Chapter 9
Biotechnology in Biodiversity Conservation: Overview of its Application for Conservation of Endangered African Tree Species

Thierry D. Houehanou, Achille E. Assogbadjo and Brice Sinsin

Abstract Over the world, one of perspective challenges in biodiversity conservation is how to meet effective conservation of threatened species. In this frame, endangered African tree species is becoming a priority that should attract development of conservation strategies.

Since biotechnology is developing rapidly as conservation strategies of biodiversity targets these last decades, it has been questioned to know (i) the current situation concerning biotechnology and endangered African tree species, (ii) the problems that prevent using of biotechnology in conservation of endangered African tree species and (iii) perspectives to help biotechnology to conserve endangered African tree species. Thus an overview on these questions showed that endangered African tree species have not taken advantages of biotechnologies strategies yet. Few biotechnologies researches based on endangered African tree species have been undertaken until now. This state of knowledge is explained by some difficulties that have been highlighted. Those difficulties concerned mostly characteristics of seeds of endangered African tree species, cost of biotechnologies strategies and bad integration of biotechnology discipline with other ones. They are preventing wide use of biotechnology strategies to conserve endangered African tree species. Considering them, some recommendations have been addressed as perspectives of conservation of endangered African tree species by biotechnology.

Keywords Biotechnology · Biodiversity · Endangered African tree species · Conservation

9.1 Background

Over the world perspective challenges of conservation biology is to protect biological diversity and the processes that sustain it in a context of human disturbance effect (Moritz 2002). Indeed, biodiversity crisis expressed by increasing of number of

T. D. Houehanou (✉) · A. E. Assogbadjo · B. Sinsin
Laboratory of Applied Ecology, University of Abomey Calavi, Abomey Calavi, Benin
e-mail: houehanout@yahoo.fr

M.R. Ahuja, K.G. Ramawat (eds.), *Biotechnology and Biodiversity,*
Sustainable Development and Biodiversity 4, DOI 10.1007/978-3-319-09381-9_9

threatened species or those at risk in one part and extinction of many species (animals and plants) in other part is becoming more perceptible. Extinction rate was estimated 100–200 times higher than historical natural level (Dudley and Parish 2006). According to Engelmann (2010), the number of plants recorded as critically endangered on IUCN Red List has increased by 60 %during the period 1996–2004. However, forest species are among the one taxon that is mostly at risk. In Africa, over 1000 tree species have been reported to be threatened with various levels of threat (WCWM 1998). Regarding the human population growth trend, biodiversity declining will be more and more exacerbated in Africa in future. Indeed, in 1900, the population of Africa was about one-quarter that of Europe one; by 2000, the two regions had about the same demographic weight, and by 2050, Africa population will be three times larger than Europe (Hirschman 2005). Thus, conservation of biodiversity in general and particularly threatened African tree species, is an important task concerning the human scientist population worldwide and mainly the ones in Africa. In this frame, plant biodiversity is receiving great importance. In fact, plant biodiversity is a natural source of medicinal and food products. It provides raw materials for several industries and is able to supply genetic information required for developing sustainable use, management and conservation of most crops (Rao 2004; Cruz-Cruz et al. 2013).

Moreover, biotechnology is become a rapid developing field that has received considerable attention since discover of DNA. Thus, their activities have been intensively focused on plant resources in these last decades. It is applying on major plant crop species as well as on tree species. Its use is allowing breeding programs for improving crop species productivity and their resistance against biological and environmental stress. Although biotechnology activities on plants resources have recently increased rapidly (Dawson and Jaenicke 2006), tree species received little attention on this matter. Biotechnology has been developed on few tree species and those concerned were mostly from high income countries. However, African tree species have been seldom emphasized by biotechnologies activities. This situation is more exacerbated in case of endangered African tree species.

Additionally threatened tree species and particularly those endangered are receiving priorities in biodiversity conservation. Thus, conservation of endangered African tree species by biotechnology should require a critical analysis for efficient using of this tool in frame of biodiversity conservation. What is the actual situation concerning biotechnology and endangered African tree species? What are problems that prevent using of biotechnology in conservation of endangered African tree species? How can we do in perspective to help biotechnology to conserve endangered African tree species?

