Titre: Towards a Sustainable exploitation of Non-Timber Forest Products in Cameroon: A literature review of Domestication and Conservation Techniques of *Prunus africana*

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Revue: *Anthropologie des savoirs des Suds,* numéro 2

Dossier: Le rôle des savoirs du Sud dans la durabilité humaine, écologique et planétaire

Numéro dirigé par Obrillant Damus (Université d'État d'Haïti, Université de Sherbrooke, Université Laval), Christine Focquenoy Simonnet (Université Lille 2), Chen Qiang (Université de Sanya), Joseph P. Saint-Fleur (Académie de Lille), Catherine Thomas (Association Comprendre et Soigner en Situation Transculturelle), Renata de Melo Rosa (Instituto Maria Quitéria)

Éditeur: Les Éditions de l'Université de Sherbrooke (ÉDUS)

Année: 2025

Pages: 113 - 136

ISSN: 2817-4070

URI: https://hdl.handle.net/11143/23279

DOI: https://doi.org/10.17118/11143/23279

Towards a Sustainable exploitation of Non-Timber Forest Products in Cameroon: A literature review of Domestication and Conservation Techniques of *Prunus africana*

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Abtract: Non-Timber Forest Products (NTFPs) play an important role in food security and population well-being. The majority of forest products (96%) are derived from NTFPs and their services. Forests are then considered 'pharmacy' and 'supermarket' for the rural community. However, in many countries, the NTFPs are still limited to traditional uses, mostly for the supply with the supply of raw materials. Also, there is a lack of knowledge on the availability of NTFPs, caused by the overexploitation, unsustainable, unregulated, and unauthorized harvesting of resources. It appears urgent to domesticate the NTFPs. Amongst them is *Prunus africana*, an endangered medicinal tree, growing at high altitudes between 900-3400 m, mainly in the moist highlands. The plant is a source of NTFPs that has captured the attention of national and international traders. It has been classified among plant species, which is prioritized for domestication in Cameroon. The bark is used medicinally to prevent prostate cancer and for the last 40 years, *P. africana* has been used in the treatment of Benign Prostatic Hyperplasia, which affects more than 50 % of men over the age of 50. The excessive exploitation of the bark of *P. africana* constitutes today a danger to the natural population of this species. There is an urgent need for species availability. Based on a review of the literature, the present paper summarizes work done on the characterization, conservation, and domestication of some species with a focus on *Prunus africana*. A systematic search strategy across multiple platforms was done, for a better coverage of both peer-reviewed articles and grey literature related to the topic. Some works were executed in the Laboratory of Botany and Traditional Medicine, of the Institute of Medical Research and Medicinal Plants Studies (IMPM). Because *P. africana* is threatened and the seeds rapidly lose their viability during the process of conservation, results showed the necessity of characterization, of determining the mechanism that occurs during seed germination, rapid propagation, and domestication of the species. The species presents certain characteristics in its shape and grows in a specific environment. *P. africana* has active components with medicinal properties and has distinct genetic differentiation among accessions. Adjusting temperature, light, and growth regulators enhances seed conservation. In the same line, the use of mycorrhizal fungi improves plant growth and facilitates the domestication process. There is then relevant information on the development of a more reliable, simpler, and more predictable propagation technique that has contributed to an increased understanding of *P. africana* with desirable traits, in response to the high demand for *P. africana*-derived products.

Key words: Characterization, conservation, domestication, propagation, NTFPs, *Prunus africana*

