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Working Paper

SELECTED SPECIES AND STRATEGIES TO ENHANCE INCOME GENERATION FROM AMAZONIAN FORESTS

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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This document is a working paper. It documents information forming part of a larger study and informs interested persons about work in progress.

It is made available in limited numbers for comment and discussion.

Preface

This document was prepared under author's contract by Messrs. Jason Clay (Cultural Survival Enterprises, Inc., Cambridge, Massachussetts, U.S.A.) and Charles Clement (Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brasil), supported by a number of experts, as one of the several Regional and Country Studies on Non-Wood Forest Products (NWFP), commissioned by FAO.

This, along with other similar and related studies, will be used for preparing a substantial publication of wider coverage on NWFP.

Comments on the document, (along with supporting materials as relevant), will be greatly appreciated.

Contents

Acronyms

AEZFM	Association of Exporters from the Free Zone of Manaus
CENARGEN	National Center for Genetic Resources and Biotechnology
CGIAR	Consultative Group on International Agricultural Research
CITA	Food Technology Research Center (Costa Rica)
CPATU	Agricultural Research Center for the Humid Tropics
CS	Cultural Survival
CSE	Cultural Survival Enterprises
CTM	Wood Technology Center (Brasilia, Brazil)
EMAPA	Agricultural Research Enterprise of Maranhao
EMBRAPA	Brazilian Enterprise for Agricultural Research
FAO	Food and Agriculture Organization
FINED	Financiadora do Estudos e Projetos
FUPEF	Foundation for Forestry Research
IBGE	Brazilian Institute of Geography and Economics
INPA	Nation Research Institute for Amazonia
NWFP	Non-Wood Forest Products
RADAMBRASIL	Radar Mapping of Brazil
SUDAM	Superintendency for the Development of the Amazon
SUFRAMA	Superintendency of the Free Zone of Manaus
USDA	United States Department of Agriculture
WHO	World Health Organization
WWF	World Wildlife Fund

Abbreviations and Key to Symbols

≈	approximately
DBH	Diameter at Breast High
FOB	Free on Board
>	greater than
ha	hectare
ind.	individual
K	potassium
<	less than
Mg	magnesium
min.	minute
MT	metric tons
N	nitrogen
P	phospherous
ppm	parts per million
±	plus or minus
SD	Standard Deviation
T	ton
yr	year

Introduction - Conservation and Development

Jason W. Clay & Charles R. Clement

Conservation is a people issue more than a biological one. Environmental problems like acid rain and ozone depletion don't create themselves, people do. Likewise, rainforests don't cut themselves, people do. If these issues are to be addressed head on, we need to look beyond the symptoms to the root causes.

The major causes of environmental degradation, including Amazonian rainforest destruction, are population pressure, poverty, greed and ignorance. These play their roles within the numerous political systems of the modern world and economic models designed to enhance industrial growth at the expense of natural resource conservation. Consequently, attempting to conserve biodiversity in Amazônia by preserving entire ecosystems is not a viable option, because it fails to recognize the presence of a large human population in the region with all of their diverse preferences and needs. Conservation, defined as the wise use of resources to enhance the quality of present and future life, not preservation, is the key. In Amazônia, as in most of the Earth's fragile ecosystems, it is a use it or lose it proposition.

Over millennia, people have interacted with the Amazonian forest, modifying it significantly from its primeval state. Thus, the forests of today are human creations and are constantly used by long-term forest inhabitants and by newcomers to the region. According to some biologists there are not 10 km^2 of Amazonian rainforests that have not been altered by people (Kent Redford, pers. com.). In addition, virtually all rainforests, in Amazônia or elsewhere in the humid tropics, are already claimed by someone. To degrade them, the rights of the people who already live there must be denied. In Brazil, for example, one indigenous group has disappeared each year since 1900, 90 groups out of 270. In other countries the situation is similar. Worldwide, cultural destruction precedes and even out paces the destruction of the forests.

The long-term survival of the rainforests and their residents depends upon the development of successful strategies to meet the economic needs of people while maintaining biodiversity. Fortunately, scientists and international and national development agencies are beginning to understand what forest residents have long known, namely that forests are capable of generating more income and employment than the same areas cleared for pasture or high tech modern agriculture.

Yet, to date, this is all theory, because the subsistence and extractive products obtained from the forest are not adequately valued in the economic model or are ignored completely. A practical model of sustainable forest development, with a more equitable relationship with external markets, has never been fully implemented or tested in a modern economy.

Forests were viewed exclusively as sources of industrial timber and all other forest products and services were ignored. An unforeseen consequence of this new view was the increased repression of forest peoples so that their timber could be extracted for the national and international markets and the improvement of the national balance of payments equation. Naturally, other forces act to repress forest peoples also, such as inter-ethnic political rivalries, colonization pressures, etc.

Only in the last decade has the tide started to swing back towards the earlier view of the forest as a storehouse of products and services. The momentum, however, remains with the "industrial" foresters and economists, because this restricted view of the forest favors those currently in political and economic positions of power. Even the term "non-timber forest products", used frequently, highlights the dominance of the industrial timber orientation.

This report discusses some of the factors necessary to develop and manage income-generating forests and what will be required to successfully process and market the numerous products that can be obtained from these forests. In addition, 19 chapters of this report provide information on specific species which appear to have considerable income-generating potential. Only a small sample of species which produce fruits, nuts, oils, flours, and/or resins have been selected, in order to highlight issues associated with achieving their potential. These issues will need to be addressed not only for these species, but also for others with similar products in other forests.

