

## FIELD GENE BANKS MAY IMPEDE INSTEAD OF PROMOTE CROP DEVELOPMENT: LESSONS OF FAILED GENE BANKS OF “PROMISING” BRAZILIAN PALMS

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### SUMMARY

In Latin America, several field genebanks were created to promote the use of “underutilized” palms during the 1970s and 1980s. Two decades later it can be concluded that these genebanks did not contribute to increased use of the target species, nor to their genetic improvement. Some have already disappeared and others are threatened with the same fate. The work on genetic conservation during that period did strengthen the mistaken idea that improvement of native tree species starts with the creation of a genebank. The question of germplasm conservation is important when genetic erosion is occurring, as happened from the mid sixties onwards with rice, wheat and maize due to the massive acceptance of modern, green-revolution, varieties. The “underutilized” palms didn’t have improved varieties; they still don’t have these today. A lot of energy went into germplasm characterization with extensive lists of descriptors, but the results were of little practical interest. It proved to be very difficult, often impossible, to obtain sufficient financial support for the field genebanks each year, with the result that these often absorbed the scant resources available for palm domestication and other work. The genetic improvement of new tree crops should start with comparative trials of promising materials, using an appropriate experimental design. When a genebank is necessary, its design should avoid pollination between promising and not promising materials and between different varieties, while diminishing the possibility of crosses between plants of the same family.

**KEY WORDS:** genetic improvement, germplasm bank, new tree crops, palms.

### RESUMO

## BANCOS DE GERMOPLASMA PODEM IMPEDIR O DESENVOLVIMENTO DE UMA CULTURA AO INVÉS DE PROMOVÊ-LO: LIÇÕES DE BANCOS DE GERMOPLASMA DE PALMEIRAS BRASILEIRAS “PROMISSORES” QUE FALHARAM

Nos anos setenta e oitenta foram criados, na América Latina, diversos bancos de germoplasma para promover o uso de palmeiras “subutilizadas”. Passadas duas décadas, pode-se constatar que esses bancos não contribuíram para o maior uso dessas espécies, nem para seu melhoramento genético. Alguns já desapareceram e outros estão ameaçados de desaparecer. O grande trabalho com conservação genética, da época, fortaleceu a idéia errada de que um programa de melhoramento de uma espécie arbórea nativa se inicia com a criação de um banco de germoplasma. A questão da conservação de germoplasma se impõe, se ocorrer erosão genética séria, como no caso de arroz, trigo e milho pela aceitação maciça das variedades modernas da Revolução Verde, iniciada em meadas dos anos sessenta. As palmeiras “subutilizadas” não tinham e ainda não têm variedades melhoradas. Utilizando-se extensas listas de descritores gastou-se muita energia na caracterização dos materiais genéticos,

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mas os dados obtidos não se mostraram de grande interesse. Garantir, a cada ano, suficientes recursos para a execução adequada do trabalho com os bancos, mostrou-se muito difícil, ou até impossível. Os bancos de germoplasma acabaram absorvendo os poucos recursos para a domesticação dessas palmeiras prejudicando outras atividades. O melhoramento genético de novas culturas arbóreas deve-se iniciar com ensaios comparativos de materiais promissores, com desenho experimental apropriado. Quando um banco de germoplasma é necessário, seu delineamento deve evitar polinização entre material promissor e não promissor e entre variedades diferentes, e diminuir a possibilidade de cruzamentos entre plantas oriundas da mesma matriz.

**PALAVRAS CHAVE:** banco de germoplasma, melhoramento genético, novas culturas arbóreas, palmeiras.

## INTRODUCTION

Many tree species are of potential interest for development into new crops. Interesting candidates can be found among the thousands of tree species used by subsistence farmers (Simons & Leakey, 2004). What would be the most appropriate method of starting the genetic improvement of such a new tree crop? The collection of its germplasm and the installation of a genebank are often seen as the starting point for the genetic improvement of a native tree species. Is this the best approach? For most seed-propagated tropical trees, with short-lived seeds, field genebanks are the only feasible form of *ex situ* germplasm conservation. This paper will describe Brazil's negative experience with field genebanks for "underutilized" palms, and discuss aspects of the genetic improvement of new tree crops and related germplasm conservation.