Introduction

The sustainable exploitation of natural resources is a key component of policy developments policies around the world. Natural resource diversity has shown its importance in human life. According to the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC, 2016), a quarter of the global biodiversity resources come from the Congo Basin Forest in Africa, often referred to as the second lung of the world. Amongst forest resource, there are both timber and non-timber forest products (NTFPs) (Suleiman *et al.*, 2017). NTFPs are defined as products or services coming from forests other than/besides timber, are important sources of nutrition, income, and medicine for the local populations (Ahenkan and Boon, 2011). NTFPs play a significant role in the life of the population by contributing to the economic development, adding value to the forest, and helping to balance the forest environment (Nguyen *et al.*, 2020). The Center for International Forestry Research (CIFOR) defines NTFPs in an inclusive, way considering wood products such as those used for fuel and even art like sculpture. CIFOR's work tends to look at the utilization of forest resources to improve the livelihoods of poor populations in rural areas (CIFOR, 2008). Unfortunately, these products are either underutilized or overexploited, and the overall biological diversity is still declining due to human activities and climate change, causing species loss, deforestation, and degradation, seriously affecting the NTFPs. At the global and regional level, the Sustainable Development Goals (SDGs) and the Africa Union Agenda 2063 mentioned the well-being of all without leaving anyone behind. This requires looking at the assets and the opportunities offered by natural resources, hence our interest in NTFPs. Many works have been done on the exploitation of NTFPs in Africa for the well-being of the local communities (Derebe and Alemu, 2023; Mugisho *et al.*, 2022; Mugido and Shackleton, 2019; Thammanu *et al.*, 2021). The main point is to establish, improve, or develop strategies and ways for sustainable exploitation of natural resources for future generations. The Central African Forest Commission (COMIFAC) has undertaken for decades policies that facilitate the exploitation based on the NAGOYA protocol for the Access to Genetic Resources and the Fair and Equitable Sharing of Benefits. Among those resources is *Prunus africana,* known as *Pygeum*, a multipurpose tree used for the treatment of several ailments and mostly known to cure Benign Prostatic Hyperplasia that affects 50 % of men above 50 years old, to prevent prostate cancer (Dreikorn, 2002; Komakech *et al.*, 2017). This medicinal plant is also used as an aphrodisiac, as well as for the treatment of many other diseases and animal ailments (Muchigi *et al.*, 2006, Jimu, 2011; Vinceti *et al.*, 2013; Komakech and Kang, 2019, Nambooze *et al.*, 2022). The commercial exploitation of *P. africana* bark began in 1972, in Cameroon, as a source of income and medicine to the population and pharmaceutical firms (Ingram *et al.*, 2009; Amougou *et al.*, 2011). Unfortunately, the increasing demand for its bark and the bad harvest techniques have led to excessive exploitation, constituting a danger to the *P. africana* population (Cunningham *et al.*, 2002; Stewart, 2003; Betti, 2008; Amougou, 2010). *P. africana* seed production and irregular fructification continue to threaten the species. In another way, climate change poses a threat to the growth and distribution of *P. africana*. Since 1995, the species has been listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as an endangered species, and by the International Union for Conservation of Nature (UICN) as a vulnerable species in Cameroon (Cunningham *et al.*, 1997; Sunderland and Tako, 1999; Steward, 2003). That is why the sustainable exploitation of natural resources appears urgent to cover the needs of future generation. Facing these challenges, domestication and conservation appear urgent for the survival of the species if not the extinction will occur during the following decades. There is a need to develop techniques for the propagation and domestication of the species. That is why the objective of this article is to present an overview of the characterization, propagation, and conservation techniques or strategies used for better domestication of a few NTFPs with a focus on *P. africana*.

Methodology and approach

To achieve the objectives, a detailed and comprehensive literature review was done to support the topic through a systematic search strategy. This was done across multiple platforms through articles, book chapters written in English and French, also through relevant policy documents addressing the domestication and conservation of *Prunus africana*, as well as some grey literature, such as reports of the Laboratory of Botany and Traditional Medicine of the Institute of Medical Research and Medicinal Plants Studies (IMPM), located within the Ministry of Scientific Research and Innovation (MINRESI), in Yaoundé, Cameroon; and from some African Regional Research Institutes. This was helpful to obtain findings and insights that are not available in peer-reviewed journals. The databases used included Scopus, ScienceDirect, and Google Scholar to ensure broad coverage of both peer-reviewed articles and grey literature. We then used keywords and/or phrases such as "*Prunus africana*," "domestication," "sustainable", "conservation techniques," and "non-timber forest products."