Obviously the development and management of income-generating forests will not be done in a vacuum. There are other important issues which, although not the focus of this report, are essential prerequisites to any successful attempts at commercializing forest products. These issues -- land and resource rights, the improvement of existing and the search for new crops, the impact of destructive economic activities, and new approaches to development in Amazônia and elsewhere -- are raised briefly here.

Land and Resource Rights - Zoning and Mapping

Clear and legal land tenure and resource rights for forest residents are essential first steps towards creating an economy based upon forest management and a wide diversity of forest products and for conserving Amazonian biodiversity. There are three specific areas that deserve attention.

First, clear titling of those areas that are most densely occupied by traditional forest residents and new migrants [e.g. Indians, rubbertappers, *caboclos* (mixed blood riverine peoples), long-term peasant populations and recent colonists]. Such titles could take many forms, including Indian reserves, extractive reserves, or individual titles. In those areas where groups have only use rights (e.g. extractive reserves), clearly spelling out who has access to the resources, which resources can be used, and over what period of time, is extremely important.

Second, determine the regions in Amazônia with sufficient biodiversity to warrant protection, either in the form of limited access or of restricted economic use. If an area is already occupied, special efforts will need to be made to assist local groups in meeting their economic needs while limiting their impact on the environment. This type of zoning will be extremely important in conserving Amazonian biodiversity.

Third, identification of those regions that have already been degraded. Work on these areas will also need to focus on land titling and identification of resource management strategies to conserve remaining forests while investing in programs to reclaim degraded areas, preferentially with the creation of new income-generating forests. The point is to fix the colonists in their area so that they will not move on to other areas and degrade them also. In Pará and Rondônia many colonists are already extracting resources from the remaining forests in their areas. Their efforts should be encouraged by investing in transportation or processing systems, by providing better harvesting techniques and seedlings of valuable tree species, or by creating new markets for their products.

The physical act of delimiting and subsequently demarcating lands, whether for individual or communal title, could be greatly facilitated through the use of existing computer technology. At present two mapping efforts in Brazil are assisting Indians and rubbertappers to scan into computers (digitalize) all existing information about border coordinates. This not only allows individuals on the ground to use hand-held locators (GIS or Geographic Information Systems) to determine and mark precise boundaries (within 1 meter), it also allows satellite images to be scanned, in order to determine where boundaries are being illegally invaded by ranchers, colonists and gold miners. The large computer systems with scanning and mapping capacity cost about US$200,000 to set up and operate. The hand-held locators cost less than US$5,000 each. Demarcation of lands with up-to-date computer technology instead of traditional surveying technology would reduce demarcation costs by one-half.

Inventories of biodiversity can be conducted using the same hand-held locators which then store the data in a memory bank which can be transfered to the main computer at the end of each day. Eventually, data from such on-the-ground systems can be used by planners or managers to see what the inventoried plot looks like from the air and then do computer extrapolations from that area to neighboring ones. While this system would become more accurate over time, even in the beginning it could be a very useful tool for identifying regions to be zoned for their biodiversity or for their potential economic interest.

Improving Existing Cultivars

One of the concerns about the loss of biodiversity in areas such as Amazônia is that at least part of the diversity being lost has economic potential. In some cases [e.g. cacao (*Theobroma cacao*), rubber (*Hevea brasiliense*)], the economic potential of former rainforest plants has been realized, but to assure long-term production, *in situ* gene banks will need to be preserved.

In other instances, although the potential has been realized, the contribution of Amazonian biodiversity may be less clearly recognized. For example, cassava (*Manihot esculenta*) is the second most important root crop globally after the potato (*Solanum tuberosum*) and presents enormous diversity in the region. Pineapple (*Ananas comosus*), which is probably native to Amazônia, is one of the most important tropical fruits today. Timbó (*Lonchocarpus timbo*), another native, is the source of rotenone, a natural insecticide. Annatto/urucum (*Bixa orellana*) and guaraná (*Paullinia cupana*) are both important Amazonian products that are now mostly produced in monoculture plantations in other areas. How important is it to preserve the many varieties of these plants, both in the wild and cultivated by indigenous people in Amazônia? Amazonian germplasm is essential for continued improvement of these species.

The continued existence of species variation in the wild will afford plant breeders a better chance of creating new disease-resistant varieties for cultivation in the future. Our agricultural history shows quite clearly that new diseases will evolve to attack the varieties that we depend upon today. To put it more succinctly, a world without rainforests will surely be a world without chocolate.

Regions identified for *in situ* genetic conservation should definitely include those areas with the greatest number of plant varieties with known economic value, as well as those with the greatest economic potential (some of which are cited in the following chapters). *In situ* conservation of the genetic diversity of cultivated crops can be undertaken most efficiently with the people that developed them and that continue to use them today. This means that cultural conservation should go hand-in-hand with genetic and biodiversity conservation.

With the genetic diversity conserved, new efforts will need to be undertaken to widen the genetic base of the major crops native to South America and widely used in the region. Because of the great diversity of pests, diseases and weeds in Amazônia, these crops will need not only the wider genetic base already mentioned, but they will need to be modified to adapt to multispecies environments (eg agroforestry systems) because most small holders do not have the capital necessary to maintain them adequately as monocultures. Most of these species were originally domesticated in agroforestry systems but modern improvement programs have adapted them to monoculture. The wider genetic base for resistance to pests and diseases and tolerance to weed competition should be combined with diverse agroecosystems so that this resistance is maintained for longer than would be the case in monoculture.