## THE SEVENTIES: CONCERN FOR CROP DIVERSITY CONSERVATION

In the mid 1960s, the rapid substitution of local food crop land races by scientifically bred varieties began in the Third World. In 1970, over 10 Mha were sown with modern wheat varieties, mainly in India and Pakistan, and about 10 Mha with modern rice varieties, mostly in India, the Philippines, Pakistan and Indonesia (Simmonds, 1981). Maize and less important annual food crops followed suit (Morris & Bellon, 2004). This development caused increased concern about genetic erosion, leading to the creation of several institutions dedicated to germplasm conservation: 1974, the International Bureau for Plant Genetic Resources (IBPGR), later renamed International Plant Genetic Resources Institute (IPGRI); 1974, Brazil's National Center for Genetic Resources (CENARGEN), later renamed National Center for Genetic Resources and Biotechnology; 1976, the Genetic Resources Unit of the

Tropical Agricultural Centre for Research and Training (CATIE). National and international support was made available for germplasm conservation, including the creation of genebanks and the collection of germplasm. Attention also went to species of much less economic importance, including "promising" species without current economic importance.

Concern with conservation of genetic resources did not start in the seventies but an important change in emphasis occurred, attributing increased importance to the creation and maintenance of *ex situ* collections, called germplasm banks or genebanks. "[This] strategy of genetic conservation starts from the view that, in the not-so-long run, living materials of all crops and their relatives will have to be maintained in substantial collections in perpetuity" (Simmonds, 1981). Before this change of emphasis, a genebank often coincided with the breeding collection used to develop new varieties; after this change, genebank genebanks were recommended which should contain the broadest possible representation of the genetic diversity of the species (Williams, 1995), since, in theory, any gene could end up being useful in unforeseen future circumstances. Curators of germplasm collections existed before the seventies, but now they gained a distinct professional profile, while their importance and number increased. This had consequences for the way germplasm was collected. In the past the starting material for a breeding program was normally obtained by prospecting populations for outstanding plants, but Marshall and Brown (1975) concluded that often the best strategy is to collect large numbers of more or less random small samples. The screening of stands for superior phenotypes was now partially substituted by the collection of large numbers of random samples or, when random sampling proved difficult, by collecting as much diversity as possible (Clement and Coradin, 1988). To describe all that diversity IBPGR prepared long lists of descriptors, an activity followed in many countries.

## THE UNSUCCESSFUL DEVELOPMENT OF “UNDERUTILIZED” PALMS OF TROPICAL AMERICA

Underutilized palm species of Tropical America were among the species receiving special attention in the 1970s and 1980s, stimulated by a National Academy of Sciences study (NAS, 1975). A series of meetings (e.g., FAO/CATIE, 1984) were held to exchange information and discuss research and development programs (Coradin & Lleras, 1988; Lleras & Coradin, 1988). To prepare for the breeding of these palms, expeditions for the collection of germplasm were organized and field genebanks installed.

In 1975, the National Research Institute for Amazonia (INPA), Manaus, Brazil, launched an enormous research program for one of these underutilized palms, *Bactris gasipaes* (peach palm, *pupunha*), because of its starchy-oily fruit used for direct human consumption and of possible interest for the production of flour for baking, animal ration and oil, and the species' potential as a source of heart-of-palm (Kerr *et al.*, 1997; Mora Urpi *et al.*, 1997). A field genebank was started in 1977 and later expanded with germplasm from four USAID-supported, international expeditions to the Amazonian regions of Brazil, Peru, Ecuador and Colombia, after which it contained 450 different accessions of 9 half-sib plants each and occupied more than 10 hectares. Expeditions and genebank establishment also took place for potential oil species, such as *Attalea speciosa* (*babaçu*, syn. *Orbignya phalerata*), *Acrocomia aculeata* (*macaúba*) and *Oenocarpus* (several *bacaba* species, and *patauí*, *O. bataua*, syn. *Jessenia bataua*). For *Acrocomia aculeata* more than 100 populations were sampled and a genebank of 9 ha was established. For *Attalea speciosa* and related species more than 200 populations were sampled. The sole reason for the creation of those genebanks was to start the breeding of these species; serious genetic erosion didn't occur and improved varieties which might substitute local germplasm were nonexistent; they are still nonexistent today.

The lay-out of the genebanks didn't follow a specific design. The accessions collected in one season were raised in a nursery and planted in the next rainy season, using nine trees (planted in a square) to represent the accession. The thousands of palms in the genebanks were to be characterized and evaluated, but this was seldom completed. Development of descriptor lists to guide characterization was taken seriously, as recommended by IPGRI; it was the subject of several undergraduate and post graduate theses, but few practical results were obtained beyond testing the lists. Once evaluated, controlled crosses among selected individuals were to

follow (Mora-Urpi *et al.*, 1997), but that phase was seldom reached in most projects, generally for lack of funds. A FINEP-financed project at INPA allowed the execution of several hundred controlled crosses, but funds were insufficient to take these to the field due to national economic instability.