Results and discussion

Overview on the Non-Timber Forest Products

Non-Timber Forest Products include fruits and nuts, vegetables, fishes and gums, medicinal plants, resins, essences, and a range of barks and fibers such as bamboo, rattans, and a host of other palms and grasses (Ahenkan and Boon, 2011). They contribute significantly to the well-being of rural and urban populations around the world (Angelsen *et al.*, 2014; Shackleton and Pullanikkatil, 2018). Many NTFPs are common in community life, such as wild fruits, nuts, or honey, and they contribute to the population's food security and nutrition. Most people (80%) in developing countries rely on these forest products for nutrition and medicine (Anon, 2000). They are also used for subsistence, source of income, and cultural value. The species are traded locally in forest or rural markets, nationally, regionally, and internationally. Marketing and trade of NTFPs have been encouraged by governments and organizations as an opportunity to increase the income of the local population. In Cameroon, more than 32 million USD annually comes from NTFPs, a source of income for 34,000 people and the exploitation of 16 products employs 283,000 persons (Ingram, 2014; Awono *et al.*, 2015). NTFPs are sources of employment through different stages of the exploitation process such as collection, processing, and marketing. It also involved minorities such as women, older persons, and marginalized communities. Women are minorities when it comes to political, social, and economic dynamics. They frequently play important roles in the NTFP sector. However, NTFPs are often underutilized or overexploited. In Ethiopia, NFTPs are neglected, and those products are not included in the country's forest management plans and strategies (Adugna, 2022). However, there is a degradation of natural resources in Kenya where we can note 74% of the overexploitation of NTFPs (Maua *et al.*, 2018). There are also poor domestication and regulation. Despite the importance of these products, there is little data to evaluate their social, economic, and ecological impact. The valorization and vulgarization are still very low for sustainable management.

Characterization of *Prunus Africana*

Biological characterization

Prunus africana, belonging to the Rosaceae family, is a species of the plant kingdom, in the Magnoliophyta phylum, Rosophytina subphylum, Rosopsida class, Rosidae subclass, Rosales order. The genus *Prunus* is the largest tree in the subfamily Amygdaloidea, and *P. africana* is the only member of the genus with known medicinal value on the African continent (Bodeker, 2014). It is found in the middle canopy layer, and its adult trees can reach 40 m in height and 1.5 m in diameter. Young trees have smooth, reddish bark, while older trees have dark, flaky, resinous bark. The leaves are simple and alternate. *P. africana* is therefore an evergreen species. The trunk sometimes has Buttresses at its base, with a concave or convex profile, measuring 08 to 10 cm thick, sometimes branching out in a V towards the ground and extending 01 m from the tree (Tassé, 2006).

Ecological characterization

Prunus africana is a widespread pan-African mountain medicinal tree with its geographic area discontinuous across Africa and is endemic to tropical Africa and Madagascar (Bodeker, 2014). *P. africana* is found at altitudes between 600 m and 3,000 m, but is more common and abundant between 1,000 m and 2,500 m. It is also found in transitional forests between lowland and montane regions (Cunningham and Mbenkum, 1993). Its distribution is significantly influenced by altitude, temperature, rainfall and cloud cover. *P. africana* is present in more than 22 African countries, many of which are in East Africa: Côte d'Ivoire, Bioko, Sao Tomé, Ethiopia, Kenya, Uganda, South Africa, Madagascar, Congo, Cameroon, Democratic Republic of Congo and Burundi (Hall *et al.*, 2000; Betti, 2008). In Cameroon, between 1990 and 2000, ONADEF (Office National de Régénération des Forêts), called now ANAFOR (National Forestry Development Agency) inventories revealed that the species was widespread in around 80 localities covering 06 regions, and particularly belonged to the specific ecosystem of sub-montane forests in the South-West, North-West, Littoral, Centre, West and Adamaoua regions (ONADEF, 2000; Cunningham and Mbemkum, 1993; Whinconet, 2007).