The recognition of this new direction in the improvement of these crops is only now dawning in the research institutes that will be responsible for the majority of the work. With the genetic resources native to Amazônia that are still adapted to agroforestry systems, it will not be difficult to modify the agroecological adaptation of the major crops.

Developing New Crops

Another facet of the undeveloped economic potential of Amazônia is the large number of potential crops that are not yet widely utilized or at least that are not produced for the market economy.

The list of Amazonian cultivars that have already found their way around the world is respectable, but it is merely a tiny fraction of what has already been domesticated by the Amerindians and used by them and peasants throughout the region. There are about a dozen domesticated fruit crops in Amazônia and another 40 or 50 that have been or still are cultivated by Indians and *caboclos*. A half dozen vegetable and root crops have also been domesticated. Five to ten local nut species are similar or superior in quality to Brazil nuts. At least 20 palms offer fruits with widely varying oil characteristics. Each Amerindian tribe has from 20 to 50 medicinal plants that have not been adequately screened for use in modern pharmacology. Numerous Amazonian plants have compounds that act as insecticides, fungicides, and preservatives, many of which are known to and used by the Indians and *caboclos*.

Many rainforest species offer tremendous potential as both income and food sources for forest residents, not to mention for countries as a whole. Most Third World countries face the problem of feeding growing populations on shrinking per capita land bases. Amazonian countries are no exception. The problem is, however, that many of the major crops in these countries, as well as the systems of land management, are imported, and are not well suited to Amazônia. There are, however, indigenous species and cultivation practices that not only produce respectable yields but could also reduce dependence on chemical fertilizers and pesticides.

EMBRAPA (Brazilian Enterprise for Agricultural Research) has recently recognized that Amazonian agricultural development needs to include extractivism, forest management, and agroforestry. For EMBRAPA these are all unconventional practices, more oriented towards the small holder and the conservation of biodiversity, than are conventional agricultural approaches. To make the production of marketable crops work within this framework, new crops will need to be discovered, in addition to the five well-studied perennial plantation options -- rubber, oil palm, black pepper, cacao, and coffee.

Each of these five crops has serious problems. Rubber is susceptible to leaf blights when produced in monoculture plantations in Amazônia. It is not yet known how densely forests can be enriched with rubber before leaf blight becomes a problem. Likewise, cacao is susceptible to witches' broom and monilia pod rot. There are some 100,000 hectares of cacao planted in Amazônia. Most are in medium to large holdings and the owners are not willing to pay the labor costs to maintain the plantations in a disease-free state. The 200,000 hectares of coffee in Amazônia, mostly in Rondônia, are productive for only eight years. Can they be maintained sustainably? Black pepper lives for only six years and then must be replanted in a new area because of nematodes and root rot. African oil palm (*Elaeis guineensis*) is starting to be attacked by diseases new to the species after only 20 years near Belém, Pará. Can an infusion of germplasm from the American oil palm (*E. oleifera*) save this agroindustry?

Even if each of the production problems identified above can be solved in the short to medium term, national and international markets are already at or near saturation for all of these products. The reason for this saturation is that all tropical countries are using the same five crops and trying to be more competitive than the next country through improved germplasm, improved agronomy, lower land and labor costs or proximity to markets. Amazônia is coming late to this competition and is at a competitive disadvantage.

Consequently, research needs to be undertaken to identify new species with economic potential and to initiate the domestication of those most likely to have markets in the short and medium terms. This work has started, although never as a primary objective of any major institution. Such work should be strengthened at all existing institutes. Perhaps a rainforest development institute could be established to coordinate this type of research effort. Regional capacity could also be developed to improve new crops genetically and technologically for local agricultural and environmental conditions, as well as for national and international markets. It is precisely this scientific capacity that is a major limiting factor to Amazonian development, although EMBRAPA, INPA (the National Research Institute for Amazônia) and several state institutions have capable staff.

Specifically, the work on new crops will need to include:

1. Developing a database on Amazonian species, including historic and ethnobotanical uses as well as current research, experiments and field trials being undertaken by Indians, rubbertappers and *caboclos*. The regular publication, and distribution to users, of compendiums on major groups of species (e.g. fruit, nut, root, vegetable, oil, essential oil, gum/resin/latex, medicinal, timber) is essential;

2. Evaluating the market potential of specific species and major species groups to establish priorities. This should be done in collaboration with commercial and marketing entrepreneurs so as to better husband scarce resources and better identify priorities;

3. Collecting, characterizing (including nutritive, chemical, and technical analyses), evaluating and conserving germplasm of priority species *ex situ*, and identifying priority areas for *in situ* conservation of important concentrations of their diversity;

4. Developing efficient seed and vegetative propagation techniques for each priority species, including *in vitro* techniques if less sophisticated techniques prove to be inadequate;

5. Selecting outstanding germplasm of priority species to distribute to growers and for continued improvement;

6. Producing extension materials on new crops for forest residents, farmers, processors, and businesses.

Such research would require an overall investment of tens, if not hundreds, of millions of US dollars over the next few decades. Research could begin, however, with a more restricted focus. Income can also be generated through the sale of information to businesses. However it is done, the money spent will definitely yield significant returns to its sponsors and to the people of Amazônia.

The Impact of Non-Sustainable Economic Activities

Most of those who dismiss the potential of extractive economies for developing sustainable sources of income for forest residents do so with insufficient critical examination of the long-term negative environmental impacts of current Amazonian development activities, such as mining, logging, hydro-electric dams, ranching or large-scale plantation agriculture. The fact that extractivism has historically been an important activity and continues to be so today, suggests that improving its efficiency and social equity should be a development objective in the region. This is especially true if the improvements are made with the intention of conserving biodiversity while improving human carrying capacity in Amazônia.

