Prunus africana (Hook. f.) Kalkman (the African Cherry)

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Abstract *Prunus africana* (Hook. f.) Kalkman, also known as *Pygeum africanum*, is the only species of the *Prunus* genus found in Africa. The reputation of this tree is due to the use of its bark extract in the treatment of benign prostatic hyperplasia (enlarged prostate). The present review compiles the knowledge of the medicinal uses, the extract composition and the threats to this overexploited tree but also possible solutions to sustainably produce its active compounds.

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1 Introduction

P. africana (Hook. f.) Kalkman is a multi-use species mainly known for its bark whose extracts are used in the treatment of benign prostatic hyperplasia, a disorder common in men over 50 years (Simons et al. 1998). In 1997, the annual trade of *P. africana* bark and its derivatives was estimated at more than $220 million (Cunningham and Mbenkum 1993).

Because the bark is harvested from the natural environment, the importance of its international trade leads to the overexploitation of the natural populations (Hall et al. 2000). This results in significant disturbances in the population dynamics (Cunningham and Mbenkum 1993; Sunderland and Tako 1999; Ndam and Ewusi 2000; Stewart 2003).

Concerns about the durability of the bark harvest have led to the inclusion of *P. africana* in Appendix-II of the Convention on International Trade in Endangered Species (CITES) in 1995 (Cunningham and Mbenkum 1993). The aim was to regulate the trade and to reduce the pressure on natural populations. However, in addition to the impacts of its trade, habitat loss due to agriculture and climate change is also threatening this species (Geldenhuys 1981; Mayaux et al. 2015). Moreover, the increase of the population concerned by prostatic hyperplasia and the renewed interest in herbal medicine make the bark of *P. africana* a product whose demand is likely to increase while the supply is remaining stable or even decreasing (Cunningham and Mbenkum 1993; Hall et al. 2000; Cunningham et al. 2014).

2 Geographical Distribution and Ecology

P. africana is a tree of the Rosaceae family, also known as *Pygeum africanum* or African cherry. It is the only species of the genus that is indigenous to Africa (Simons et al. 1998). This tree is restricted to high conservation value Afromontane forest islands (White 1983) in the African continent (Angola, Cameroun, Democratic Republic of the Congo, Ethiopia, Kenya, Malawi, Nigeria, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zimbabwe) and outlying islands (Bioko, Grand Comore, Madagascar, Sao Tome e Principe) (Kalkman 1965) (Fig. 1). Cameroon and Madagascar are the countries that contain the largest populations of the species because of their relatively large areas of montane forests (Stewart 2003).

P. africana is a light-demanding species growing within the secondary forests (Stewart 2003; Kadu et al. 2013). This tree is most abundant in open areas along