Chemical characterization and biological activities

Chemical characterization is currently used to identify and analyze the content of various *P. africana*-derived components, quantitatively and qualitatively, at different stages and organs such as leaves, bark, stem and root (Nyamai *et al.*, 2015; Begeno, 2020; Rubegeta *et al.*, 2022). Several analytical schemes, involving liquid-solid extractions, saponifications, LC- APCI-MS (triple quadrupole) analysis, chromatographic or HPLC separation, 1D and 2D spectroscopic techniques namely IR, 1H NMR, 13C NMR and DEPT-135 were developed, optimized, and validated to determine the phytochemical compounds of *P. africana* (Thompson *et al.*, 2019; Deresa *et al.*, 2022). *P. africana* is rich in nutrients, antioxidants and various compounds such as atranorin, atraric acid, ursolic acid, oleanolic acid, atraric Acid, lauric acid beta-sitosterol and its esters, ferulic acid and its esters, N-butylbenzene sulfonamide, benzoic acid, two oleanolic derivatives and p-hydroxybenzoic acid compounds (Mutuma *et al.*, 2020; Deresa *et al.*, 2022). Triterpenoids, phenols, sterols, and fatty acids are the most important in *P. africana* (Jennifer *et al.*, 2022). These compounds have been shown to improve the conditions of patients having benign prostate hyperplasia, and enlarged prostate and also manage the inflammation. They are active against fungal and bacterial diseases. Additionally, they are used to treat diarrhea, dysmenorrhea, infertility, irregular menstruation, kidney disorders, fever, obesity, pneumonia, hypertension, malaria, chest pain and other various diseases (Bii *et al.*, 2010; Komakech *et al.*, 2017; Mutuma *et al.*, 2020; Deresa *et al.*, 2022; Jennifer *et al.*, 2022). Chemical analysis highlights useful constituents of *P. africana* with beneficial antifungal and antibacterial activities. The extract and isolated compounds of *P. africana* support could be considered a valuable source of bioactive compounds in antimicrobial drug development and provide scientific proof for their medicinal uses. There is a need for enhanced *P. africana* biochemical analysis with high-throughput techniques to urgently increase biochemical characterization and analyze the beneficial effect of biochemical compounds of ideotypes in various environments, to meet the ever-increasing demand for *P. africana* and its biochemical constituents, that may be useful for its sustainable valorization.

Molecular characterization

Characterization is an important baseline for the domestication process in many species. Molecular characterization or using molecular tools such as DNA, RNA, and proteins, to differentiate plant material is essential for a better conservation of plant resources, and to ensure their sustainable use. This process has been applied to *P. africana* using molecular tools. Therefore, studies have shown high genetic diversity in *P. africana* using molecular tools such as randomly amplified polymorphic DNA (RAPD) (Mucgihi *et al.*, 2006) and microsatellite markers (Avana *et al.*, 2006). The study shows that accessions from Cameroon, West and East Africa are genetically close. However, the genetic structure shown a lower level of genetic diversity in East Africa. *P. africana* accessions from Cameroon accounted for 21 % of the total variation detected in the analysis of chloroplast DNA haplotype (Nzweundji *et al.*, 2020) has no effective phylogeographic component in the genetic structure observed in the western populations. This previous study allowed the determination of the correlation between genetic and geographic distance within and between their populations. Mihretie *et al.* (2015) demonstrated that in Ethiopia, haplotypes of *P. africana* belong to one single lineage and those from East Africa and Madagascar contain haplotypes from up to four more divergent lineages.

Cultivation of Prunus africana

In Cameroon, *P. africana* has been cultivated for over 20 years (Cunningham and Mbenkum, 1993; Tchoundjeu *et al.*, 2002; Rousseau *et al.*, 2017). In terms of industrial cultivation, only 9 ha of pure plantations have been established by the Cameroon Development Corporation (Ndam and Tonye 2004). The annual *P. africana* planting targets of 2 ha set in 1986 and 5 ha set in 1992 (Ndibi and Kay, 1997) were far too small to have a significant impact (Hall al., 2000). Subsequently, the number of trees increased through local communities and personal cultivation of the species. Still, in Cameroon, *Prunus africana* was cultivated in heavily exploited forests, and parallel actions have been launched in Bioko, Equatorial Guinea (Sunderland and Tako, 1999). Macleod (1986) reported that 7,000 *Prunus africana* seedlings available for use on Mount Oku had been “established” in the Forestry Department nursery at Kumbo (North West region in Cameroon and, in the Bui Division), and CERUT (1999) notes that 2,500 seedlings have been “raised” at Mangem for use on Mount Manenguba. More recent plantings have taken the form of progeny evaluation trials, complementing molecular studies examining genetic and chemical variation across the geographical range. In Kenya, attempts to cultivate the plant were underway, a 0.4 ha block at Ngong (Simons al., 1998;