The relative value of extractivism, both current and improved, can be better understood in the context of the long-term economic costs of the various types of environmental degradation associated with most conventional development programs in Amazônia today. Among these are: water pollution (by sediments, chemicals and heavy metals -- the 600,000 gold miners in Amazônia are responsible for 8% of the mercury released into the Earth's atmosphere each year and have already contaminated some of the major tributaries of the Amazon River); declining soil fertility and the eventual abandonment of huge areas used inappropriately for agriculture and ranching; increases in malaria and other diseases associated with mining and colonization; loss of biodiversity; and the release of carbon and greenhouse gases (while the average Brazilian does not release nearly as much carbon as the average American per year, recent research shows that the average Amazonian colonist produces more carbon than any other identifiable group on the planet).

If these impacts are treated as components of the cost of production, rather than as "externalities", conventional development alternatives must be viewed as generally anti-economic in Amazônia. While we don't expect these externalities to be adequately internalized in the immediate future, recognition of their long-term impacts reenforces the argument in favor of extractivism, forest management and other environmentally friendly development alternatives.

New Directions for Development in Amazônia

Most development and production programs should concentrate on areas that are already well populated so as to prevent new colonization in largely uninhabited regions. These areas fall into two types.

First, those areas that are currently inhabited by long-term extractivists, whether Indian, rubbertapper, or *caboclo*. Helping these groups make a better living should be a priority, knowing full well that what they see as a decent living is constantly changing. In addition, the rules of the game are changing -- laws, policies, markets, subsidies for pasture and agricultural alternatives to the sustainable use of forests. If these long-term forest residents cannot survive with the opportunities currently available to them, they will be inclined to degrade their own areas, move to other areas and degrade these also, be forced to work for others who would have them clear the forests for other purposes, or abandon their areas, not only leaving them defenseless to newcomers but also swelling the ranks of the urban unemployed in the region. Incidentally, most people in Amazônia already live in cities, and some 60 percent of them are unemployed or underemployed.

Second, those once-forested areas that have already been degraded by recent colonists. This type of region is important for three reasons. 1) Because of past degradation, the area will not support agriculture or livestock in the medium to long term. It is imperative to get as many of these areas as possible back into tree crops before the soils become permanently degraded. 2) If colonists cannot be kept in these areas by helping them make a decent living, they will continue to migrate further into the forests, repeating their mistakes along the way. 3) Whoever can institute programs that will turn project failures (eg Rondônia) into successes will receive considerable attention and will have a great deal of influence in discussions on successful development programs for the region as a whole.

Whether they work with long-term residents or new colonists, programs should be tailored to the needs and skills of the intended beneficiaries. Beneficiaries all need land rights if they are to protect their resource bases in the short term, much less plant trees for some longer-term payoff. Land rights are only the first step. Land rights, whether through demarcated Indian areas, extractive reserves, or individual titles, are only token gestures unless the groups are organized to protect their rights and the legal system is prepared to hear their cases.

Even land rights and locally organized groups will not necessarily guarantee sustainable development and the conservation of biodiversity. There are probably no more than a handful of individuals out of the millions of people in Amazônia who want to live exactly as their parents did. Most have new wants and needs, and to fulfill them they are using resources differently -- even the long-term residents, Indian groups and extractivists. As they become more integrated into the market economy they need to know how to modify traditional production systems in ways that produce more for sale or trade while not degrading the resource base upon which they and future generations will depend.

Many sections of this report address precisely these issues -- adding value through transport or local processing of raw materials, identifying and increasing the density of income-generating species, expanding existing markets and creating new ones, diversifying production, and so on.

The most important point, however, is to get beyond production in our thinking. Development programs can no longer center exclusively on identifying products that can be produced sustainably or getting the product to the farm or forest gate. They also have to address the related issues of markets and value. Added value for products can lead to increased income from less overall production, thus conserving resources while using less land, labor and capital. Adding value is also important socially. Traditionally both extractivists and their products have been looked down upon in Brazil and elsewhere. If we merely help such groups enter the market through production, they will end up in the marketplace exactly where they are in the social scheme of things today -- at the bottom. These people and products can play a very important role in helping us save one of the most important ecosystems on the planet; but to do this they want a better quality of life.

The market-oriented activities of forest groups and colonists will change the forests forever. That is a fact. The forests of Amazônia cannot be preserved entirely in their natural state. Hopefully, they can be conserved -- conservation through use. The current forest residents, even though they use Amazônia's fragile resources, are the best hope for protecting it. But they will not be satisfied to live a life of poverty in order to insure the quality of everyone's air or the genetic diversity that might save lives or feed others.

Work will need to be undertaken both with forest groups and with recent colonists to zone Amazônia into areas of protected and restricted use, of extraction and limited clearing and agriculture, of intensively manipulated agroforestry and annual and perennial agriculture and/or livestock. Zoning should be used to protect those areas which are deemed important strategically.

More than half of Amazônia's inhabitants are recent colonists or the descendants of those who moved into the region under the military government. No strategy to save the region's biodiversity will succeed if the needs of this group are not addressed. Many colonists in western Amazônia, in areas like Rondônia and Acre, are attempting to live on land that is half cleared. Many have begun to harvest forest products as part of their survival strategy. In those cases, programs to add value to such products will benefit these people. Likewise, programs to increase the density of income-generating species in their remaining forests would eventually provide them with increased income as well.

