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Review

The African cherry (*Prunus africana*): Can lessons be learned from an over-exploited medicinal tree?

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Abstract

For the last 35 years, the African cherry (*Prunus africana* (Hook. f.) Kalm.) has been used in the treatment of benign prostatic hyperplasia and other disorders. The bark, from which the treatment is derived, is entirely wild-collected. The major exporters of bark include Cameroon, Madagascar, Equatorial Guinea, and Kenya. Groupe Fournier of France and Indena of Italy produce 86% of the world's bark extract, both for their own products and for the free market. Worldwide exports of dried bark in 2000 have been estimated at 1350–1525 metric tons per year, down from its peak of 3225 tons in 1997. Bark extracts (6370–7225 kg per year) are worth an estimated $4.36 million per year. In 2000, Plantecam, the largest bark exporter in Africa, closed its extraction factory in Cameroon, due to complex ecological, social, and economic factors. Wild-collection is no longer sustainable (and probably never was) where harvest seriously affects morbidity and mortality rates of harvested populations. Since 1995, it has been included in CITES Appendix II as an endangered species. In this paper, alternatives to wild-collection to meet future market demand are investigated, including conservation practices, enrichment plantings, small- and large-scale production, and protection of genetic resources. The species is at the beginning of a transition from an exclusively wild-collected species to that of a cultivated medicinal tree.

Keywords: *Prunus africana*; *Pygeum africanum*; Forest conservation; CITES; Benign prostatic hyperplasia; Non-timber forest products; Cameroon; Madagascar; Kenya; Equatorial Guinea

1. Introduction

The African cherry (*Prunus africana* (Hook. f.) Kalm.) is a widespread tree in montane habitats of Africa, providing multiple uses for the peoples throughout its range (Table 1). About 35 years ago, bark extracts were found to be effective in the treatment of benign prostatic hyperplasia (BPH; Bombardelli and Morazzoni, 1997). Raw bark or bark extracts are shipped primarily from Cameroon, Madagascar, Kenya, and Equatorial Guinea, with small amounts from other countries. The extract is manufactured into various herbal products. The most popular product is the capsular form, sold under its former scientific name, *Pygeum africanum*. Currently, *Prunus africana* bark is entirely wild-collected, although attempts at cultivation are underway in Kenya (Dawson, 1997; Dawson et al., 2000).

Prior to the discovery in 1966 that it is an effective herbal remedy, *Prunus africana* was a relatively common, but never abundant, montane species. *Prunus africana* has been the subject of several studies addressing inventories (Geldenhuys, 1981; Ewusi et al., 1992; Tchouto, 1996; Kilum-Ijim Forest Project, unpublished data), ecology (Fraser et al., 1996; Stewart, 2001), cultivation potential (Sunderland and Nkefor, 1996; Dawson, 1997; Dawson et al., 2000), genetic characteristics (Barker et al., 1994; Dawson and Powell, 1999), traditional uses (Mbenkum and Fisiy, 1992; Nsom and Dick, 1992; Iverson, 1993; Cunningham, 1996; Stewart, 2001), chemical constituents (Longo and Tira, 1981; Catalano et al., 1984; Fourneau et al., 1996), bark yield studies (Ewusi et al., 1996), and harvest effects (Parrott and Parrott, 1989; Cunningham and Mbenkum, 1993; Stewart, 2001). From the beginning, the harvest has been known to be destructive (Macleod, 1987; Ngengwe, 1996; Walter and Rakotonorina, 1995). By 1995, because of the growing international demand for the bark, it was included as an endangered species in Appendix II of the Convention of International Trade in Endangered Species (CITES) at the Ninth Conference of the Parties. The reasons for its demise include economic, social, and ecological factors. As we search the globe for other natural products

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Table 1
Recorded traditional uses of *Prunus africana*

Country	Part used	Use	Source
Cameroon	Branches	Tool (axe, hoe) handles	Stewart (2001), Cunningham and Mbenkum (1993), Nsom and Dick (1992)
		Ceremonial spear handles	Stewart (2001)
	Timber	Roof support	Stewart (2001)
		Bridge decks	
		Fuelwood	
		Window and door frames	Iverson (1993)
	Bark	Traditional medicine (45 human ailments)	Stewart (2001), Cunningham and Mbenkum (1993), Nsom and Dick (1992)
		Traditional medicine (11 ailments of domestic animals)	Stewart (2001)
	Leaves	Traditional medicine	Stewart (2001)
	Fruit and leaves	Wildlife food	Stewart (2001), Cunningham and Mbenkum (1993)
	Seeds	Traditional medicine (rare use)	Stewart (2001)
	Flowers	Honey production	Stewart (2001)
Uganda	Timber	Mortars and pestles	Cunningham (1996)
		Beehive supports	
		Beer boats	
		Pitsawn lumber (trees >50 cm diameter at breast height (DBH))	
		Building poles (5–15 cm diameter at breast height (DBH))	
		Bean stakes (1.5–5 cm diameter at breast height (DBH))	
		Firewood, charcoal	Lambert (1998)
		Furniture, flooring, paneling	
		Carving	
		Building poles and posts	
		Utensils	
Kenya	Timber	House building and furniture	Beentje (1994)
	Bark	Traditional medicine (fevers)	Kokwaro (1976)
		Traditional medicine (gonorrhea)	Lindsay (1978)
		Traditional medicine (purgative)	Beentje (1994)
	Leaves	Traditional medicine (stomach pain)	Kokwaro (1976)
	Bark	Traditional medicine (purgative)	Beentje (1994)
South Africa	Bark	Traditional medicine (chest pain)	Van Wyk et al. (1997)
		Traditional medicine (intercostal pain)	Hutchings et al. (1996)
	Timber	Wagons	Palmer and Pitman (1972)
East Africa	Leaves	Traditional medicine (stomach pain)	Glover et al. (1966)
West Africa	Timber	Truck bodies	Howe (no date)
		Chopping blocks	
		Bridge decks	
		Cabinets and furniture	
Zaire/Burundi	Leaves	Traditional medicine (insanity)	Baerts and Lehmann (1989)
Unspecified	Unspecified	Traditional medicine (cattle purgative, fever, stomach pain)	Kalkman (1965)
		Arrow poison	Kalkman (1965)
			Neuwinger (2000)
		Anti-inflammatory, kidney disease, urinary tract complaints, fevers, malaria, wound dressing, appetite stimulant	Neuwinger (2000)