Dawson and Powell, 1999, Dawson al., 2000). This stand was planted in 1913 as a timber stand. Over the following 79 years, a further 64 stands were established in Kenya, bringing the total area planted with *P. africana* to 628 ha. One of the plantations (16.2 ha) was established in Nyeri Hill Forest in 1992. The species gained interest in national and international trade. *P. africana* from Kenya was not growing well in Cameroon, due to the ecological parameters with low altitudes (450 m and below) where young trees proved vulnerable to being attacked by cerambycid borers (Cunningham, 1995). *P. africana* is currently being evaluated on-station in Uganda, Kenya and Cameroon. Plants from Kenya were taller after four years than those from Uganda. Seedling stock was used in the progeny trial (provenance Kibujoi) started in 1998 at Kakamega, Kenya (Simons *et al.*,1998). At Kakamega, the average height was 1.13 m after 15 months of growth, and the tallest tree in the trial was 3.38 m tall. Average 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, the average height was 1.21 m, and there were significant differences in height and diameter between progenies (Marcelin, 1998). In South Africa, Geldenhuys (1981) reported occasional planting in the Bloukrans River Gorge area of Cape Province, in 1969, and Brown (1964) mentioned *P. africana* fire breaks planted during the period 1941-1954 in the Mafuga Central Forest Reserve, Uganda. In Rwanda, arboretum plots of *P. africana* were established at Ruhande in 1953 and 1979, and research plots at Gisovu, Rangiro and Rutovu between 1970 and 1985 (Kabera, 1988; Mbonyimana, 1988).

Domestication of Prunus africana

Plant domestication reduces pressure on wild populations and guarantees supply (Mujike, 2022). However, plant domestication can come up against multiple constraints, including a lack of information on various propagation techniques; plant adaptation to *ex-situ* conditions; high phenotypic plasticity; and issues related to the qualitative and quantitative variability of secondary metabolites produced by plants under *ex-situ* conditions. According to Bonnéhin (2000), plant domestication is a three-stage process through the care of wild plants, plant cultivation, genetic manipulation of the plants to achieve specific objectives, such as the early production of fruit or wood, or the adaptation of the plants to different agroecosystems. *P. africana* domestication has been reported as essential to the plant's survival (Cunningham and Mbenkum, 1993). Attempts to domesticate *P. africana* have been made in several countries in Africa such as Kenya, Cameroon, and Uganda, through generative and vegetative propagation (Komakech *et al.*, 2020; Tchoundjeu *et al.*, 2002). A constraint to the domestication of *P. africana* is the availability of viable seeds in sufficient quantities (Hall *et al.*, 2000).

Propagation methods

Germination and seedling production of P. africana.

The intermediate nature of *P. africana* seeds limits their *ex-situ* conservation (Sunderland and Nkefor, 1997). The best conditions were achieved when the seeds came from ripe fruits and were harvested directly from the trees, shelled immediately after harvesting and then stored, without drying, at 5 °C. Even under these conditions, germination was only 35 % after 12 months of storage (Jaenicke *et al.*, 2004). Long-term storage of *P. africana* seeds as a means of *ex-situ* conservation has therefore proved impossible, although short-term storage during the planting seasons is possible. The recalcitrant nature of the seeds, the irregularity of the flowering and fruiting period, making its sexual regeneration difficult, as well as the overexploitation of the bark reduces the availability of the seedlings. Very few studies have been carried out on the reproductive biology of *P. africana*. The species is generally allogamous, flowering and fruiting over a relatively long period, with the stigmas of each flower being receptive for a short time (Munjuga *et al.*, 2000). It grows on well-drained soils of advanced volcanic material. It can be grown from seed, which can be obtained from the fifteenth year onwards, or from wild plants. Temperatures range from 24 °C to 29 °C, with average annual rainfall around 1,500 meters is suitable. After 02-03 months of storage, the seeds lost their viability. However, reproduction through seed germination gave 50 % after 06 months of storage (Sacande *et al.*, 2004). Nzweundji *et al.* (2019) obtained after 06 months of storage 66 % with 10 mM gibberellic acid and 100% with 10 mM sodium nitrate. Histochemical analyses during germination revealed the presence and mobilization of protein-like bodies close to the embryo axis and accumulations of starch. In addition, during germination and growth of *P. africana*, polyembryony occurred where three shoots per seed were developed (Nzweundji, 2016). This phenomenon of polyembryony is useful for conservation and breeding programs of the species. Good seed production must be achieved at intervals of two or three years. Farmers recognize these limitations and raise the prices of the seeds. In Cameroon, *P. africana* seed has been sold for 8 USD per kg-1 (Cunningham *et al.*, 2014). According to Hall *et al.* (2000), exploratory studies of *Prunus africana* germination success under a range of controlled laboratory and nursery conditions have been reported in several African countries (Cameroon, Kenya, Madagascar and South Africa). From these studies, it became clear that seeds must come from fruits harvested at the right stage of ripening and de-pulped before sowing or storage. For successful long-term storage, suitable temperature conditions must be provided, and the water content of stored seeds should be around 15 %. Doubts as to whether *P. africana* seeds are strictly recalcitrants, as is generally assumed, have been expressed (Were and Munjuga, 1998), and the presence of germination inhibitors in the pericarp of fresh seeds has been suggested (Geldenhuys, 1981). The seed is considered recalcitrant and, unless carefully stored, only a negligible proportion remains viable after a period as short as three weeks (Sunderland and Nkefor, 1997). Were and Munjuga (1998) compared the germination of Kenyan (Kibujoi) seeds from green, violet/green and violet fruit, in each case with and without pulp. The highest initial germination (72 %) was obtained with seeds dried to 15 % moisture 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 around half the initial viability. The effects of pre-treatment and exposure to different light intensities respectively were largely offset by the effect of pulping. Although Sunderland and Nkefor (1997) noted no germination in full light, this effect could not be separated from an associated desiccation effect. A positive view of shade for regeneration is also suggested by Geldenhuys (1981) and shared by Kigomo (1987) who, at South Nandi, Kenya, noted increasing regeneration of *P. africana* (and other species considered shade-bearers) as the light penetrated the diminished terrain. In South Africa (Bloukrans River Gorge), germination percentages of up to 90 % have been reported for freshly pulped seeds, although germination only begins after around 50 days (Geldenhuys, 1981).