9.2 State of Knowledge on Endangered African Tree Species (EATS)

Since conservation of endangered tree species represents important task in conservation biology of biodiversity, several researches have focused worldwide on these tree species this last decade to conserve them. However, in Africa endangered

tree species are missing sufficient data for managing and designing their sustainable use or conservation. Indeed, although some African tree species were reported as threatened with various levels of threats on international Red List of UICN, it remains also many others ones without sufficient data and therefore their status is misunderstood. In the tropics, in general and in Africa mainly, the flora was least described (Maxted et al. 1997). Thus, many African tree species that are endangered were not always mentioned in a report due to the lack of information on their distribution, biology, ecology etc. Considering endangered African tree species that have been listed by international or local reports, knowledge related to conservation ecology has been mostly highlighted on these tree species. For instance, in spite of the fact that several African studies (Sinsin et al. 2004; GlèlèKakaï et al. 2009; Adjonou et al. 2010; Houehanou et al. 2011, 2013), focused on endangered African tree species, those studies addressed mostly ecological researches questions. Moreover, few applications were delighted from these ecological researches to secure conservation or sustainable uses of these tree species. This is a general problem of researches in low-income countries. Indeed, researches in developing countries are mostly funding by high-income or developed countries and therefore, applications are not always easy to be done.

Over the world, biotechnology activities as conservation strategies are advancing. Regarding taxa coverage by biotechnologies activities, more than 140 genera received biotechnologies activities in the entire world but most of them took place in high-income regions (Dawson and Jaenicke 2006). FAO (2004) recorded biotechnologies activities in 76 countries with 71 and 3 % undertaken respectively in high-income countries and in Africa. Most of biotechnologies activities of Africa were concentrated in South Africa (FAO 2004). Few biotechnological studies were undertaken in others parts of Africa on endangered African tree species. Those existent studies, concerned characterization of genetic structure of some endangered tree species such as *Adansonia digitata* (Kyndt et al. 2009), *Milicia excelsa* (Bizoux et al. 2009) and *Vitis vinifera ssp. Sylvestris* (Zoghlami et al. 2013). This state of knowledge is showing that African taxa are very few covered at present by biotechnologies activities. Consequently, from state of knowledge it can be concluded that endangered African tree species have not taken advantage of biotechnologies strategies yet, although their conservation is a priority in biodiversity conservation frame.

9.3 What is Biotechnology?

Biotechnology could be split up in two simply words such as biology and technology. It is then “any technological application that uses, living organisms or derivatives, to make or modify products or processes for specific use”. Thus, it concerns a range of scientific tools that, provides powerful methods for the sustainable development of agriculture, fisheries and forestry (Dawson and Jaenicke 2006).

Biotechnology is not sum up to genetic engineering as considered by many people but it includes genetic engineering and is much wider than this one (Dawson and Jaenicke 2006). Hence, according to Dawson and Jaenicke (2006), biotechnology can come at present into four areas such as (i) tissue culture and micro propagation, (ii) characterizing genetic diversity, (iii) genetic maps, marker assisted selection and genomics and (iv) genetic modification.

9.4 Summary of Biotechnology Conservation Strategies

Four main conservation strategies are developing biotechnologically to promote management, sustainable use and conservation of plant biodiversity. There are generally grouped into (i) tissue cultures and micro propagation, (ii) characterizing genetic diversity, (iii) genetic maps, marker assisted selection and genomics and (iv) genetic modification.

- Tissue culture and micropropagation
  This area is also called *in vitro* techniques and includes the use of cryopreservation and other storage methods for *in vitro* conservation of plant material. However, *in vitro* culture covers a wide range of techniques involving the growth under sterile conditions of plant germplasm (especially shoot tips, meristems, somatic embryos or embryogenic callus) (Paunescu 2009). In general, *in vitro* culture could be divided into two categories such as: (i) slow growth procedures, where germplasm accessions are kept as sterile plant tissues or plantlets on nutrient gels; and (ii) cryopreservation where plant material is stored in liquid nitrogen (Rao 2004). Cryopreservation is the technique that ensures the safe and long-term conservation of the germplasm of species.
- Characterizing genetic diversity
  Characterizing genetic diversity includes biotechnologies areas applications that partition variation within and between populations of a species and aims to (i) assess reproductive biology (gene flow, breeding systems) of species and (ii) detect the relationships between taxa (phylogenetics),hybridization and human impacts on plant populations (Dawson and Jaenicke 2006). Molecular approaches based on genetic variation by determination polymorphism in DNA have become more available in these two last decades (Jamnadass et al. 2009; Dawson et al. 2009). Indeed, DNA-based techniques introduced over the past two decades have potential to identify polymorphisms represented by differences in DNA sequences. These methods have advantages, to analyze variation at the DNA level itself, excluding all environmental influences (Rao 2004).
- Genetic maps, marker assisted selection and genomics
  This area of biotechnology activity starts since 1990s, and aims to develop molecular markers and genetic linkage maps for identifying statistical associations between markers and genes that control a proportion of the genetic and phenotypic variation of a given trait (Dawson and Jaenicke 2006).