to treat the world's growing need for new medicines, we may be able to learn some lessons from this internationally traded species.

This paper will summarize the species' biology, ecology, and pharmacology; document how a common medicinal tree became endangered; and will present the various solutions that have been suggested to conserve the species and to meet future market demand. From this review, it will become apparent that the species is entering the transition from an exclusively wild-collected species to that of a cultivated medicinal tree.

2. Ecology and biology

Prunus africana is a member of the Rosaceae (subfamily Amygdaloideae), a family with its highest diversity in temperate regions (Cronquist, 1981). Although the relationships among the other subfamilies of Rosaceae and its purported sister groups have yet to be determined (Kalkman, 1988; Morgan et al., 1994; Potter et al., 1999), the family is generally considered monophyletic (Morgan et al., 1994; Judd et al., 1999). The genus *Prunus* is the largest member of the subfamily, and includes the commercially important cherry

(*Prunus avium* (L.) L.), peach (*Prunus persica* L.), plum (*Prunus domestica* L.), and almond (*Prunus dulcis* (Mill.) D.A. Webb). *Prunus africana* is the only member of the genus on the African continent and may be chemically distinctive. *Prunus crassifolia* (Hauman) Kalkm. populations, endemic to the Kivu District in the Democratic Republic of Congo, may be a different species, but this has not yet been confirmed. Herbal formulations of *Prunus africana* are sold under its synonym, *Pygeum africanum*. Kalkman (1965), in his revision of the genus, placed *Pygeum* in the genus *Prunus* based on the morphological similarity of the two genera, especially their floral characteristics.

Prunus africana is a medium–large canopy tree 30–40 m in height. Young trees have smooth, reddish bark whereas older trees have dark, platy, resinous bark. It has the rare ability to regenerate its bark, as long as the vascular cambium is not destroyed. Leaves are simple and alternate. They are evergreen but some fall prior to fruit development. Leaves, twigs, fruits, and bark emit a "cherry" odor when crushed, which is characteristic of the genus. The odor is due to cyanogenic glycosides (Kalkman, 1965; Fraser et al., 1996). The fruit is a drupe, each with a single seed. The reddish color of mature fruits suggests it may be bird dispersed (Howe and Westley, 1986).

Prunus africana has a wide distribution in Africa. It occurs in montane regions of central and southern Africa and the islands of Bioko, São-Tomé, and Grande Comore (Kalkman, 1965). *Prunus africana* is most abundant in open areas along forest margins and in disturbed areas (Geldenhuys, 1981; Ewusi et al., 1992; Ndam, 1996) and is not shade-tolerant (Kiama and Kiyiapi, 2001). Tsingalia (1989) found larger seedlings (>0.5 m) along forest margins where, he suggested, predation rates were lower, while Ndam (1996) found the most seedlings in forest gaps or fallow fields. These studies suggest that *Prunus africana* is a light-demanding, secondary-forest species. Recruitment is low or sporadic (Ewusi et al., 1992).

Because of deforestation at lower elevations, *Prunus africana* is confined to disjunct "forest islands" that differ genetically (Barker et al., 1994), with the Madagascar population being the most distinct (Martinelli et al., 1986). The tree occurs at altitudes between 1000 and 2500 m in montane forests (Kalkman, 1965; Cunningham and Mbenkum, 1993; Sunderland and Tako, 1999). Distribution appears to be related to mean annual temperature and rainfall and/or cloud cover (Hall et al., 2000). Because of their relatively large areas of montane habitat, Cameroon and Madagascar contain the largest populations of the species.

3. Pharmacology

Benign prostatic hyperplasia is a non-cancerous enlargement of the prostate, which is common in men over the age of 50 (Tyler, 1994). The prostate surrounds the urethra, the tube that drains the bladder. When the prostate is enlarged, urination becomes incomplete or difficult. The causes of BPH are not fully understood, but may involve the conversion of testosterone to dihydrotestosterone (DHT) by the enzyme 5-α-reductase (Bartsch et al., 2000; Tyler, 1994). Estrogens and growth stimulating hormones may be involved as well (Awang, 1997). DHT is important for prenatal fetus development and development of male sexual characteristics during puberty, whereas testosterone is the main male hormone responsible for fertility, muscle strength, and masculine features. Despite the alleged dominant role of DHT, other causes for BPH are being investigated.

