a	Kenya	EA
Adlard	206	Jan 1955	Malawi; Namtope stream, Dedza Mountain	FHO
Armitage	51	Oct 1954	Zimbabwe; Banti	BR
Bagshawe	1537	Mar 1907	Uganda; Masinde	BM
Bally	174	Apr 1938	Kenya; Chyulu Hills	EA
Bally	268	Apr 1938	Kenya; Chyulu Hills	EA
Bally	7653	Apr 1938	Kenya; Chyulu Hills	EA
Bamps	3218	Feb 1972	Rwanda; Kibuye	BR
Bancroft	49	n/a	Tanzania; Meru	BR
Birch	60/224	June 1960	Kenya; Tigoni	EA
Birch	61/48	Feb 1961	Kenya; Ryers Farm	EA
Bond	12	Dec 1950	Tanzania; Nou Forest	EA
Bouxin	959	May 1971	Rwanda; Kigeme	BR
Bouxin	1578	May 1972	Rwanda; Rukizi	BR
Brummitt *et al.*	15654	May 1980	Malawi; Thyolo	K
Burtt-Davy	1426	Sept 1929	Malawi; Chintembwe Mission	BM/FHO
Chapman	209	n/a	Malawi; Matipa Forest Reserve	FHO
Chapman	1369	Jun 1961	Malawi; Kalichero	FHO
Chapman	6362	Aug 1982	Malawi; Thyolo	BR/FHO
Chase	924	Sep 1948	Zimbabwe; Imbeza Forest	BM
Chase	3946	Sep 1951	Zimbabwe; Inyamatschira Mountains	BM/BR
Chase	4904	Apr 1953	Zimbabwe; Inyanga	BM
Chase	5068	Sept 1953	Zimbabwe; Inyamatschira Mountains	BM/K
Chase	6198	Sep 1966	Zimbabwe; Cloudlands	K
Chase	7853	Oct 1962	Zimbabwe; Watsomba	BR/K
Cheeseman	7439	Dec 1932	Ethiopia; Dangila	BM
Christiaensen	1271	Jan 1956	Congo *; Lwiro	BR/K
Clements	745	1937	Malawi; Mangoche Mountain	FHO
Compton	32122	Jul 1966	Swaziland; Forbes Reef	K
Compton	30683	Aug 1961	Swaziland; Havelock	K
Compton	32369	Sept 1965	Swaziland; Forbes Reef	K
Cooper	78	Dec 1926	Kenya	FHO
Dale	294	n/a	Kenya; Tinderet North Forest	FHO
Davies	2503	Oct 1958	Zimbabwe; Nyamazi Inn	BR/K
Donis	3946	Aug 1950	Congo *; Rumengabo	BR
Dummer	2420	Mar 1915	Uganda; Kipayo	BM
Eggeling	1136	Mar 1933	Uganda; Budongo	EA
Eggeling	1270	Mar 1933	Uganda; Budongo	BM/FHO/K
Eggeling	1459	Dec 1933	Uganda; Padeggi	FHO
Eggeling	3775	Jul 1938	Uganda; Kalinzu Forest	FHO

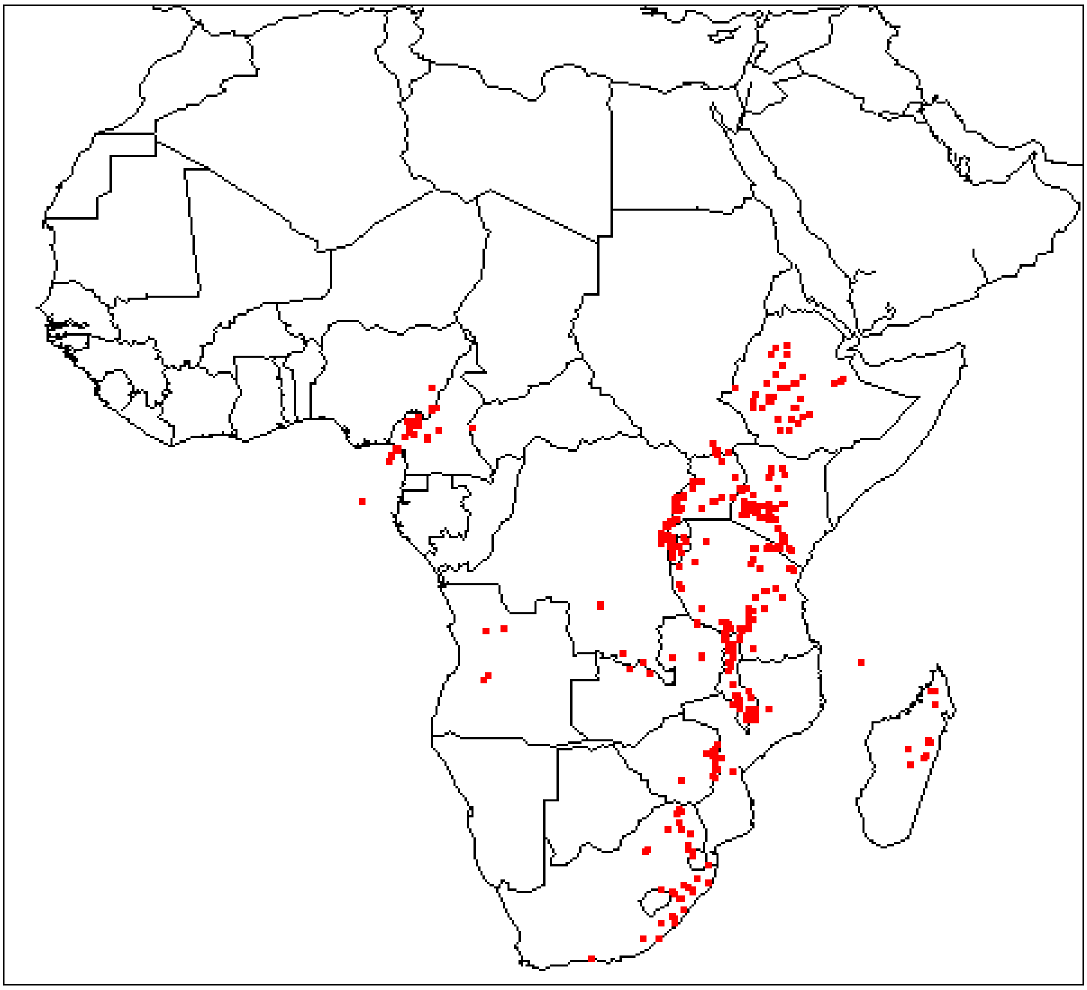
Collector	Number	Date of Collection	Country and locality	Herbarium