- Genetic modification
  Genetic modification is the use of recombinant DNA and asexual gene transfer methods that alter the structure or expression of specific genes and traits (Dawson and Jaenicke 2006). A genetic modified organism or transgenic, is one that has been obtained by the insertion of one or more genes from another organism. Active research in this area has been ongoing since the 1980s.

9.5 State of Knowledge on Application of Biotechnology Strategies on Endangered African Tree Species

As biotechnology strategies are receiving interest in biodiversity conservation these last decades, it become important to highlight an overview on how its application are growing with endangered African tree species. As different conservation strategies of biotechnology exist, they have not been applied with the same importance on endangered African tree species. Biotechnology area of *in vitro* culture and cryopreservation has been used easily to collect and conserve genetic resources that are difficult to conserve as seeds (Rao 2004). This has involved development of several *in vitro* techniques for storage of species that propagate by vegetative or that produce recalcitrant seed. While cryopreservation has been established for conserving mostly vegetative propagation species, it is much less advanced for recalcitrant seed species (Rao 2004). Indeed, according to this precedent author, recalcitrant seeds are high sensitive to desiccation and their developmental stage and water content at maturity are complex and heterogenic. In comparison with crop species, only limited research has been performed on rare and endangered species with this biotechnology strategy. Moreover, although propagation technique could be used in conservation of endangered species, this technique was not widely applied in Africa (Wala and Jasrai 2003; Mng'omba et al. 2008). Numerous endangered plants on which researches have been focused for applying biotechnology strategy like *in vitro* technique have been from temperate and tropical origin (without Africa) until now (Engelmann 2010).

Characterizing genetic diversity strategy has been applied widely on tree species over the world. In Africa, it has been used for some specific cases. For instance domestication program and conservation approaches of bush mango species from Central and West Africa have been guided with genetic diversity approach (Lowe et al. 2005). However, regarding genetic diversity study of endangered tree species in Africa, this is enough limited.

The two remaining biotechnologies areas ((i) Genetic maps, marker assisted selection and genomics and (ii) Genetic modification) are least applied in Africa on plant genetic resources until now. Consequently endangered African tree species have not been well focused by these biotechnologies researches areas.

9.6 Updating of Conservation Approaches on Endangered African Tree Species

There are two approaches (*in situ* and *ex situ*) for conservation, which are globally used to conserve plant biodiversity in the entire world. *In situ* conservation involves maintaining plant biodiversity in their natural areas while *ex situ* conservation on the other hand, involves conservation outside the natural area (Rao 2004). According to this last author *ex situ* conservation approaches is generally suitable to conserve in danger species population. Therefore, *ex situ* conservation strategies should be used mostly on endangered tree species. However, as the global strategy of plant conservation states that at least 60% of threatened plant species should be within protected areas (Vellak et al. 2009) there is increasing concern about the extent to which *in situ* conservation strategies contribute to conserve mostly endangered plant species. Thus, *in situ* and *ex situ* conservation approaches should be combined to design conservation strategies and secure conservation of endangered tree species particularly the African ones.

By past, most biotechnologies activities for conservation approaches focused on crop species and agroforestry ones. This is revealing that wild tree species were neglected in conservation strategies. Although, *ex situ* conservation approaches is seen sometime as the only option for conserving some highly endangered and rare species (Ramsay et al. 2000), the traditional conservation approach of *in situ* is used generally to conserve wild tree species. Then, in the case of wild tree species, conservation approaches of *ex* and *insitu* could be combined for their conservation. In this context, botanic gardens that play important role in *ex situ* conservation of plant biodiversity (Engelmann 2010), are able tool that combine sometimes *ex* and *in situ* conservation approaches. Indeed, in the botanic garden, some plants that are present can be in their natural areas while others ones can be outside of their natural area. Highlighting importance of botanic gardens in plant biodiversity conservation, it has been estimated that botanic gardens conserve more than one third of the world's flowering plants which among more than 15,000 threatened species have been identified (UNEP 1995; Engelmann 2010; http://www.bgci.org/ourwork/1977/). This is involving that Botanic gardens over the world are guarantying conservation of most endangered African tree species.

Apart of Botanic gardens, value of agroforestry ecosystems for conserving plant biodiversity through tree species diversity, has become more widely recognized by several researches (Kindt 2002; Kirschenmann 2007; Dawson et al. 2009). This approach named *circa situ* conservation permitted conservation of lots tree species among which some endangered African tree species, in agricultural landscape such as *Adansonia digitata, Milicia excelsa* etc. Thus, conservation of diversity of endangered African tree species by agroforestry ecosystems is promoting world widely.