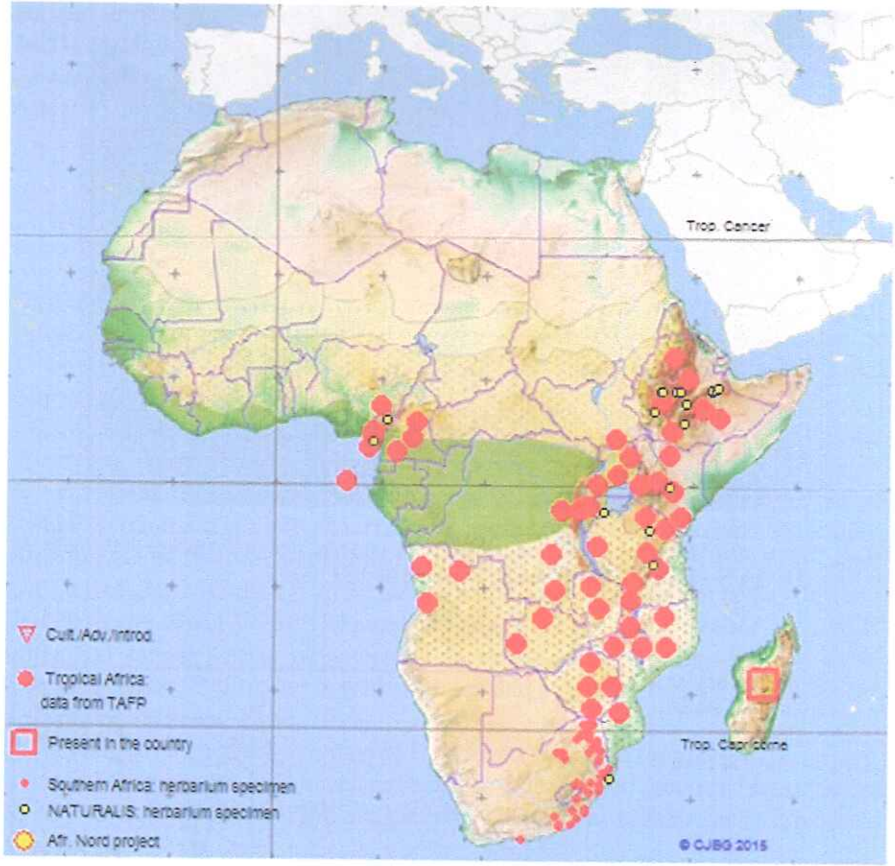

Fig. 1 Geographical distribution of *Prunus africana* (Hook. f.) Kalkman in the African continent and outlying islands (Source: http://www.ville-ge.ch/musinfo/bd/cjb/africa)

forest margins and in disturbed areas (Geldenhuys 1981; Ndam 1996) and occurs at altitudes between 1000 and 2500 m (Cunningham and Mbenkum 1993; Sunderland and Tako 1999). It can reach 30–40 m in height and a diameter of 1 m. Its bark (Fig. 2) is light to dark reddish fissured (Stewart 2003).

Its evergreen canopy is medium to large with simple and alternate leaves (Stewart 2003) and small white flowers pollinated by insects (Farwig et al. 2008). The fruit is a drupe that becomes purple colored at maturity (Stewart 2003) and it is dispersed by birds and mammals such as red colobus and black and white colobus (Chapman and Chapman 1999; Chapman et al. 2003; Fashing 2004). Birds can disperse the relatively small seeds over distances of more than 300 km (White 1983). The different organs (Fig. 3) (Sim 1907) and the bark emit a characteristic "cherry" odor of the genus (Stewart 2003).

Three different zones can be distinguished based on flowering periodicity: the equatorial zone where some individuals are flowering almost continuously and the southern and northern zones where the flowering period seems to correspond with

Fig. 2 *Prunus africana* (Hook. f.) Kalkman bark from a tree located in Tshivanga at the entry of the Kahuzi Biega National Park (Democratic Republic of the Congo)

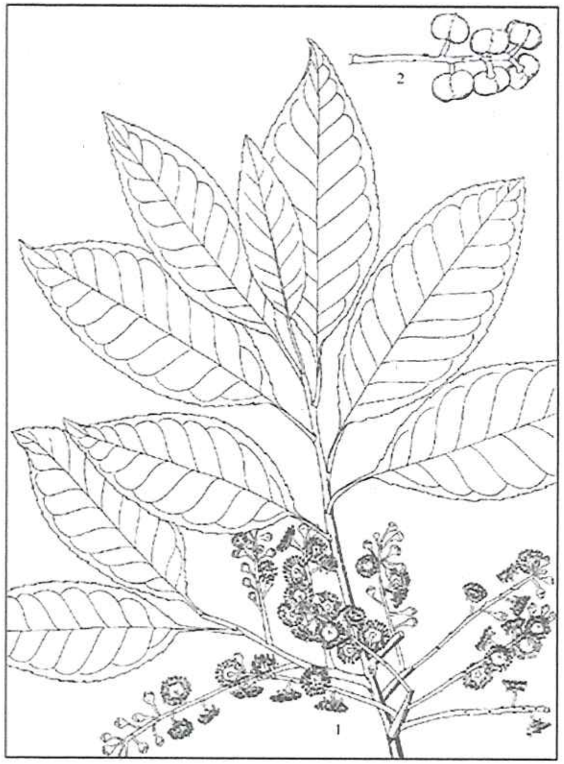

Fig. 3 Flowering branch (*1*) and fruit (*2*) of *Prunus africana* (Hook. f.) Kalkman (Adapted from Sim 1907 [14])

cool and dry conditions (Hall et al. 2000). *P. africana* starts to produce seeds at 15–20 years, a relatively late age (Simons et al. 1998). The fruiting period, generally associated with rainfall, seems to appear the 2–3 months after the flowering period (Hall et al. 2000).