The work described here on four groups of underutilized palms didn't contribute to their development as crops. With the end of the oil crisis in 1986, and the difficult financial situation (in February 1987 Brazil declared a moratorium on part of its foreign debts), the support for this work was reduced to a minimum. No new oil crops had been developed or were on the way to being developed. *Bactris gasipaes* turned into a very successful heart-of-palm plantation crop, but INPA's main genebank was not of interest for the development of a heart-of-palm variety; it is more practical to select the spineless plants preferred for heart-of-palm production in Yurimaguas, Peru, where they dominate the local land race. *Bactris gasipaes* fruit didn't succeed as a source of flour, meal, animal ration or oil (for a discussion of possible reasons see Clement *et al.*, 2004). Its main use continues to be its consumption, after boiling, as a snack. Although the Amazonian fruit market developed very well in the last decades, 25 years of research and development on *B. gasipaes* didn't promote the use of its fruit (Clement *et al.*, 2004).

It proved to be very difficult, often impossible, to obtain each year sufficient financial support for the field genebanks; the costs to maintain, characterize and evaluate the *B. gasipaes* germplasm bank at INPA were estimated to be US\$ 177,500 over two decades (not considering surveillance against theft of fruit, necessary equipment for characterization and evaluation including office equipment, use of office space, transport, supervision and overhead of the research institution) (Clement, 2001). Often the work on these palm field genebanks used most, or all, of the limited resources available for crop development. As a result, other ways of contributing to the development of these palms didn't take place, while crop development of other species suffered seriously.

Today the genebanks of *Acrocomia aculeata* and *Attalea spp.* have disappeared, while the genebanks of *Oenocarpus spp.* and *Bactris gasipaes* are menaced with the same fate. Nevertheless enthusiasm for germplasm field banks remains high (e.g.: the call for research proposals for the conservation and sustainable development of Brazil's Amazon, CNPq 2005) and new attempts to create them continue to occur.

Many of those involved in the study, development and promotion of useful trees consider that it is established wisdom that genetic improvement of a native tree species

starts with the establishment of a genebank. This point can also be illustrated with two studies of the Amazonian palm, *Astrocaryum tucuma* (*tucumã-do-amazonas*, syn. *A. aculeatum*), whose fruit pulp is considered a delicacy by the population of Manaus, Amazonas. About a decade ago, Manaus' emerging *cafés regionais*, a buffet restaurant specialized in local foods, started selling *tucumã* sandwiches. In this way *A. tucuma* entered the fast-food circuit, began to increase in economic importance and started receiving more attention from researchers. The first article in a refereed scientific journal, dedicated exclusively to this palm, was published in 1999 by Kahn & Moussa. The authors conclude that the palm has favorable conditions for genetic improvement, however, it doesn't have an *ex situ* collection. The second article in a refereed journal (Schroth *et al.*, 2004) summarizes the common domestication plan for a palm as germplasm collection and breeding, while presenting a complementary option. These two studies of *A. tucuma* seem to consider a field genebank as the natural starting point for this native tree's genetic improvement.

## GENETIC IMPROVEMENT OF NEW TREE CROPS

As it takes years to select, breed and test the results obtained, time is one of the most important considerations in a tree improvement program. Improved genetic materials should be made available as quickly as possible, even if this requires the use of some shortcuts (Zobel & Talbert, 1984). Early results will also help to maintain support for the program. Even if sufficient financial backing is available at the start, a simple improvement approach is to be preferred. Continued support cannot be taken for granted, as long as the new crop doesn't have real social-economic importance. An uncomplicated approach will give certain robustness to the program, facilitating the maintenance of part of the activities when support decreases (e.g., by substituting progenies of planned crosses by open-pollinated ones).