The extract from *Prunus africana* bark contains several pharmacologically active compounds (Catalano et al., 1984; Fourneau et al., 1996; Longo and Tira, 1981) that may interfere with the development of BPH. Phytosterols (β-sitosterol, β-sitostenone) reportedly inhibit the production of prostaglandins in the prostate, which suppresses the inflammatory symptoms associated with BPH and chronic prostatitis (Bassi et al., 1987; Breza et al., 1998). Pentacyclic triterpenes (oleanolic and ursolic acids) are believed to inhibit the activity of glucosyl-transferase, an enzyme involved in the inflammation process. Ferulic esters (*n*-docosanol and *n*-tetracosanol) reportedly lower blood levels of cholesterol, from which testosterone is produced (Bombardelli and Morazzoni, 1997). These compounds are believed to work synergistically to counteract the structural and biochemical changes associated with the disease (Awang, 1997; Bassi et al., 1987; Bombardelli and Morazzoni, 1997; Simons et al., 1998).

A number of studies have shown the effectiveness and safety of *Prunus africana* bark extracts to reduce BHP symptoms (reviewed in Bombardelli and Morazzoni, 1997; Ishani et al., 2000). Both reviews included a number of open and double-blind, placebo-controlled clinical studies that demonstrated the efficacy and safety of *Prunus africana* extracts in the relief of symptoms, including frequent urination, painful urination, and urgency. The extracts are well tolerated in clinical studies, producing only minor side effects (mostly gastrointestinal).

Allopathic medical therapy for BPH includes drugs and non-surgical or surgical treatments. Drugs include the anti-androgens finasteride (Proscar, manufactured by Merck) and terazosin hydrochloride (Hytrin, manufactured by Abbott), which are synthetic inhibitors of the enzyme 5-α-reductase (Rhodes et al., 1993; Bartsch et al., 2000). Other treatments include a number of smooth muscle relaxants, which prevent pressure on the urethra. Non-surgical techniques include balloon dilation, thermotherapy, and stents. Surgery involves removal of excess tissue. Because of a number of side effects from drugs and surgery, phytotherapy is an increasingly popular option and is the primary treatment in the European Union. Several other herbal preparations are also effective; the most widely used is saw palmetto extract (*Seronoa repens* (Bartram) Small, Arecaceae; Bennett and Hicklin, 1998). The market for *Prunus africana* is closely tied to that of *Seronoa repens* (Pomatto, 2001). While saw palmetto may act to inhibit 5-α-reductase and as an anti-androgenic and anti-estrogenic (Wilt et al., 1998), *Prunus africana* appears to interfere in the associated inflammatory response in the prostate. Thus, some herbal formulations contain both products. Others contain pumpkin seed extract (*Cucurbita pepo* L., Cucurbitaceae) or stinging nettle root (*Urtica dioica* L., Urticaceae), which are thought to be anti-inflammatory due to their β-sitosterol content (Berges et al., 1995; Klippel et al., 1997; Pegel, 1997).

4. Aspects of the commercial harvest

4.1. Cameroon

Until the late 1960s, *Prunus africana* was known only for its timber, as fuel, and as a traditional medicine (Stewart, 2001). In 1966, the effectiveness of its bark in the treatment of BPH was discovered (Debat, 1966). Cameroon has the longest history of bark harvest, and most studies of the harvest are from here, particularly from Mount Cameroon. Commercial harvest began in 1972, when Plantecam Medicam (later Plantecam) began harvesting in the Northwest and West Provinces. After obtaining a license to harvest on Mount Cameroon in 1976, Plantecam built an extraction factory at the base of the mountain. In addition, harvest began on Mount Oku and continued until 1986. During this time, the harvest was carefully controlled to prevent mortalities. Despite this effort, many trees suffered crown die-back or pathogen invasion, and many trees died (Parrott and Parrott, 1989; MacLeod and Parrott, 1990). During this time, Plantecam had a monopoly over the entire market, from harvest to market product in Europe. They used trained harvesters who followed harvesting regulations (regulations stipulate that opposite quarters of the tree may be harvested. Bark removal may begin no less than 1 m from the tree base and may go no higher than the first branch. No bark may be removed from branches. After 4–5 years, the remaining bark may be removed). Plantecam lost that monopoly in 1987 when 50 new independent contractors were issued licenses, although Plantecam still held the sole exporting license. These new harvesters felled or totally debarked trees of all size classes, causing high mortalities (Cunningham and Mbenkum, 1993).