3 Medicinal Uses

P. africana is multi-use species known mainly for the beneficial effects of its bark as treatment for prostate enlargement. Nevertheless, this species is also known for its timber and its leaves, roots and bark as traditional medicines in Africa (Cunningham and Mbenkum 1993; Kadu et al. 2012).

Before the 1960s, *P. africana* was only used for traditional purposes. In 1966, the effectiveness of its bark to treat prostate hypertrophy (an enlargement of the prostate) and Benign Prostatic Hyperplasia (BPH) was discovered (Debat 1966). Benign prostatic hyperplasia is a non-cancerous enlargement of the prostate that commonly affects men over 50 (Bombardelli and Morazzoni 1997; Simons et al. 1998). More than 50% of men over the age of 60 have urinary symptoms that can be attributed to BPH (Wilt and Ishani 1998). The number of side effects of other treatments of BPH (drugs and surgery) make phytotherapy an increasingly popular option (Stewart 2001). Moreover, *P. africana* is well tolerated and costs less than most prescripted medications (Wilt and Ishani 1998).

Though the mechanism of action of *P. africana* bark remains unclear, its efficacy to treat BPH symptoms is believed to be due to at least three groups of compounds: (a) phytosterols (β-sitosterol, β-sitostenone) having anti-inflammatory properties (Carbin et al. 1990), (b) pentacyclic triterpenoids (oleanolic and ursolic acids) providing anti-edematous activity (Bombardelli and Morazzoni 1997) and (c) ferulic acid esters (*n*-docosanol and *n*-tetracosanol) that lower blood levels of cholesterol, from which testosterone is produced (Bombardelli and Morazzoni 1997). These phytochemicals (Fig. 4) are believed to work synergistically to counteract the physiological changes associated with the disease (Bassi et al. 1987; Bombardelli and Morazzoni 1997; Simons et al. 1998).

Although the bark is the plant material commonly extracted, it has been found that wood, flowers and fruits have similar therapeutic values (Debat 1974).

The extract from the plant material is used in a variety of pharmaceutical forms such as tablets, capsules or cachets (Hall et al. 2000). To produce hundred 50-mg capsules, 5 g of extract are enough (Simons et al. 1998). Usually, *P. africana* extract is blended with other extracts known to have similar properties such as saw palmetto (*Serenoa repens*) (Lowe and Ku 1996).