A simple approach to the genetic improvement of new tree crops is also the most appropriate one, as trees are outbreeders and candidate species will show high variability between and within populations, permitting the use of breeding methods based on mass selection. Differences in productivity will be the most important feature to evaluate. This quantitative aspect can only be measured with precision in trials with repetitions. Consequently, the first generation of field trials will consist of comparative experiments of promising seed sources, with an appropriate statistical design. These promising seed

sources can be land races, in the case of species already domesticated, and provenances in the case of 'wild' species. Seed for these trials should come from outstanding trees and not from randomly selected ones. If the most appropriate land race is already known, the program can start with selection of superior trees followed by open-pollinated progeny trials (e.g., Cornelius *et al.*, in press). These trials will give information on within and between family variability, which can be used for selection aimed at improved seed production in these same trials. With this approach, already the first generation of field trials can furnish improved material for planting, meeting the demand for rapid delivery of results of practical use to farmers.

The use of breeding methods based on mass selection for new tree crops has an important consequence in terms of the need of characterization. Even though Simmonds (1981), correctly warns against over-emphasizing germplasm characterization, detailed characterization might be useful for annual crops for which variety development requires a series of successive generations. In that case it can be imagined that sometimes plants with a very special combination of traits are needed, justifying the detailed description of germplasm. For new tree crops detailed germplasm characterization is superfluous, as simple breeding methods based on mass selection will be used.

## TREE FIELD GENE BANKS

When a species' germplasm is conserved *in situ*, by farmers or as part of the natural vegetation, there is no need for *ex situ* conservation. In these cases a breeding collection is sufficient. In practice such a "breeding collection" may largely, or completely, coincide with the above mentioned comparative field trials. If an unforeseen need for plants with certain characteristics arises, the species' distribution will present the best possibility for identifying and selecting the appropriate plants.

The importance of large genebanks for annual crop breeding seems to support the use of genebanks in the genetic improvement of new tree crops. Such an argument does not take into account the differences between trees and annual crops. Because of their size and duration tree field genebanks are much more expensive than are similar collections of annual crops. Germplasm accessions of crops such as rice or maize will occupy a small piece of land for some months in order to be described and evaluated. The seed of these accessions can then be stored for decades in cold storage. Tree field genebanks on the other hand will occupy much larger areas, not for months but for many, many years; they can only be discontinued if feasible methods for *in vitro* storage become available.

When adoption of new varieties causes genetic erosion, timely action is much more difficult in the case of annual crops. The substitution of annual crop germplasm can happen very rapidly, as the total crop area is renewed yearly. In the case of trees, variety substitution will be a slow process, as trees, like annuals, will normally only be substituted when they complete their economic cycle. It will take many years before all plants of a tree species have reached maturity and need to be replaced. In the case of trees, once genetic erosion through variety substitution has started, there will be ample time to act, while the ongoing elimination of local tree germplasm can be helpful in finding the necessary support for actions towards its conservation.

If serious genetic erosion occurs and a tree field genebank needs to be installed, its correct design is essential. A badly designed, annual-crop genebank can be corrected in a year; with trees the opportunity to correct the design will only present itself much later, if at all. The tree genebank will serve to distribute seed, normally open-pollinated, to researchers and interested laymen. Therefore the lay-out must avoid undesirable pollination. Such a design may also allow renovation of the genebank without the necessity of controlled pollination. Separate genebanks, at a sufficiently large distance from each other, are needed for promising and not promising germplasm. The same goes for plots with different land races.

Within-family pollination is generally undesirable because of possible inbreeding depression. The best option is to use one-tree-plots; an acceptable, but not as good alternative, is having the plants of the same family in a row. Planting a rectangle or a square per family should always be avoided. The installation of a well designed field genebank will need extra time and supervision, but is a necessary investment. A field genebank proposal for a perennial species should never be approved without a careful examination of the proposed design.

## CONCLUSIONS

Major annual crops will need special genebanks, but new tree crops normally won't, because of the differences between trees and annuals in plant size, generation length, breeding methods, and the speed with which genetic erosion by germplasm substitution is likely to occur. For the genetic improvement of a new tree crop special field genebanks are not only unnecessary, they can even be detrimental, as they absorb vast amounts of resources and divert attention from the real objective, the development of a new crop. Their establishment should only be considered when serious genetic erosion can be shown to occur.

Too much is often expected from genebanks. The diversity of the many, potentially useful tree species cannot be saved by *ex situ* field genebanks, to serve for variety development at an unknown moment in the future, when there supposedly will be more interest in their use. In fact, it is just the other way around. A species' social-economic importance can create the need and justification for its conservation. One of the first steps in promoting increased use of new tree species is genetic improvement to produce better varieties as soon as possible. Often, the rest of the development depends upon this first step being efficiently and effectively taken.

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