In theory, harvest of *Prunus africana* is sustainable since the bark can regenerate if bark removal does not destroy the vascular cambium. In practice, this has not been the case. The dire state of the remaining populations of *Prunus africana* in Cameroon appears to be due to complex and inter-related social and economic factors. For example, until the late 1980s, hundreds of square kilometers surrounding Mount Oku in the Northwest Province were completely forested. Today, only 10,000 ha of montane forest remain. For generations, a secret society, known as the *kwifon*, regulated forest use through sophisticated rules for managing watersheds and forest ecosystems. Sacred forests were reserved for the gods and on certain days of the week, forest use was forbidden. When these traditions were followed, the gods protected the forest and overexploitation was avoided (Fisiy, 1994). The traditional resource protection ethic (by the *kwifon*) was weakened when Plantecam's monopoly was broken. "Outsiders" stripped and felled trees throughout Cameroon. For example, a survey of four sites on Mount Cameroon that were harvested during this time found that 70% of the trees had been harvested and only one of the 114 trees surveyed had not been ring-barked; they found no evidence that the harvesting regulations were being followed (Tako et al., 1996). The traditional authorities had no control over these outsiders. The outsiders violated the local taboos and suffered no adverse consequences. The fear of sanctions by the forest gods dissolved (Mbenkum and Fisiy, 1992; Fisiy, 1994). Thus, harvest of *Prunus africana* bark contributed to the erosion of the resource preservation ethic that continues to this day. To complicate matters, in 1994 the CFA franc (the currency of Central Africa) was devalued by 50%, making it more profitable for European companies to obtain their bark from Cameroon rather than from other countries. A widespread illegal and destructive harvest followed on Mount Cameroon and, presumably, other parts of Cameroon (Ewusi et al., 1996; Sunderland and Nkefor, 1996). Destructive harvests continue throughout the country, occurring even on private farms and sacred forests (Popoola et al., 2002, personal observation).

Socio-economic factors are probably the major factors in the continued destructive harvests in Cameroon, and probably elsewhere within its range. The extremely low prices paid to harvesters compared to the high commercial prices charged for the finished capsules may partially explain why illegal harvests occur (Ewusi et al., 1996). Middlemen are willing to pay higher prices than buyers at the factories and they provide easy access to exporters. If a mechanism were in place to assure an equitable distribution of the profits, sustainable practices would be in the best interests of harvesters.

Because of the depletion of *Prunus africana* populations from the West and Northwest Provinces, the national focus of harvest occurs in remote areas of Mount Cameroon far from villages (Cunningham et al., 2002, personal observation). As late as 1997, Cameroon accounted for about 70% of the world's supply of bark. Between 1986 and 1991, an annual average of 1923 metric tons of bark was exported from Cameroon (Cunningham and Mbenkum, 1993). They estimated that this amount of bark represented about 35,000 debarked trees, affecting approximately 6300 ha of montane forest. Ewusi et al. (1996) estimated that 1500 tons of bark have been exported from Cameroon annually since 1994. Evidence of resource depletion in Cameroon is mounting. In March 2000, Plantecam closed its extraction factory due to reduced harvest allotments on Mount Cameroon, business decisions by the parent company (Groupe Fournier), and competition from other exporters (T. Simons, personal communication). Since then, documentation of bark harvest has been more difficult to obtain, although export appears to be diminished since the closure of Plantecam (T. Sunderland, personal communication). Current bark export figures are unavailable.

4.2. Madagascar

Bark is harvested from the eastern montane forests, particularly from the forests near Antananarivo south of Lake Alaotra (Cunningham et al., 1997) and recently from the Moramanga and Ambatondrazaka Forests (O. Behra, personal communication). Densities of *Prunus africana* are reportedly low and may be the legacy of past exploitation (Dawson and Rabevohitra, 1996). Trees are generally felled and stripped of all bark; harvest takes place during the wet season. Regulations do not specify a minimum size tree as in Cameroon (>30 cm DBH). Dawson (1998) found harvested trees as small as 15 cm DBH and concluded that trees too small to have reached reproductive age were not spared. Harvesters are supposed to leave two trees per hectare as a seed source, chosen by the Forestry Department, but this is not enforced. Felling is not allowed near a water source. Permits are issued for 2 years and no limits on quantity are specified (Cunningham et al., 1997). Bark is dried and sold to middlemen who transport it to the processing factory in Fianarantsoa. Protected areas are routinely harvested illegally (Dawson and Rabevohitra, 1996) and harvesters are willing to travel long distances to obtain bark (Walter and Rakotonorina, 1995).

The Société pour le Dévelopment Industrielle des Plantes de Madagascar (SODIP) exports bark extract to the Italian companies Inverni della Beffa and Indena Spa, which produce "Pygenil" and market bark extract. SODIP operates a bark extraction factory in Fianarantsoa and processes all bark harvested in Madagascar, although recently some raw bark has been exported (O. Behra, personal communication). SODIP began operation in 1988 and requires about 1000 metric tons of bark per year to be economically viable (Walter and Rakotonorina, 1995). Bark processed or exported showed a steady increase to 1200 tons in 1995, according to data summarized by Cunningham et al. (1997). This author was not able to confirm recent levels of harvest or export.