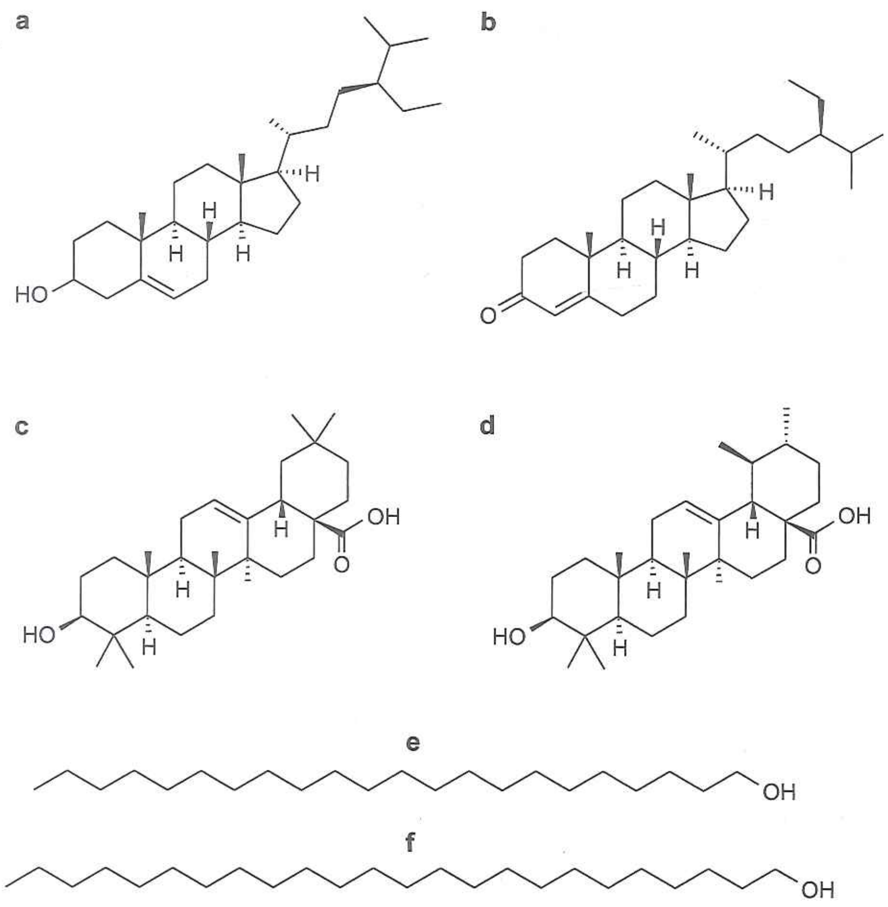

Fig. 4 Some of the phytochemicals present in *Prunus africana* extract involved in the treatment of Benign Prostatic Hyperplasia (BPH). (**a**) β-sitosterol, (**b**) β-sitostenone, (**c**) oleanolic acid and (**d**) ursolic acid, (**e**) *n*-docosanol and (**f**) *n*-tetracosanol

4 International Trade

Following the discovery of the use of *P. africana* in the treatment of BPH, pharmaceutical companies began hiring people to harvest bark for exportation to European countries (Cunningham and Mbenkum 1993). The first countries to export from the early 1970s were Cameroon, Madagascar, Democratic Republic of the Congo (DRC), Kenya and Uganda (Cunningham et al. 1997). Cameroon, where the harvest began in 1972 around Mount Cameroon, has the longest history in *P. africana* bark trade (Stewart 2003).

In the 1990s, the annual quantity of dried bark or extract from *P. africana* exploited to export to Europe ranged between 3200 and 4900 tons, making it the

Table 1 CITES national export quotas for *Prunus africana* (Source: https://cites.org/eng/resources/quotas/export_quotas)

Country	Quotas	Unit	Specimens
Burundi	0	–	
Cameroon	1,082,879	kg	Dry bark
Democratic Republic of the Congo	232	kg	Dry bark
Kenya	0	–	
Madagascar	0	–	
Uganda	176,179	kg	Dry bark

Fig. 5 Products derived from *Prunus africana* extracts

first of any African medicinal plant in international trade (Cunningham et al. 2002). The global value of this international trade of products was estimated to be more than USD 220 million per year with Cameroon providing approximately 60% of the volume annually traded (Cunningham and Mbenkum 1993; Cunningham et al. 1997). However in the country, the price of the bark was less than USD 0.10 per kg compared to the international value of USD 2 per kg (Cunningham et al. 1997). The majority of the overall product value was taken by the pharmaceutical companies (Clark and Sunderland 2004).

In 2012, due to the establishment of quotas per exporting country, the volume traded was less than 1000 tons with Cameroon providing almost 75% of *P. africana* bark at the market price of USD 6 per kg (Cunningham et al. 2014). Over the last 40 years, the changing demand and markets have led to strong fluctuations in the values and volumes of bark traded (Ingram and Schure 2010).

Madagascar, Kenya and Burundi have a zero quota granted by CITES in 2016 so the global supply is supplied by Cameroon, DRC and Uganda (Table 1). Most of the bark harvested in Cameroon is exported to Italy and France while bark from DRC is exported to France and Belgium (Cunningham et al. 2002). The herbal products derived from *P. africana* (Fig. 5) are sold under its synonym, *Pygeum africanum* (Stewart 2003). Originally only two brand-name products were produced with *P. africana* extracts but now more than 40 brand-name products can be found on the market of ten countries (Wei et al. 2005). Capsules containing bark extracts have been marketed in Europe (mainly Austria, France, Italy and Switzerland) for over 40 years (Cunningham and Mbenkum 1993).

5 Threats

Unsustainable Harvest

Currently, all the *P. africana* bark found on the market is from wild harvest (Hall et al. 2000). In theory, the harvest of its bark is supposed to be sustainable. Indeed the tree has the faculty to regenerate its bark as long as the vascular cambium is not damaged (Stewart 2003). Unfortunately, it is not the case in practice. The wild populations of *P. africana* are highly vulnerable due to bark overexploitation (Hall et al. 2000; Kadu et al. 2012).