Eyles	8502	Oct 1935	Zimbabwe; Inyanga	K
Faden *et al.*	72/201	May 1972	Kenya; Ngangao Forest	K
Fanshawe	8832	Jul 1964	Zambia; Solwezi	BR/FHO/K
Friis *et al.*	157	Nov 1970	Ethiopia; Yebu	BR
Gaetan Myembe	36	May 1958	Tanzania; Mbeya Peak	EA
Gaetan Myembe	155	Jul 1961	Tanzania; Sao Hill	K
Gane	43	Aug 1952	Tanzania; Mdandawangu River	BR
Germain	3135	Dec 1944	Congo *; Nyambagira	BR/K
Germain	3425	Jan 1945	Congo *; Mogunga	BR/K
Germain	3501	Jan 1945	Congo *; Nirangongo	BR
Gerstner	6700	May 1948	South Africa; Qudeni Forest	K
Ghesquiere	3888	Mar 1937	Congo *; Rutshuru	K
Gillett	14717	Dec 1952	Ethiopia; Agheremariam	K
Gillett *et al.*	17109	Feb 1966	Kenya; Ngangao Forest	EA
Gilliland	964	n/a	Zimbabwe; Inyanga	FHO
Gilliland	1903	Apr 1935	Zimbabwe; Inyanga	BM/FHO
Gilliland	1868	Apr 1935	Mozambique; Garuso Forest	FHO
Goldsmith	36	Oct 1965	Zimbabwe; Chirinda Forest	FHO
Goldsmith	66	Aug 1966	Zimbabwe; Chirinda Forest	BM/K
Gossweiler	9751	Dec 1932	Angola; Cuima-Lepi	BM/K
Greenway	2473	Aug 1930	Tanzania; Mpwapwa	K
Hermann	2025	n/a	Congo *; Mumvu	K
Hermann	2301	n/a	Congo *; Mumvu	K
Hermann	2347	n/a	Congo *; Mumvu	K
Honore	661	n/a	Kenya; Mount Kenya	FHO
Hornby & Hornby	703	Aug 1935	Tanzania; Mpwapwa	EA
Humbert	9222	Aug 1929	Kenya; Kijabe	P
Kaghembe	4	Mar 1969	Tanzania; Mkuzu	BR
Kerfoot	2710	Dec 1960	Kenya; Timbili	K
Kerfoot	2996	Nov 1961	Tanzania; Mbeya Range	BR/K
Kerfoot	3700	Feb 1962	Tanzania; Mbeya Peak	K
Kerfoot	4234	Aug 1962	Tanzania; Mbeya Range	K
Kirk	n/a	April 1859	Malawi; Mungazi	K
Kirk	n/a	Oct 1859	Malawi; Tshiradzuri	K
Leonard	538	Feb 1958	Rwanda; Visoke	P
Letouzey	126	Dec 1946	Cameroon; Mbam massif	P
Letouzey	140	Dec 1946	Cameroon; Mbam massif	P
Lewalle	1499	Jan 1967	Burundi; Nyabigondo	BR
Linder	3835	Aug 1986	Tanzania; Lake Ngwazi	K
Lovett *et al.*	706	May 1986	Tanzania; Ngwazi	BR