4.3. Kenya

In Kenya, *Prunus africana* is present in moist forested areas above 1500 m (Hall et al., 2000). Bark is harvested on privately owned forest land when it is converted to tea estates, resettlement lands, and other uses; harvest is forbidden from protected areas (Cunningham et al., 1997). The species is exported as dried bark, chipped bark, and timber. Harvest began in 1995 with the export of 150 tons of bark. Export peaked at 500 tons in 1998 and about 300 tons were shipped in 2000. Figures from 2001 to 2002 are not available (L. Quentin, personal communication). Only one exporter (Jonathan Leakey) has been involved in the *Prunus africana* trade in Kenya and he ships dried or chipped bark to Prosynthese (a subsidiary of Groupe Fournier of France). The CITES management authority for Kenya objected to the continued harvest without a Detriment Study and halted the harvest at the end of 2002 (Q. Luke, personal communication). Cultivation trials have been conducted, but large-scale plantations are not yet in production (Barker et al., 1994; Dawson, 1997).

Mature trees are also exploited for their timber. Following harvest of mature trees for local and export timber products, Nzilani (2001) examined the Kakamega and South Nandi forests in western Kenya. She found few saplings and young trees, suggesting poor recruitment resulting from the removal of mature trees.

4.4. Equatorial guinea (Bioko)

The status of harvest on the island of Bioko, off the coast of Equatorial Guinea was examined by Sunderland and Tako (1999). Although patchy in its distribution, *Prunus africana* occurs in the altitudinal band between 1200 and 2500 m. Harvest takes place in relatively accessible sites, primarily on the road leading to the summit of Pico de Basilé and in the forest near Moka, although plans are underway to extend the harvest to less accessible areas. Commercial harvest on Bioko began in 1992–1993. The Equatorial Guinean Forestry Department has set an annual export quota for *Prunus africana* bark at 500 tons per year. This figure was arbitrarily set through discussions with the CITES authority but was not based on inventories of existing populations. No other regulations or harvesting guidelines are in place, except for legislation to protect certain areas of the country, some of which contain populations of *Prunus africana*. Inventories have not been conducted on which to base management decisions and license conditions.

Currently, Aprovechamiento Agricola (APRA), a subsidiary of NATRA, a Spanish exporter of agricultural products, is the only exporter of *Prunus africana* bark. At first, only dried, unprocessed bark was exported, but in 1997, APRA began to grind the bark into powder form. Ultimately, the bark products are sold to MADAUS in Germany. Between 1992 and 1998, an average of 210 tons of bark per year was exported from Bioko. APRA's monopoly is likely to end as other exporters enter the trade on Bioko.

Sunderland and Tako (1999) examined current harvesting practices and noted girdling of trees and disruption of the vascular cambium, resulting in crown die-back. On Pico Basilé, they observed that 21% of the trees were dead and 47% showed crown die-back. The remaining 32% were recently harvested and had not yet displayed the effects of harvest. They note that village control over outsiders is limited due to the State dominance over land and security issues. These observations led them to conclude that the current harvest is unsustainable, despite the (so far) relatively modest levels of harvest.

4.5. Uganda

In 1992, bark was harvested on a trial basis from the Kalinzu-Maranaganbo Forest and the Kasyoho-Kitomi Forest Reserve in western Uganda. Bark was transported to Mombasa, Kenya where it was exported to France. However, the bark harvest was destructive and the sole exporter ceased operations in Uganda (Cunningham et al., 1997).

4.6. Tanzania/Democratic Republic of Congo

Little is known of the harvest in Tanzania or the Democratic Republic of Congo. Montane forests are not abundant. Cunningham et al. (1997) surmise that the source of bark may be from the Kivu range and exports may contain bark from *Prunus crassifolia*, which may be endemic to this area (Kalkman, 1965). Bark exported from Tanzania may be from the Democratic Republic of Congo although, with years of civil unrest in this county, the levels of export in either country have not been documented (Cunningham et al., 1997).

4.7. South Africa

Prunus africana has a limited distribution in South Africa, and a small harvest occurs in the Eastern and Transkei Mistbelt Forests located in the eastern montane regions generally between the cities of Umtata and Peitermaritzburg. Small amounts are exported and may be unreported (C. Geldenhuys, personal communication).

Experiments are currently underway to examine the leaves of *Prunus africana* as a source of marketable constituents. Although leaves have lower levels of active compounds, they may offer an alternative to the destructive bark harvest, especially if trees can be pruned to an easily harvestable height (C. Geldenhuys, personal communication).

4.8. Asian sources

Several species of *Prunus* are present throughout the Indo-Pacific (Kalkman, 1965). Prosynthese (a subsidiary of Groupe Fournier) has investigated related Asian species as a source of the active ingredients present in *Prunus africana* (Cunningham et al., 1997). The results of this search have not been publicized.

4.9. Rwanda

In the Virunga Mountains in Rwanda, all forest described as *Prunus africana* habitat has been converted to agricultural land (Sayer et al., 1992). Thus, harvest no longer occurs in Rwanda.

5. International market demand

Harvest of *Prunus africana* bark began as a relatively small operation in Cameroon yielding only 10 tons in 1976 (Cunningham et al., 1997). Since then, the market has grown considerably. Cunningham and Mbenkum (1993) estimated an average of 1923 metric tons were exported from Cameroon between 1986 and 1991. In 1997, worldwide annual exports were estimated at 3225 metric tons of bark with a retail value estimated at $220 million (Cunningham et al., 1997). Pomatto (2001), in her market survey, estimated worldwide exports of dried bark in 2000 were 1350–1525 tons per year, down from their 1997 peak. Bark extracts (6370–7225 kg per year) were worth an estimated 2.45 billion CFA (approximately $4.36 million) per year. She attributes the reduction in bark exports to a decrease in demand for herbal products in general and that insurance companies will pay for prescription medicines but not for herbal remedies. In addition, she surmises some consumers are reluctant to buy products derived from an endangered species.