Studies showed that most trees are even debarked from upper branches or felled and left to die to facilitate the access to the bark (Cunningham and Mbenkum 1993; Stewart 2003). Even partially strip barking living trees expose them to ring-barking and to insect attacks that can cause 50–90 % of post-harvest tree mortality (Ndam and Ewusi 2000). In Equatorial Guinea, 68% of exploited *P. africana* trees for local trade were experiencing death or canopy dieback (Sunderland and Tako 1999). Early studies trying to evaluate the impacts of bark harvest showed that it affected negatively the population structure, increased the mortality and decreased the fecundity (Parrot and Parrot 1989; Ewusi et al. 1992; Cunningham and Mbenkum 1993; Walter and Rakotonirina 1995). Death rates in commercially harvested wild populations of *P. africana* trees larger than 10 cm of diameter at breast height (dbh) can be 50–100 times higher than the natural mortality rate (Stewart 2003; Forboseh et al. 2011). Moreover, with the over-exploitation of large trees, there is a shift to trees with increasingly smaller diameters at breast height (Cunningham and Mbenkum 1993). The impacts on the population are ever higher since the density of mature trees is generally low in forests but also threaten ecosystem integrity (Ewusi et al. 1992; Hall et al. 2000).

The harvest of bark is geographically limited because of *P. africana* distribution in a specific ecosystem. It also increases the pressure on small areas (Cunningham et al. 2002). This harvest is still occurring even in our days, in Cameroon in areas with a protected status (Mount Oku, Mount Cameroon and Mount Kupe) endangering

also other species (Cunningham and Mbenkum 1993). Moreover, in Madagascar, the prescription that two seed trees per hectare should be left in the exploitation area is not applied (Walter and Rakotonirina 1995; Hall et al. 2000). It is in Madagascar and in Cameroon that *P. africana* bark is under the greatest threat (Cunningham and Mbenkum 1993; Walter and Rakotonirina 1995). At an average *P. africana* density of 5.5 trees ha^{-1} (Eben Ebai et al. 1992) and a bark yield of 55 kg per tree, the commercial harvesting of 1923 tons of bark each year would affect over 6300 ha of Afromontane forest annually (Cunningham and Mbenkum 1993).

With the world population aging, it is known that 88% of men in western countries will have the chance of developing histologic evidence of BPH (Cunningham and Mbenkum 1993). The demand of *P. africana* bark is then likely to be increasing which will strengthen the pressure on wild populations (Dawson et al. 2000; Hall et al. 2000).

Loss of Habitat

P. africana is not only threatened by the unsustainable harvest of its bark but also by the loss of its habitat. For example, the forest cover of *P. africana* habitat in Ethiopia has been reduced from 35% in the beginning of the nineteenth century to less than 2.8% now (Mayaux et al. 2015). In Cameroon, the discovery of the potential of *P. africana* have resulted in a densification of the human populations in the concerned areas, causing a clearing of the forest for farming purposes (Cunningham and Mbenkum 1993).

There exist different major threats to montane ecosystems that are *P. africana* habitat: clearing for agriculture, timber extraction, browsing and trampling by livestock, and fire (Cunningham et al. 2008). Forest disturbances have impacted on species populations that can show an episodic natural regeneration as a result (Cunningham et al. 1997).

Considering the range of the species overall, the destruction of montane forests is probably the major factor affecting its conservation status (Hall et al. 2000).

Climate Change

Climate change is another threat to *P. africana* populations that has to be considered. Sensitivity of Afromontane forest plants to small changes in temperature and rainfall can have high impacts on plants viability (Conway 2009). In South Africa, a study showed that 47% of *P. africana* standing stems of more than 10 cm diameter at breast height were dead due to increasing aridity in the Southern Cape region (Geldenhuys 1981). Moreover, climate changes can influence regeneration at the edges of the species' natural range (Geldenhuys 1981).

The countries that are more likely to be negatively affected by changes in mountain ecosystem climates are Tanzania, Madagascar, Cameroon, Democratic Republic of the Congo and Uganda (Ingram et al. 2015).

6 Protection Status

In 1995, growing concerns about the sustainability of *P. africana* harvest led to the species to be listed in CITES Appendix-II (Cunningham and Mbenkum 1993).