Lovett & Lovett	700	May 1986	Tanzania; Ngwazi	EA
Lovett & Lovett	2219	May 1987	Tanzania; Ngwazi	BR/K
Machin	792	Jun 1934	Kenya; Kakamega forest	BR/FHO
Makandy	1	May 1953	Tanzania; Olmotonyi	BR

Collector	Number	Date of Collection	Country and locality	Herbarium
Mann	1207	Dec 1862	Cameroon; Mount Cameroon	K
Mgaza	195	Jan 1959	Tanzania; Magamba to Mkuzi	K
Mgaza	454	Feb 1962	Tanzania; Magamba Forest	K
Michel	3574	Aug 1952	Burundi; Kininya	BR
Michelmore	242	Jul 1934	Zimbabwe; Gungunyana	K
Michelson	416	Jun-Aug 1943	Congo *; Col de Bibatama	BR
Milne-Redhead & Taylor	10877	Jun 1956	Tanzania; Songea	BR
Monod	11977	Aug	San Tome; Pico Pequeno	BM/COI
Moon	1256	May 1923	Kenya; Nandi/Elgayo Forest	FHO
Mooney	5687	Feb 1954	Ethiopia; Shashamanna	BR/K
Morbeck	5	Jan 1974	Kenya; Tigoni	EA
Muller	1543	Sep 1970	Malawi; Lichenya Crater	K
Paget-Wilkes	10	Jun 1968	Tanzania; Mufindi	K
Pardy	9	Jan 1936	Zimbabwe; Inyanga	FHO
Parry	70	Jul 1951	Tanzania; Sao Hill	EA
Perdue & Kibuwa	9154	Nov 1967	Kenya; Londiani	BR
Perdue & Kibuwa	11004	Aug 1971	Tanzania; Lake Ngwazi	EA
Perignon	74	Jun 1939	Congo *; Mumvu	BR
Pichi-Sermolli	906	Mar 1937	Ethiopia; Lungi	EA
Pierlot	529	Mar 1953	Congo *; Muhunzi	BR
Phillips & van Rensburg	1624	Jun 1940	South Africa; Hekpoort	K
Proctor	1260	Jul 1959	Tanzania; Sao Hill	EA
Proctor	1883	Jun 1961	Zambia; Ndundu	K
Procter	3444	Dec 1966	Tanzania; Meru Crater	BR/K
Runyinga	475	July 1976	Rwanda; Gisenyi-Wisogo	BR
Satabie	41	Nov 1974	Cameroon; Mbam massif	K
Schaller	25	May 1959	Congo *; Mikeno-Karisimbi slopes	EA
Scheepers	959	Apr 1960	South Africa; Piesang Kop	BR/K/P
Schlieben	4043	Jun 1933	Tanzania; NW Ulugurus	BM/BR/P
Schmitz	2398	May 1949	Congo *; Keyberg	BR
Schmitz	2408	May 1949	Congo *; Keyberg	BR
Schmitz	2472	Jul 1949	Congo *; Keyberg	BR
Schmitz	2507	Aug 1949	Congo *; Keyberg	BR
Service Forestier	16522	Feb 1957	Comoros; Karthala Forest	FOFIFA