Vegetative propagation

The availability of *P. africana* seedlings is hindered due to their recalcitrant seeds. That is why the use of vegetative parts (leaves, stems, roots etc.) of the original plant is needed to produce new plants. The use of growth regulators [Indole-3-butyric Acid (IBA) and Naphthalene Acetic Acid (NAA)] on the juvenile leafy stem cuttings of *P. africana* reduce the mortality of the cuttings which is only between 0-2 % (Kebede *et al.*, 2013). It is noted that the substrate also plays an important role during cutting; and 80 % of rooting was observed in the sawdust (Tchoundjeu *et al.*, 2002). In Cameroon, Kenya and Madagascar, vegetative propagation by cuttings from juvenile *Prunus africana* plants have been carried out with varying degrees of success (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 mixture of the two (78 %). In Kenya, the application of indole butyric acid increased success rates. In Cameroon, clonal trials were launched in 1998 to compare the growth of trees developed from rooted cuttings and trees developed directly from seed. Aerial layering of *P. africana* is also possible, and experimental work in Kenya has shown that success is influenced by substrate but not by the application of indole butyric acid. In Cameroon, using a peat-based substrate, 80 % of air-laid shoots 1-2 cm in diameter on mature trees had produced roots after five weeks, and most survived after transfer to the nursery as independent plants.

Tissue culture

In vitro culture or micropropagation is a technique of tissue culture used to regenerate a whole plant from plant cells or tissues in a nutrient medium in an aseptic environment (Roberts and

Schum, 2003). The technique is important for mass production, and species conservation, for the multiplication of commercial plants. Overcoming recalcitrance in difficult genotypes can be greatly done by using tissue culture through optimization of the key medium components (Benson, 2000). Because the conventional method of vegetative propagation is often limited by some biotic and abiotic environmental conditions such as long flowering cycle and recalcitrant seeds (Min *et al.*, 2010), Micropropagation using nodal segment explant improves the production of *P. africana,* and 98 % of survival rate is observed when using growth regulators (Komakech *et al.*, 2020). 100 % of budding and rooting were observed as well as the development of multiple shoots (Nzweundji *et al.*, 2016). Micropropagation success of *P. africana* is influenced by cytokinin and, the physiological and biochemical status of single node cutting (Nzweundji *et al.*, 2015). An optimum rate of 75 % of root initiation was observed in *P. africana*, and 98% of survival rate after planting on a mixture of sterilized soil and perlite [2:1 v/v (Volume/Volume)] (Komakech *et al.*, 2020). The liquid culture provided 50 embryos per explant from cotyledons after 1 month (Nzweundji, 2016). To date, there are few reports on somatic embryogenesis of *P. africana* using liquid culture. Micropropagation of medicinal plants has become then highly important in providing quality stock plants to meet conservation and pharmaceutical needs (Nilanthi and Yang, 2014).