In 2005, Cunningham summarized in the CITES Significant Trade Review evidences of the destructive and highly unsustainable harvest of the bark (Ewusi et al. 1992; Sunderland and Tako 1999; Stewart 2001; Nkeng et al. 2009; Ingram 2014). This report was discussed at the CITES meeting in Lima in 2006. In 2007, the European Union banned the importation of *P. africana*. But because of the pressure from the private sector and from the Cameroon government, the ban was lifted in 2011 and quotas have been established for the main producing countries (Cunningham et al. 2014). This lift was mainly based on the "Management Plan for Prunus", a report published by different research organizations including the Center for International Forestry Research (CIFOR) (Ingram et al. 2009; Ingram 2014). However, there were many reservations about the poor quality of the report even among the authors (Cunningham et al. 2014).

Besides its status for CITES, *P. africana* is also listed in the Red List of International Union for Conservation of Nature (IUCN, www.iucnredlist.org) as a vulnerable species. Despite those designations, *P. africana* exported volumes are still making it Africa's most exported medicinal plant species (Cunningham et al. 2002).

7 Bark Harvesting and Composition

As mentioned previously, *P. africana* is among the few African tree species that exhibit complete bark regrowth and is even able to withstand complete bark removal (Stewart 2003). This ability offered the potential for sustainable harvesting of *P. africana* bark (Cunningham and Mbenkum 1993). The method currently presented as sustainable for bark removal is the two-quarter method (Fig. 6), with the procedure described by Ndam and Yogo (1999). Only the trees with a dbh of more than 30 cm can be debarked. The trees with a dbh below 50 cm should be debarked with two strips in opposite sides, each no wider than 1/4 of the tree circumference, from 1 m above the ground up to the first branch. From those with a dbh of 50 cm or more, four strips should be removed, each no wider than 1/8 of the tree circumference. Moreover each portion debarked on the tree should be separated from the next one by an untouched section of the bark of the same width. Lateral roots with a minimum diameter of 20 cm on trees with a dbh above 50 cm can also be debarked.

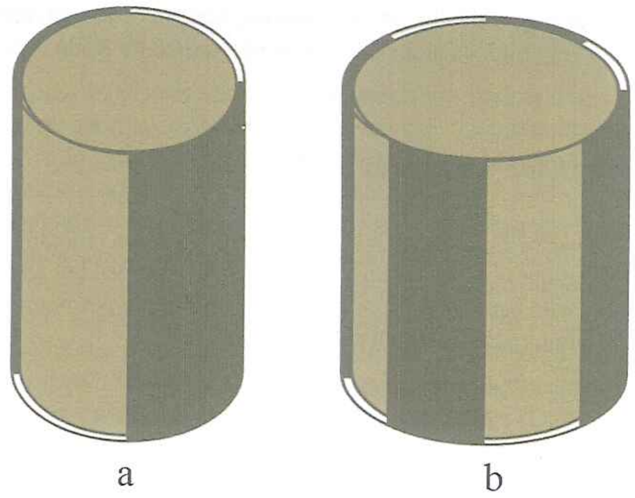

Fig. 6 Two-quarter method for *Prunus africana* (Hook. f.) Kalman bark harvest (bark in *dark brown*) for trees with a diameter at breast height (dbh) of less than 50 cm (**a**) and for trees with a dbh of more than 50 cm (**b**) from 1.30 m height to the first branch

The trees should completely recover from the first debarking before subsequent debarking (Ndibi and Kay 1997).

The recommendations for a sustainable harvest of *P. africana* bark also include the time between the harvest of the first 50% of the bark and the harvest of the last part. The minimum time of rotation has been found to be 7–8 years (Ingram 2014). The problem for the harvesters is that the bark yield decreases with an increase of the rotation time. From a 5-year rotation to a 6-year rotation, the bark yield can be reduced by more than 20% (Cunningham et al. 2014).

In practice, the use of this harvest technique shows that the tree responds differently depending on the site. In moist sites, bark regrowth occurs but in dry sites, bark does not recover (Cunningham et al. 2014). This leads to wood-borer and fungal attack on the debarked trees (Cunningham et al. 2002). Insects' attacks also occur in lower altitude sites, even on healthy *P. africana* trees (Cunningham et al. 2014).