Perhaps the most important initiative, though, would be to work with such groups to put more of their degraded areas into perennial crops. Few economic studies exist, however, regarding the profitability of these tree crops so far from major markets. Without such information it is hard to determine which perennial crops should be encouraged. Logically, emphasis should be placed on trees that produce marketable crops within a few years. Improved or state-of-the-art processing can also help the colonists benefit from improved market potential. For example, cacao from Rondônia is very high in quality, but is worth very little on the world market because it is so poorly processed. Better processing, then, would serve to assist colonists in making a better living where they are, rather than moving and cutting more forests.

Another important Amazonian group that needs to become part of the overall effort to sustainably develop the region and conserve its biodiversity is the urban poor. If this group sees the Amazonian forest as essential to its own survival, they will form political alliances with similar groups in rural areas. Together they can become a majority -- and a potentially powerful political movement.

One way to involve the urban poor in sustainable development and the conservation of biodiversity, as well as in ongoing political relationships with the rural poor, is through the processing of forest products. It often makes little sense (depending, of course, on the commodity) to process forest products in the forest itself. Usually it is better to transport the product to neighboring towns or cities for processing and packaging for sale in national or international markets. One way to insure that local processing benefits both urban and rural poor is to set up the factories so that they are owned by both. Collectors in the forest would own 50% and processors in the cities would own 50% of the operation. This agreement has the added advantage of encouraging both groups to insure that the factory is profitable.

This volume represents an attempt to redirect the thinking about development in Amazônia. Many peoples' experiences are summarized here. When summed, they show the need for new or modified directions for strategies to protect biodiversity, harvest, process and/or market forest products, and generate income for Amazonian residents -- Indian and colonist, rubbertapper and *caboclo*, rural and urban. While this volume is limited to a discussion of species and strategies specific to Amazônia, the approach is applicable to most tropical forest areas in the world.

Strategies for Enhancing Income Generation from the Tropical Forest

Jason W. Clay

During the past decade, the idea of conserving the tropical forests by using them more appropriately has become more fashionable. This idea is not new, of course, since tropical forest people have a long history of exploiting the forest, frequently on a sustainable basis, although occasionally not, especially when population pressures or market demand drives exploitation to non-sustainable levels.

These pressures to exploit non-sustainably are growing at a rapid rate. Population in tropical countries is growing quickly and most governments use forests to relieve pressure in overcrowded agricultural areas. This results directly in deforestation, because the new residents are unfamiliar with the forest or desire to continue an agricultural way of life. As long as governments fail to address the population issue, forests will disappear.

At the same time, people everywhere in the tropics have increasing desires to consume as they are drawn deeper into the expanding world market economy. Local definitions of "quality of life" are changing as people listen to the radio and watch television, even if only once a month. In order to consume more, forest peoples must obtain money or trade goods, which can result in over-exploitation of one or more of their forest resources, especially if there are only a few with market value.

If governments fail to address population issues and continue to favor agricultural strategies over forest-based conservation strategies, the next century will witness the demise of the tropical-forest ecosystems of Africa, Asia, and the Americas. This does not have to happen. If governments and international development agencies decide to foster a forest-based economy this scenario could be avoided. This forest-based economy could evolve from forest extractivism, both in its current form and with management and marketing improvements.

During the past three years, Cultural Survival Enterprises (CSE), the trading arm of the not-for-profit human rights organization Cultural Survival, has worked with a few specific groups in the Brazilian Amazon to demonstrate that, in their areas, forests are worth more standing than razed for pasture or conventional agriculture. Scientific research and subsequent economic projections suggest that, in the long term, forest areas are worth more for their sustainably harvested wood and non-wood products than they are when clear cut for logging and/or conversion to pasture, agriculture or even plantations. As a result of work with local groups, for the first time these projections are not paper profits -- theoretical calculations about the value of forest products -- they are real incomes in real peoples' bank accounts.

CSE has concentrated on Non-Wood Forest Products (NWFPs) -- nuts, fruits, oils, resins, essences, pigments, flours, and handicrafts. In the past three years, CSE has brought 350 different NWFPs out of the Brazilian Amazon for sampling by 120 different companies in the US and Europe. These companies range from Fortune 500 members to small, start-up operations created solely to market rainforest products and return profits to rainforest groups.

The major lessons learned from these efforts are discussed in this chapter, in order to provide a theoretical and practical outline for a strategy to improve the marketing of NWFPs. Although these ideas were developed in the Brazilian Amazon, they can be easily adopted and adapted by producer groups, other NGOs, state and national governments, and international development agencies in any tropical forest area. The ideas alone, however, will not immediately increase marketing of NWFPs. Therefore, a discussion of some necessary research and development topics follows.

The Lessons

1. Land and resource rights are essential. Forest residents are unlikely to protect forest resources if they do not have clear rights or guaranteed access to these resources or if they feel that at any time they can be displaced by outsiders. After all, why should a person save a valuable tree if someone else can come along at any time and cut it?

Likewise, forest residents will not invest time or money in such activities as forest enrichment, sustainable harvesting techniques, processing equipment, facilities to reduce post-harvest losses or the reclaiming of degraded areas if they do not have guarantees that their resource rights will be protected. Clear title to resources is one way to guarantee them, but zoning and restricted access constitute what can be effective variations where rights are shared by the state and forest residents.

2. Start with products already on the market. Existing products offer the best chance of quickly creating national and international markets that can generate increased income in the short term for forest residents. Introducing new products, on the other hand, takes time: up to 5 years for foods, 10 years for personal care products, and 20 for pharmaceuticals. Yet, if forest residents don't start generating income from forests in

the short term, much of the forest that is left will already have been destroyed before the new products come on line.