Groupe Fournier of France and Indena of Italy produce 86% of the world's bark extract, both for their own products and for the free market (Pomatto, 2001). Most *Prunus africana*-based herbals are sold within the European Union. However, as BPH becomes more prevalent in aging American men, and as the efficacy of the product becomes more widely known, the demand for *Prunus africana* products in the lucrative American market is expected to grow as well. Saw palmetto products, which are also used in the treatment of BPH, are one of the most rapidly growing sectors of the American herbal market (Brevoort, 1998). This sector of the market is closely tied to present and future sales of *Prunus africana* products, especially as formulations containing both products become more common (Pomatto, 2001). Saw palmetto products are also entirely wild-collected and the ecological impacts of the harvest of saw palmetto fruits are unknown (Bennett and Hicklin, 1998).

6. Aspects for conservation

As stated above, 1350–1525 tons of bark are harvested annually from African trees. This has serious implications for the Afromontane forest ecosystems because these forests contain high proportions of endemic plants and animals (Collar and Stuart, 1985), which make them the focus of international conservation efforts. High mortalities and morbidities caused by felling or harvest may alter the forest structure and reduce a wildlife food source, although *Prunus africana* is not a keystone species (Maisels and Forboseh, 1999). An obvious question is whether the therapeutic chemical constituents can be synthesized, thereby alleviating pressure on wild stocks. Based on numerous trials, the effectiveness of *Pygeum* products appears to be due to a synergistic interaction of the many constituents of the bark extract (Awang, 1997; Bassi et al., 1987; Bombardelli and Morazzoni, 1997; Simons et al., 1998). Thus, for the time being, whole bark appears to be necessary for effective treatment. However, alternatives to wild-collection must be investigated, including the implementation and enforcement of conservation measures as well as efforts to cultivate the species.

6.1. Wild-collections

Efforts to conserve the species have been made from the very first harvests. Macleod (1987) recommended that the first harvest be of opposite quarters of bark and that after 4–5 years the remaining bark could be removed. This harvesting technique was not based on any bark removal experiments but on observations of harvested trees. These recommendations were the basis for current regulations in Cameroon but are often questioned as a sustainable harvesting procedure (Cunningham and Mbenkum, 1993; Sunderland and Tako, 1999; Stewart, 2001). While these regulations are laudable, nearly all qualitative and quantitative work has found high levels of mortality and morbidity of this "sustainable" harvesting practice. In addition, monitoring and community control of the harvest is difficult due to the species' clumped and scattered distribution (Ewusi et al., 1992).

Recommendations to control the harvest have been made for years. These included revocation of harvest permits (Cunningham and Mbenkum, 1993), determining resource inventories prior to permit issuance (Ewusi et al., 1996), and strict control over harvesting practices, including quotas, harvest zones, minimum sizes, and enforcement actions (Besong et al., 1991; Cunningham and Mbenkum, 1993; Cunningham et al., 1997). Inventories have been conducted only for Mount Cameroon (Ewusi et al., 1992; Tchouto, 1996) and on Mount Oku (Kilim-Ijim Forest Project, unpublished data). Population structure on Mount Cameroon suggested that recruitment is affected by harvest and that natural populations have been reduced by 50% (Ewusi et al., 1996). Parrot and Parrot (1990) claimed that harvest on Mount Oku caused 80% mortality. Observations of harvesting methods and the effects on tree health were reported by Ndam et al. (1993) and Cunningham and Mbenkum (1993), and simulations of morbidity and mortality were modeled by Stewart (2001). Observations on Mount Cameroon and on Mount Oku led to estimates that bark harvest kills about 50% of all tress harvested (Ewusi et al., 1996; Stewart, 2001). Experiments to test the specific effects of bark removal, such as the effect on growth, morbidity, mortality, or decreased reproduction, have not yet been conducted.

Stewart (2001) modeled harvest frequencies and different mortality levels in Cameroon (Mount Oku). Based on her models and assuming half of harvested trees die, it was recommended that a harvest frequency be no more frequent than once every 10–15 years and that large reproductive trees remain unharvested. Others (Cunningham et al., 2002, Hall et al., 2000) have also recommended longer times between harvests.

Ewusi et al. (1996) estimated an average bark yield of 137 kg per tree, based on Plantecam's records of total weight of bark removed and the total number of trees harvested. They also state that since 1994, when uncontrolled illegal harvests began, annual harvests were an estimated 1500 tons per year, which is more than three times as much as the previous average harvests of 450 tons per year. This study led to a reduced harvest quota on Mount Cameroon, from 1000 to 300 tons per year. Ultimately, Plantecam, faced with a reduced quota and other business decisions, closed the extraction factory in Cameroon.