There is a tendency to harvest *P. africana* bark during dry or low rainfall periods (Cunningham and Mbenkum 1993; Walter and Rakotonirina 1995). Using the method described previously, between 15 and 100 kg (depending on the size of the tree) can be obtained from a tree at each harvest (Tsobeng et al. 2008). To produce 5 kg of extract 1 ton of dry bark (that corresponds approximatively to the double of fresh bark) is needed to be harvested from mature trees (Cunningham et al. 1997).

Differences in genetic and chemical constituents of the bark have been found across the distribution range of *P.africana* that may reflect environmental differences within the range of a species (Kadu et al. 2012). A study in Cameroun, Democratic Republic of the Congo and Madagascar has already shown that the chemical composition of the bark depends on its origin (Martinelli et al. 1986).

Madagascar, a region genetically distinct from the African continent, seems to have populations with very high chemicals constituents studied by Kadu et al. (2012).

8 Perspectives for a Sustainable Use

For a sustainable use of *P. africana*, it is important to focus on reducing the impacts of the current techniques of harvest on the populations' survival but also on looking for alternatives to wild harvest. A lot of research is absolutely necessary to underpin a sound harvest aiming at a sustained production of bark.

Bark, Cambium and Wood Anatomy

The macroscopic phenomenon of *P. africana* bark recovery has been studied and it is known that after debarking, *P. africana* rapidly produces new bark on the wound surface (Cunningham and Mbenkum 1993; Vermeulen and Geldenhuys 2004; Geldenhuys et al. 2007). No information exists of this phenomenon at the microscopic level. However, to understand how *P. africana* can regenerate its bark, it is essential to study the tissues and the anatomical feature modification due to the injury. Delvaux et al. (2013) proposed the size of the conducting phloem as a key-factor for bark regeneration. Research should make it clear how, when and where new cambium is generated and how fast new tissues are being formed.

Inventory and Monitoring

To assess the state of the *P. africana* populations and the impacts of the current techniques on their survival, a standardized and accepted method of sampling needs to be adopted. The National Management Plan for *P. africana* in Cameroon (Ingram et al. 2009) included inventories that used different methods, with very different results, even for the same locations (Cunningham et al. 2014). In their study, Morrison et al. (2008) found that grid-based systematic designs were the more efficient and practical method for sampling.

It is also important to assure that bark is not harvested from protected areas. A recent project carried out by ITTO-CITES has developed a DNA tracking technology for *P. africana* bark (Darren 2016). With this technique, it is possible to identify the origin of the harvested bark and if it was from authorized harvest zones.

9 Cultivation

Unlike *P. africana*, other tree species from which the bark is commercially harvested (cinnamon, cork oak, chestnut, *etc.*) have made the transition from wild harvest to production in agroforestry or plantation systems (Lubbe and Verpoort 2011).

In Cameroon, several attempts have started to cultivate *P. africana* more than 20 years ago (Cunningham and Mbenkum 1993). Small-scale farmers began producing the species in agroforestry systems (Cunningham and Mbenkum 1993; Tchoundjeu et al. 2002). In terms of industrial cultivation, only 9 ha of pure plantation have been established by the Cameroon Development Corporation (Ndam and Tonye 2004). The annual *P. africana* plantation targets of 2 ha set in 1986 and 5 ha set in 1992 (Ndibi and Kay 1997) was far too small to have a meaningful impact (Hall et al. 2000). Attempts at cultivation are also underway in Kenya (Dawson et al. 2000; Dawson and Powell 1999).

There are different cultivation practices to consider that can be found in Ingram et al. (2015). For example, Tchoundjeu et al. (2002) found that vegetative propagation is suitable for *P. africana*, giving other options to domestication. The harvest of leaves is another alternative to bark harvest, since both plant material have the same pharmaceutical properties (Debat 1974).

For *P. africana* conservation, it is important to have regional approaches because of the genetic variation across the range but even at the country level. Indeed, differences have been found in populations in Madagascar and in Cameroon (Dawson and Powell 1999). It would be especially interesting to do research on the potential of the species in agroforestry systems.

10 Conclusion

The growing interest for *P. africana* is strengthening the threats the species is facing. It is therefore necessary to protect wild populations and find other ways to produce *P. africana* bark in order to sustainably supply the pharmacological industry with its valuable extract.

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