3. Increase Competitiveness. One of the main reasons that forest residents can be maintained in their current impoverished position is because they do not benefit from the value that their products generate. This situation was created by lack of competition in the marketplace. In order to increase local revenues, competition must be increased. There are various ways to accomplish this.

Alternative markets and buyers help. The breakup of trading and shipping monopolies also increases competition. Investing in production systems that reduce overall costs helps by making production and processing more efficient. (One of the curious effects of monopoly capitalism as it has been exercised in the Amazon has been to discourage either sustainable harvesting practices or economically viable production systems.) Enrichment programs or reclamation of degraded areas also increases competition by forcing marketing or trading monopolies to compete when such programs are associated with processing or value-added programs.

4. Diversify production and reduce dependence on a few products. The diversification of products is absolutely essential to the overall viability of extractivism in the Amazon, and consequently the conservation of the forest and the maintenance of biodiversity.

Strategies should be developed one product at a time, however, and should focus initially on the largest volume and highest value commodities. (Interestingly enough, individual producers probably should not diversify their own production too much or they will reduce their efficiency and overall impact on any single market.) The resulting profits can then be reinvested to continue to diversify production. Particular attention should be paid to commodities that generate high value per unit of labor, complement the seasonality of other products, and provide food or other essential goods to the producer group.

5. Diversify the markets for raw and processed forest products. To reduce the overall risk to producer groups, the number and type of end users for each product should be diversified. For example, Brazil nuts (*Bertholletia excelsa*) can be used as nuts (shelled or unshelled), or in ice cream, baked goods, cereal, candy, oil, flour, and so on. Market diversification can also be achieved through market positioning -- regular, organic, wild, or natural -- and through local, regional, national, and/or international marketing strategies. Diversifying markets can also increase demand.

6. Add value locally. Evaluate the markets for each product, determining where value is added, where risk exists and where local communities stand to gain the most in the short, medium, and long terms. Sometimes, eliminating intermediaries through improved transportation might work; other times, adding value through local or regional processing could be most beneficial. Depending on the product, adding value locally does not always make economic sense.

7. Capture the value that compounds as the products travel farther from the forest. Each transaction adds value to products. While value is added according to labor, risk, and capital investment, it is also compounded through scarcity and monopoly. Most forest residents who collect products that are ultimately exported currently receive less than 15 percent of the New York City wholesale price of the commodities that they sell. (Keep in mind that they often pay equal or higher prices than those in NYC for basic commodities -- sugar, rice, beans, meat, gasoline.) If they continue to receive such a small portion of their products' value, they will inevitably be forced to degrade their resource base as they try to make a living, or they will leave the forest altogether allowing colonists and ranchers to move in and degrade it.

8. There is strength in numbers. Individual producers or producer groups have little power in the marketplace. They cannot provide the quantities of product that even a small manufacturer would need. The Xapuri Brazil nut shelling factory, for example, produces 70 metric tons (MT) of Brazil nuts per year, but M & M Mars uses 70 MT of peanuts per 8-hour shift in Snickers candy bars. Individually, local Brazil nut shelling cooperatives could never convince large companies like M & M Mars to use their nuts. By working together, producer groups can control larger market shares, exerting considerable influence over entire markets.

In general, even trading higher volumes through local organizations rather than one-on-one through intermediaries will give individual producers access to higher prices. Furthermore, the same skills and institutional structures that allow groups to sell larger quantities of product into the market enable them to purchase manufactured items in bulk, and thus save money.

9. Make a decent profit, not a killing. It is possible to add value locally and to increase overall income. Pricing, however, is a tricky issue. High prices reduce overall markets for forest products and give manufacturers a reason to look for cheaper alternatives. Likewise, each decision to eliminate intermediaries as a way to add value locally must be carefully studied.

For example, Brazil nut gatherers are quite keen on eliminating the Belém shelling monopoly; but if the monopoly was dissolved today, who would collectors sell to? Would they be better off in the short term? Would they even be able to stay in the forest? What other risks does that intermediary take, or services does he or she provide? Who will provide them in the future in that person's absence?

10. Solutions must be equal to the problems. Model projects with built-in subsidies are not viable solutions. Solutions that address only the needs of one of the different groups (Indians, rubbertappers, peasants, colonists) are not viable. Solutions that do not address the principal commodities traded in the region [Brazil nuts, rubber (*Hevea brasiliensis*), assaí (*Euterpe oleracea*), babassu (*Orbygnia phalerata*)] are not solutions. Solutions must be on the same scale as the problems, yet divisible, starting with one village or group at a time. This being said, no single solution will reverse the destruction of the Amazon forest nor other tropical forest.

11. International markets are for the protection of ecosystems, not for the people who live in them. Most consumers are concerned about the environment. Thus it is essential to invest in monitoring systems which ensure the sustainability of production. The sale of commodities must be linked with systems that ensure that the quantity of products taken from the forest does not destroy it.

By the same token, the harvest of any product will change the forest; yet such manipulations have taken place since humans entered the forests and have not destroyed them. What is needed, then, are careful environmental impact assessments and monitoring systems that examine at the outset the impact of increased trade on individual species. This is the type of monitoring that is required for products that are already being harvested and sold onto the market. For new products, such studies should be undertaken before the commodities are harvested. Monitoring and research needs to be undertaken for each commodity by scientists and forest residents. In the end, it is the local communities whose present markets and future livelihoods will depend on such certification. The authority to monitor and certify should be primarily theirs.