Mycorrhization

Prunus africana is one of the priority species for domestication in Cameroon (Cunningham et al, 2014; Nzweundji *et al.*, 2020). During the process of domestication, species meet challenges during their growth and development due sometimes to the lack of Arbuscular Mycorrhizal (AM) fungi in the soil. A mycorrhiza is a mutually beneficial association between a green plant and a fungus called mycorrhizal fungus. The plant brings organic compounds (sugars) to the fungus, and the fungus brings water and mineral nutrients (phosphorus). Kamko et al, (2020) found six species of AM fungi belonging to the Gigaspora, Glomus and Acaulospora genera from the *P. africana* rhizosphere. Gigaspora margarita was found to be the best result of its effects on root system development leading to better resistance of the cutting during field transplantation. With 80 % of root colonization by mycorrhizal fungi, seedling heights were significantly increased (Tchiechoua *et al.*, 2020). This mycorrhizal symbiosis could represent an innovative approach to solving the problem of *Prunus africana* regeneration. Tchiechoua *et al.* (2023) also investigated the rhizosphere soils of *P. africana* in Cameroon and Kenya and found abundance with the families Glomeraceae and Gigasporaceae, and less representation of the families Acaulo-sporaceae, Pacisporaceae, and Archaeosporaceae.

Conservation strategies

The domestication of agroforestry species requires, among other things, the development of conservation strategies (Jimu, 2011). Species must be selected for conservation considering their economic importance to the population, their distribution in their natural environment, their conservation status, the use of their potential for improvement livelihood, and policy recommendations (Dawson *et al.*, 2001; Mponya *et al.*, 2020). This is the case of *Prunus africana*, which is a priority medicinal plant for domestication in plant genetic resources conservation programs in Africa (Bodeker *et al.*, 2014). Species conservation can be *in situ* or *ex-situ*. Given the overexploitation of *P. africana*, which has led the species to be classified as vulnerable, several actions have been undertaken for its perenisation (Bodeker *et al.*, 2014).

In situ conservation

In situ conservation involves conserving the genetic diversity of the species in its natural environment. As in the case of *Prunus africana*, it is important to identify the areas in which the plants are to be introduced. To guarantee good conservation, areas such as natural parks or protected zones, or community forests, should be favored. In Kenya's Embu District, for example, 250 sacred forest plots have been identified for reforestation by *P. africana* populations (Dawson *et al.*, 2001). This is also the case of the Chirinda forest in Zimbabwe, which has been established as a forest reserve with the participation of the local population for its protection (Terry *et al.*, 1999). Populations introduced into the sites are propagated from material harvested over a wide area of the species' distribution. This strategy broadens the genetic base of the population and promotes genetic variability for their better survival at the site of introduction.

Ex situ conservation

This involves protecting the species outside its natural environment. This strategy is generally used in conjunction with in situ conservation. The material used for conservation is produced from seed or vegetative propagation (in vitro culture, cuttings, layering) (Nzweundji *et al.*, 2015; Nzweundji *et al.*, 2019). Conservation can take place in gene banks, in plantations or on small family farms in association with other plants. Conserved material needs to have information on its origin and genetic variation (Jimu, 2011). In *P. africana*, seed conservation in gene banks can be very difficult, as seeds are intermediate and lose their viability relatively quickly. Nevertheless, conservation techniques using variations of temperatures, lights and different growth regulators have been developed to increase seed viability for up to 06 months (Nzweundji *et al.*, 2019). *P. africana* plantations have been established in Cameroon and Kenya (Dawson *et al.*, 2001). Lodoen (2009) reported that in the North-West and South-

West regions of Cameroon, 1.5 million trees were planted over an area of 625 ha between 1976 and 2008. In addition, another project based in the Bui department in the South-West region of Cameroon planted 275,000 trees between 1991 and 1994 (Cunningham *et al.*, 2002).