Service Forestier	26150	Sept 1966	Madagascar; Ampitsahambe	FOFIFA
Shabani	1011	May 1973	Tanzania; Lake Ngwazi	EA
Smeds	1442	May 1958	Ethiopia; Amba	K
Smith	3021	Mar 1954	Tanzania; Odoroto Selian	EA
Swynnerton	n/a	Mar 1920	Tanzania; Mount Kilimanjaro	BM
Swynnerton	107	Apr 1907	Zimbabwe; Chirinda	BM/K
Swynnerton	1344	Apr 1907	Zimbabwe; Chipete Forest	BM/K
Taylor	3243	Jan 1935	Uganda; Mpanga forest	BM

Collector	Number	Date of Collection	Country and locality	Herbarium
Tewesa	1	May 1953	Tanzania; Meru Forest Reserve	K
Thomas	1682	Dec 1935	Sudan; Ibahin	K
Trapnell	1714	Mar 1937	Zambia; Lunzua	K
Trapnell	2182	Aug 1951	Tanzania; Mdandu	EA
Troupin	11557	Feb 1960	Rwanda; Uwinka	BR
Troupin	14354	Feb 1972	Rwanda; Sabinyo	BR/K
Vesey-Fitzgerald	6078	Feb 1969	Tanzania; Meru Crater	EA
van Vuuren	216	Jun 1957	South Africa; Jacksonstuin	K
Welwitsch	465	May 1857	Angola; Pungo Andongo	K
Westphal *et al.*	624	Jul 1967	Ethiopia; Alemaya-Harar	BR
Westphal *et al.*	2632	Nov 1967	Ethiopia; Wondo valley	BR
Westphal *et al.*	3100	Jan 1968	Ethiopia; Asella	BR
White	1065	Aug 1949	Kenya; Irangi	BM/FHO
White	1223	Aug 1949	Kenya; Ruguti River, Mount Kenya	BM
de Wilde	6104	Dec 1969	Ethiopia; Kebre Mengist	BR
de Wilde	6304	Apr 1965	Ethiopia; Nekemti	BR
de Wilde *et al.*	6145	Apr 1965	Ethiopia; Menagasha	P
de Wilde *et al.*	7776	Aug 1965	Ethiopia; Bonga	P

Where for Herbaria; BR = National Botanic Garden of Belgium, Brussels; BM = Natural History Museum, London; COI = Botanical Institute of the University of Coimbra, Coimbra; EA = East African Herbarium, Nairobi; FHO = Daubeny Herbarium, Oxford Forestry Institute, Oxford; K = Royal Botanic Gardens, Kew; P = Laboratoire de Phanerogamie, Musée Nationale de l'Histoire Naturel, Paris.

*Congo; Democratic Republic of Congo



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