Wild-collection appears viable only in cases where there is a strong regulatory framework and strict enforcement of the harvest (Ndibi and Kay, 1997). This is possible only where there are sanctions against unsustainable harvesting methods and strong community support. Traditional conservation ethics erode quickly once outsiders harvest with impunity (Cunningham and Mbenkum, 1993; Fisiy, 1994; Sunderland and Tako, 1999). However, traditional practices can protect certain areas, such as sacred forests and groves. On Mount Oku, Cameroon, traditional practices protect the Lumutu Sacred Forest and several sacred groves throughout the community (Stewart, 2001). In the Embu District of Kenya, over 250 sacred groves are protected in agricultural areas (Dawson et al., 2000).

A major reason illegal harvests occur is the low prices paid to harvesters, who must harvest many trees from a given location as quickly as possible. Ewusi et al. (1996) suggest that if revenue from controlled and legal exploitation were distributed fairly among the stakeholders, destructive harvests could be eliminated.

6.2. Cultivation

Over 35 years of wild-collections have led to serious resource depletion that appears to threaten the resource. Cultivation may be one mechanism to protect the resource. The Conservation through Cultivation Programme at the Limbe Botanic Garden in Cameroon and the International Centre for Research in Agroforestry (ICRAF) cultivation experiments in Kenya are leading cultivation efforts. Cunningham and Mbenkum (1993) recommended *Prunus africana* plantations at low altitude, especially in areas of abandoned oil palm stands. However, trees at low altitudes are more likely to become infested with wood borers and fungal pathogens, seriously reducing timber value (Cunningham et al., 2002). Available land at higher altitudes is scarce, at least in Cameroon; nearly all lands outside of forest preserves have been converted to farm crops or pastures.

6.2.1. Enrichment plantings

Enrichment plantings have long been recommended as a way to replace the trees lost to harvest. In 1972, the Cameroon Office National des Eaux et Forêts (ONADEF) established an enrichment plantation in Ntingue near Dschang. Unfortunately, these forest reserve trees reportedly were recently debarked (Cunningham et al., 2002). The Forest Department of Kenya has started enrichment plantings for timber production (Dawson et al., 2000). No enrichment plantings are known for Madagascar but, considering that the species is genetically unique (Barker et al., 1994, Dawson and Powell, 1999), enrichment plantings may be critical where harvesting has removed mature trees. Vegetative techniques, such as grafting and cuttings (Leakey, 1994) may be used in this case to speed the recovery in denuded Madagascar forests as well as other heavily harvested areas, such as the Bamenda Highlands of Cameroon. Where enrichment plantings occur, they should include opening the canopy and clearing the competitive undergrowth around reproductive trees (Ndam, 1996). However, plantings must not occur to the detriment of other forest species. With the large market potential for future bark sales, it could be tempting to manage a natural forest for *Prunus africana* production.

Cunningham et al. (2002) conducted an economic analysis of enrichment plantings in Cameroon. Based on the historical annual bark volumes processed at Plantecam (1923 tons per year), they calculated that a 12-year-old stand on 820 ha with 1363 trees planted per hectare would supply enough bark for a 12-year rotation.

6.2.2. Plantations

Regulations in Cameroon specify a 2% regeneration tax on the value of raw material and a transformation tax paid to the Forestry Department. These revenues were legislated to finance forest regeneration. However, this provision has never been enforced. Only one 2-ha plantation has been planted. It is located near Buea and the trees were interplanted with other food crops. In Kenya, the Forestry Department has established successful *Prunus africana* plantations for timber production (Dawson et al., 2000). Their success holds promise for large-scale production elsewhere.

6.2.3. Small-scale farm production

As natural forests continue to be cleared in the densely populated areas surrounding Afromontane forests, the management of small-scale farms for *Prunus africana* production may be one of the best alternatives for long-term conservation (Cunningham and Mbenkum, 1993; Cunningham et al., 1997; Dawson et al., 2000; Cunningham et al., 2002). Cunningham et al. (2002) examined the economic potential of small-scale farm production of *Prunus africana*. Seedlings are commonly inter-planted in coffee plantations and other fields, where they reportedly do not compete with crop production. This is seen as a way to diversify their operations, especially since the tree can be marketed for a number of products (axe and hoe handles, traditional medicines, firewood, poles, seed sales, and mulch) even as it matures to a market commodity. In the Northwest Province of Cameroon, they estimate that over 3500 farmers are already planting *Prunus africana* as a cash crop. This effort is supported by development projects. Although some farmers use trees grown from seed, they also gather seedlings from the forest, which may reduce forest regeneration if they are removed in large enough numbers.

The only serious constraints for small-scale producers are the vagaries of the international market and the lack of control over their own market. Although it is possible that the world demand for *Prunus africana* bark may collapse due to the synthesis of its medicinal components, this scenario seems unlikely, at least for the time being. Thus, worldwide demand for the bark is expected to continue and even increase as western men age and as the popularity of a non-surgical intervention increases. Even if the worst case ensues and the market for bark collapses, small-scale farmers will still have the market for its timber. It may also be possible to market the bark as a local medicinal product.