Prunus africana and climate change

There are climatic factors favorable to the growth of *Prunus africana*. The plant thrives in conditions where average annual rainfall is around 2000 mm. Seedlings develop best between 2000 and 3000 mm of annual rainfall (Achoundong, 1995; Awono, 2011). For better growth, *P. africana* annual temperatures should not exceed 29 °C. Their young plants develop best at air temperatures between 24 and 29 °C (Nkuinkeu, 1999). According to CITES, P. africana needs sufficient light for good growth and survival. The wavelength required for good plant growth is around 680 nm. Light appears to be a determining factor in seedling growth and development of seedlings. It's worth noting that seedlings wilt in light levels below 30 %, while at 40 % shade, internode development continues normally (Sunderland and Nkefor, 1997). Conscious of the fact that *P. africana* is an endangered species but occupies an important place in the economy and society, the rate of debarking and the quantities harvested are quite high and guarantee an uncertain future for future generations and especially for the species. Climate change may have an impact on *P. africana* populations. According to some studies, global warming may alter the climatic conditions that affect the area where the tree can thrive, leading to population shifts or changes in natural habitats and therefore the geographical distribution of *P. africana*. All this could have consequences for its survival and reproduction. With global warming, temperatures are rising, which may cause the tree to move to higher altitudes to find more favorable conditions. Climate change, which is associated with an increase in the frequency and intensity of droughts, can affect water availability for *P. africana*, leading to a reduction in its growth and reproductive capacity. Climate change can also make *Prunus* more vulnerable to diseases and pests, as warmer climatic conditions can favor their spread. *P. africana* plays a role in combating climate change in several ways. The plant can absorb carbon dioxide (CO2) from the atmosphere, helping to reduce the levels of this greenhouse gas responsible for global warming. In addition, *P. africana* is a species that promotes biodiversity by providing a habitat for a variety of animal and plant species. Preserving and planting this species in forest ecosystems can help maintain ecological balance and combat the degradation of natural habitats, which are also important factors in the fight against climate change. Overexploitation of this species for its medicinal properties may jeopardize its positive contribution to the environment.

A great deal of research, as well as this one, has sufficiently demonstrated the vital importance of *Prunus africana*. However, problems of conservation, domestication and sustainable use (Mpouam *et al.*, 2020; Mujike, 2022) jeopardize the plant's future survival. Indeed, *Prunus africana* is classified by the International Union for Conservation of Nature (IUCN) as a rare and vulnerable species due to the ongoing degradation of its ecosystem linked to the strong pressure exerted on the resource and the application of unsustainable harvesting methods (Awono *et al.*, 2015). Although its trade has been regulated since 1995 by the CITES Convention, numerous constraints and limitations of a social, economic, political, cultural and technical nature are obstacles to the management of *P. africana*. To ensure a brighter future for *P. africana* in Cameroon, its exploitation is based on quotas allocated annually by the Ministry of Forests and Fauna (MINFOF) to exploitation permit holders (Awono, 2015), we can add the need for sustainable exploitation, by limiting *Prunus africana* harvesting in areas reserved for conservation. For FAO (The Food and Agriculture Organization of the United Nations, 2006), a sub-regional natural resource management strategy is needed. This strategy would target political, socio-economic, commercial and ecological objectives, and should integrate two complementary approaches. The first is to ensure sustainable use of resources in their natural environment (*in-situ*), while the second is to encourage cultivation in agricultural areas (*ex-situ*). Good governance and sustained management of *P. africana* in Cameroon would not go amiss. Ensuring a future for *P. africana* also requires harmonizing the legal and regulatory framework for cultivation with socio-cultural considerations. In most of Cameroon's socio-cultural environments, rules exist to regulate the hazard exploitation of plants with therapeutic values. These include respecting the harvesting period, as well as the traditional method of propagation of the plants. Given these traditional considerations, the exploitation of leaves to the detriment of bark is more sustainable. To protect *P. africana* and other species from climate change, conservation efforts are needed. This may include the creation of nature reserves, the promotion of sustainable harvesting practices, as well as studies on the tree's genetic adaptation to new climatic conditions.

Conclusion and perspectives

The domestication process of NTFPs gives hope for a sustainable management of genetic resources. The techniques used are opening opportunities for domestication and the development of cultivars with desirable traits that will cover the high demand for *Prunus africana*-derived products. The synergistic effects of active components and the complexity of bark extract for the treatment of hyperplasia benign prostatic lead to difficulty in identification and therefore the synthetic production of bioactive compounds. The techniques applied will enable plant propagations of other medicinal plants which could enable their mass clonal propagation and improve the conservation of medicinal plants. Alternative methods of exploitation of the species while conserving the species are ideal. More research needs to be done for the identification of active components from new plants using High-performance liquid chromatography (HPLC) as well as the best acclimatization of plantlets is required.

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