These are the 11 major lessons learned through recent CSE efforts to market non-wood forest products. Although they will probably be modified over time, they are offered here as ways to help think about the best strategies to conserve tropical forests, their people, new arrivals and biodiversity. The program initiatives elaborated in this chapter build upon these lessons, and suggest a comprehensive short-term strategy to turn the tide of deforestation in the Amazon. The ultimate success of this strategy -- both its broader, theoretical issues and its specific, detailed suggestions -- will only be possible if those interested in these issues work together, addressing the problems in as complementary and comprehensive a way as possible.

Research Needs

The research outlined in this section includes a number of general suggestions relating to currently traded non-wood forest products. What is outlined here are ways in which the rights of forest residents to such resources could be guaranteed or respected through specific marketing as well as legal strategies.

Currently Traded Forest Products

As a rule of thumb, initial research should be focused on commodities that are already being extracted, harvested, or otherwise produced and traded on the market. Such production and trade implies not only that there is already demand, but that some forest residents are supplying it and, depending upon the length of time they have been doing so, that production and trade might not be environmentally destructive. Research and development should concentrate on four general areas for each product: existing and potential markets; sustainability of production over time; potential of each commodity for possible enrichment programs; and the forest groups that could benefit from market development.

If products are already being sold onto some markets, it should be easier, hypothetically, at least, to expand those markets. By contrast, creating markets for new or unknown products would take 5 to 20 years, as mentioned earlier. In addition, creating markets for commodities that forest residents have not previously collected will require changing overall production schedules and habits and could lead to environmental degradation and even species loss.

Research, then, needs to be undertaken on the history of trade of forest products in this century. The data can then be compared with today's market information. For example:

- What is or is not being traded today versus 90 years ago, and why?

- What is being collected and traded by some groups but not by others, and why?

- How can costs be lowered by eliminating intermediaries?

- What implications does such research suggest for follow-up studies (e.g., on transport, processing, etc.)?

- What other potentially marketable by-products come from the same plant, fruit, or seed?

- What would it take to develop markets for those by-products?

The answers to these questions will help identify possible priorities to be addressed not only by research institutions but by forest peoples as well.

Improved Harvesting Techniques

In many cases, the issue of sustainably producing NWFPs from tropical forests has more to do with harvesting technology than with actual levels of current off-take. Pau rosa (***Aniba roseadora***), an essential oil whose harvest has almost eliminated the species from the Amazon, can probably be harvested sustainably. Likewise, copaíba oil (***Copaifera multijuga***), chicle (***Manilkara zapota***), and other latexes, and certain fruits, can be harvested sustainably, even though they often are not [eg buriti (***Mauritia flexuosa***)].

Some new techniques would require education rather than equipment, others the reverse. For example, copaíba oil should be harvested by drilling a hole with a brace and bit and tamping it, rather than making a hole with an ax, which does not heal. (Research could reveal if trees can be patched and made productive again.) The brace and bit could be sold at the depot where the copaíba is purchased. They need not be fancy or expensive -- one bent piece of iron tooled on one end with a section of pipe on the other, serving as the handle.

If NWFPs are to become a more important part of overall solutions for generating income for forest residents, reducing overall levels of deforestation, and protecting biodiversity, research should be undertaken on the harvesting techniques for each NWFP to determine what it would take to convince collectors to use alternative methods.

Guaranteed land and resource rights (or usufruct rights) are perhaps even more important than harvesting techniques in encouraging the sustainable harvest of NWFPs. Such rights, in fact, can allow producers to develop sustainable processing techniques. Furthermore, they allow harvesters to develop long-term harvesting strategies for single species and multiple species associations. Finally, they allow harvesters to make financial investments in the equipment needed to harvest or add value by processing their products.

Chemical Analyses and Health and Safety Information

The main impediment to the entry of NWFPs into the personal care products market is the lack of readily available health and safety data and chemical analyses. Manufacturers of soaps and shampoos, for example, are required in the US and England to have documented evidence that the products they use in manufacturing are safe for human use. In fact, the requirements are as strict for anything that goes on the skin (since it is porous) as for products that go into the body. Without health and safety data, NWFPs cannot be used. Although documentation of past use in the country of origin can supply important background information, it is not sufficient to clear the product for use.

Much of the health and safety information needed by manufacturers probably already exists, but it is not readily available. It may only be found in obscure or private sources. Much of this data probably was compiled during the heyday of the trade in NWFPs from 1880 to 1930. Even though the scientific techniques were less precise at that time, the information could be very useful nonetheless. Much of this data, probably stored in the old Brazilian Oil Institute library, has been lost since the library was split up in the early 1950s.

A number of Brazilian government agencies probably have information on specific products, too, but no one has had the time or money needed to collect all the data in a comprehensive way. Likewise, Brazilian industries, research institutes, and individual scientists certainly must have data, but no one has been able to compile it. Once the compilation of this data is completed, it would become clear what additional studies would need to be undertaken.

In addition to health and safety data, industries must know the standard chemical properties for each product as well as the acceptable ranges within and between categories. These are also the guidelines that are used to determine if a product has been diluted or otherwise contaminated. Often a number of varieties of a single oil might exist (there are more than 30 varieties of copaíba in the Amazon, for example), so it is important to know the variety being received and/or the range for that or all varieties. Full, yet basic, chemical analyses cost up to US$1,000 per sample. More than one sample of each commodity from each region would have to be analyzed in order to generate baseline data.

Some excellent research facilities exist in the Amazon to obtain new data on those products identified as priorities for development. In fact, new data can frequently change priorities as exotic properties can have strong market value (e.g., the interest in short chain fatty acids by the chemical industry).