6.3. Protection of genetic sources

The genus *Prunus* has been recognized by the International Board for Plant Genetic Resources as a priority for both in situ and ex situ conservation due to the economic importance of fruit crops (Barker et al., 1994). Studies using the Random Amplified Polymorphic DNA (RAPD) technique on samples from trees from Ethiopia, Kenya, Cameroon, Uganda, and Madagascar showed genetic differences between these countries, with the Madagascar populations showing the most differences (Barker et al., 1994; Dawson and Powell, 1999). Significant differences were also found among the Cameroon and Madagascar populations. This agrees with the unique phytochemical differences observed by Martinelli et al. (1986), who found significant differences between bark extracts from mainland Africa and Madagascar. Dawson and Powell (1999) concluded that the Madagascar populations might be particularly worthy of conservation in light of their genetic uniqueness. Thus, protection of genetic sources may be necessary within both areas. Selection for growth form, timber properties, and medicinal constituents should be investigated.

6.3.1. In situ conservation practices

Where wild-collection occurs, it has been recommended that certain forest areas be set aside as representative viable populations (Cunningham and Mbenkum, 1993; Barker et al., 1994; Cunningham et al., 2002). This would be most successful where local traditional authorities or communities are actively involved (Ewusi et al., 1992; Ndibi and Kay, 1997). In addition, forestry laws need to be in place and actively enforced to protect these conservation areas (Ndibi and Kay, 1997; Sunderland and Tako, 1999).

Although *Prunus africana* serves as a valuable food source for frugivorous birds and mammals, it is not, as suggested by Cunningham and Mbenkum (1993), a keystone species. In addition, *Prunus africana* has alternate-year fruiting phenology that is not synchronous throughout the forest (Stewart, 2001). Recent data on the phenology of major Kilum-Ijim forest species on Mount Oku failed to identify any keystone food plants. Rather, the staggered fruiting of over 40 animal-dispersed species provides food sources in all months of the year (Maisels and Forboseh, 1999). Thus, in situ management strategies should include conservation of representative forest areas and since traditional practices already encourage it, the conservation of sacred forests and groves should be strongly encouraged, as recommended by Cunningham and Mbenkum (1993).

6.3.2. Ex situ conservation practices

Barker et al. (1994) and Dawson and Powell (1999) showed the genetic uniqueness of each country's populations. Even within an area, the species demonstrates differences. Cunningham et al. (2002) discusses three different varieties in Cameroon reported by harvesters. Secure field gene banks have been recommended (Cunningham and Mbenkum, 1993; Cunningham et al., 2002) as a mechanism to conserve the different genetic strains. Further, the harvest of populations of *Prunus crassifolia*, possibly a separate species endemic to the Kivu region of the Democratic Republic of Congo, may cause severe population decline before science has a chance to examine it. Thus, it is critical to establish secure field gene banks for established *Prunus africana* and *Prunus crassifolia* genotypes (Cunningham et al., 2002).

The felling or girdling of large reproductive trees reduces seed production and possible recruitment. Stewart (2001) documented the large numbers of seeds produced by large trees and her model simulations showed the importance of conserving large trees. A reduction in seed and animal dispersal may further isolate the montane populations. Storage of seed as a conservation strategy does not appear to be possible. Sunderland and Nkefor (1996) demonstrated the recalcitrant nature of *Prunus africana* seed, which fails to germinate if stored for more than 18 months.

6.4. Convention of International Trade in Endangered Species (CITES)

CITES is the principal international conservation strategy for the protection of internationally traded endangered species. In 1995 (effective in 1996), *Prunus africana* was included in Appendix II as an endangered species. Listing specifies that trade in wild and cultivated material must be licensed in exporting and importing countries. Difficulties in identification of the various *Prunus africana* products have been cited as a problem in its effective implementation, especially in importing countries (Cunningham et al., 1997). This has led to under-reporting of the trade. In addition, some countries lack independent scientific CITES Authorities, allowing exports to occur without a valid non-detriment finding. Cunningham et al. (1997) made several recommendations to improve CITES oversight.

7. Conclusions

Problems with the sustainability of the *Prunus africana* bark harvest have resulted from a lack of knowledge of sustainable harvest levels and from the huge demands on present wild populations. Although harvests on Mount Cameroon were relatively benign when conducted by trained harvesters (Mapanja Harvesters Union and the workers from Plantecam), harvest in other parts of its range is unrestrained and destructive, even with the efforts of government harvesting regulations. In other words, the species is "mined." On a continent with few jobs, short-term economic gain appears to be more important than long-term sustainability. In addition, the huge gap between the price paid for the bark and for the final capsules encourages collection from the wild and seems to hamper efforts to synthesize the various constituents. Exploitation has generated considerable pressures on wild populations outside the few preserves, sacred forests, and sacred groves and has weakened the regeneration ability of *Prunus africana* populations.

Unfortunately, investigations to determine sustainable harvest levels were not conducted during the development of the product. After a mere 35 years of harvest, *Prunus africana* has become a CITES endangered species and may no longer be commercially viable in Cameroon; harvest has been halted in Uganda and in Kenya. Clearly, current harvesting practices are not sustainable. A combination of protection of wild populations (especially genetically unique populations), enrichment plantings within forests, and small- to large-scale cultivation techniques appear be necessary to meet current and projected market demand. Investigations into leaf cultivation may hold promise. To meet future market demand, it appears that the species is entering the transition from an exclusively wild-collected species to that of a cultivated medicinal tree.

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