9.7 Biotechnology Strategies in Relationship with Conservation Approaches of Biodiversity

Each of biotechnology strategies contributed to each conservation approach of plant biodiversity. Biotechnology strategies like seed storage, field gene banks, DNA and pollen storage contribute exclusively to *ex situ* biodiversity conservation. They are used to conserve biodiversity plant outside their natural area. However, characterizing genetic diversity is used to assist in developing both *in situ* and *ex situ* conservation of biodiversity. More generally results of this biotechnology area are used to develop genetic conservation strategies of biodiversity plants in their natural area. Moreover, comparing *ex* and *in situ* conservation approach of plant biodiversity, it has been argued that *in situ* approach has some advantages (Maxted et al. 1997). Firstly, it allows the process of evolution to continue in relationship with other biological systems of concerned species habitat. Indeed, none species is static but is continually interacting with physical environment and is competing with other species in the ecosystem. Secondly, it is much easier to conserve viable population of species in their natural habitat rather than in an *ex situ* situation. Therefore, using characterizing genetic diversity should be more accounted for *in situ* conservation approach of endangered African tree species. Then, although biotechnologies strategies that contribute to *ex situ* conservation have focused lowly on endangered African tree species until now, it would be better to develop in future mostly research that will be able to contribute to their *in situ* conservation.

9.8 Difficulties Linked to Biotechnologies Strategies Application on EATS

As various biotechnology strategies are being used for biodiversity conservation, application of each of them defined above, has some advantages and disadvantages in the context of endangered African tree species. Disadvantages allow application to be difficult on endangered African tree species and are summarized in below points.

- Characteristics of seeds of endangered African tree species: As a large number of important tropical and sub-tropical tree species produce recalcitrant seeds; seed storage strategies are not possible (Roberts 1973). According to Engelmann (2010) numerous forest tree species, especially from tropical origin, produce recalcitrant seeds (i.e. seeds that cannot be dried to sufficiently low moisture level to allow their storage at low temperature; see Roberts 1973). Then, conservation of endangered African tree species by *in vitro* technique would be very difficult. This situation is reinforced by the fact that tropical and sub-tropical tree species are ecologically viable in environment of high temperature. Consequently it would be more difficult to conserve their seed in very low temperature comparatively to seeds of temperate regions that are naturally adaptive to low

temperature. Therefore, conservation with *in vitro* technique would be more suitable for trees of temperate regions.

- Cost of biotechnology strategies: All biotechnology strategies are costly and time consuming and are generally applied to one species at a time (Dawson et al. 2009). Additionally, many biotechnology techniques require considerable investment in infrastructure, consumables, staff salaries and training (Dawson and Jaenicke 2006). This is preventing application of biotechnologies strategies on most endangered African tree species and explains why until now most biotechnology researches are conducted in high-income countries.
- Biotechnology strategies require to be integrated approach: Although characterizing genetic diversity can reveal great detail about genetic variation in trees species, application of results has been very limited (FAO 2004; Dawson et al. 2009). This situation has been explained by the fact that molecular approaches did not combined generally others aspects such as social, ecological or economical. In the context of endangered African tree species those aspects will need to be integrated to make easy application of results.

9.9 Future Recommendations for Better Conserving Endangered African Tree Species with Biotechnologies

Considering difficulties linked to biotechnologies application on endangered African tree species, and requirement of its conservation, it would be better to take into consideration some issues.

- Updating of list of endangered African tree species for allowing conservation researches on more exhaustive list. Thus, each African country should work for establishing local red list of tree species. Such list could be accounted for a regional or country scale list of endangered African tree species.
- African countries should develop their own funding biotechnology research on priorities endangered tree species. Such a self-funding research would enhance facility in results application. Then, after establishing list of endangered tree species, a prioritizing species for biotechnology strategies will become important. Regarding context of limited financial resources in Africa, prioritizing should be required on endangered African tree species for developing biotechnology strategies efficiently.
- As biotechnologies strategies are generally costly and time consuming and applied to one species at a time, alternative would be researching on technique that can be more easily used on many species.
- Regarding application of biotechnologies results that was limited in Africa and particularly on endangered African tree species, biotechnologies specialists should work in future in collaboration with other disciplines such as social, economic, ecology etc. Interdisciplinary science will reinforce application of biotechnologies results on endangered African tree species.

- Developing partnership between African and high-income countries should be an opportunity to enhance biotechnology research on endangered African tree species.
- Enhancing genetic diversity characterization researches of endangered African tree species will be opportunity researches in future.
- Prioritizing *in situ* conservation approach on endangered African tree species by enhancing research on prioritizing area for conservation of endangered African tree species should be required. Such research would be a part of a new concept (*gap analysis of protected area*) process for biodiversity conservation.

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