Reducing Post-Harvest Losses

Most products from the Amazon have well defined and relatively short harvest seasons. Markets for such products, however, could easily be sustained throughout the year if produce were available. Harvest, itself, is usually an arduous task. Transportation to market is difficult and often must wait until a change of season. All of these factors make the reduction of post-harvest losses a potentially profitable activity. In short, once a product is harvested it makes sense to ensure that as much of it as possible can be sold. To the extent that the product can be sold for a longer period of time, it will generally not only command a higher price during the "off" season, it will also raise or at the very least stabilize the price during the peak period of availability. (Most forest residents are offered very low prices for their product during periods of peak production.) To date, little time or energy has been invested in reducing post-harvest losses.

The Brazil nut illustrates the point. Little is known, for example, about how to store Brazil nuts in the forest during the rainy season before they are transported to market. What are the best storage facilities? Should they be elevated? Should they be thatched roofed, slat sided, etc? Should the nuts be picked up as soon as they fall of the trees, or is it better to leave them in the *ouriço* (the true Brazil nut fruit is a hard woody sphere that holds the seeds of commerce) on the forest floor until they can be sold?

Once the nuts are sold to traders, they are traditionally shipped from the Western Amazon by open barge to Manaus or Belém where they are shelled and packaged for export. On these journeys, 25-35% of the nuts rot. Covering the barges or processing the nuts closer to the forests would reduce the post-harvest losses and make financial sense.

The ways to reduce post-harvest loss should be examined for each commodity. This information can be gathered in the commodity specific market research suggested below. (It should be noted, however, that such losses, often give the appearance of being value added, because they force the price up at the next market stage, e.g. processing in Belém.)

Transport

The development of markets for sustainably harvested commodities and the destruction of the rainforests both depend, ironically, on the same thing: improved transport systems. Today, this usually means the construction of roads. Anyone familiar with the Amazon has seen the satellite photos clearly documenting the impacts of road building or subsequent paving. Often the roads are built for a specific short-term purpose -- oil or mineral exploration, surveys, and so on. Yet each year the deforestation creeps out further from the roads' radii as new feeder roads expose more and more forests to chain saws.

Forest residents have long realized that roads are both their salvation and their demise. Unfortunately, roads make land too cheap; not valuable enough to protect. They make the supplies of land seem limitless, so few invest in relatively more expensive conservation practices when it is simpler to move a few miles down a road.

Roads also represent another kind of market freedom, however. In the past, every commodity traded in the Amazon was monopolized regionally by elites who controlled river transport, usually by controlling through violence the mouth of a river system. Without roads these monopolies would continue. If roads are built before land rights for forest residents are established, however, long-term residents are inevitably pushed aside in the rush of colonists, rich and poor alike.

Although large roads are now inevitable, alternative transport systems in the Amazon should not be overlooked. River transport can surely regain some of its importance once the river trading monopolies are broken, land rights to large indigenous and extractive areas are guaranteed, and the high cost of constructing and maintaining roads and moving commodities by truck are better understood. Rubbertappers in Xapuri now use river transport to export their nuts to the US even though only three years ago it was assumed that the large Brazil-nut trading monopoly in Belém was able to prevent "unauthorized" exports.

River transport, though slow and in some cases seasonal as water levels drop, is far more efficient than overland transport. What is needed are good economic studies to determine which commodities would benefit most from investments in which types of riverine transport systems.

The studies then need to be followed by government and entrepreneurial action. Before the TransAmazon highway initiative and the creation of the Manaus Free Zone, the state and federal governments and the regional banks all supported river transport, the former with incentives and favorable regulations, the latter with working and building capital. The revival of river transport will require the renewed action of these regional agents.

Another form of transport, blimps, should also be examined carefully as a nondestructive means of transporting goods out of and into inaccessible areas. The most common manned blimps have been used by the US Navy. There are hundreds in existence that have carrying capacities varying from 200 to 2000 kg, excluding the pilot.

Most existing blimp designs do not have the thrust to lift logs that weigh an average of five tons (≈ 5 m^3). Even if blimps could be designed with enough capacity for a five-ton payload, the current price of mahogany or cedar in most of South America (US$6/30$m^3$) is equivalent to only $US0.01 to $US0.03 per kg. The idea of the blimp as the workhorse of the rainforest has merit, but not for logging at current prices.

NWFPs have much higher per-kilogram values than even the most expensive tropical hardwoods. Furthermore, they occur in much smaller units. Brazil nuts in the shell, for example, are worth US$0.06 to US$0.20 per kg depending on their distance to the shelling plant. If they were shelled in the forest prior to transport, they would increase in value to US$0.60 to US$0.80 per kg. Copaíba and patauá (***Jessenia bataua***) oils are valued at about US$2.00 per kg. Andiroba (***Carapa guianensis***) oil is worth about US$1.00 per kg. Vanilla (***Vanilla planifolia***) from the western Amazon is worth US$10.00 per kg. Cupuassu (***Theobroma grandiflorum***) is worth about US$0.80 per kg (and both seed and pulp can be sold). Handicrafts range from US$2.00 to US$100 per kg. Even ecotourists or birders are worth US$0.30 to US$0.40 per kg per hour. (According to tour guides, blimps could be kept busy during the dry season at a rate of US$200 per person for a group of six plus guide, on a four-hour trip.)

Although river transport may sound mundane and blimps far-fetched, alternatives to roads will certainly make economic sense in many areas and are definitely worth researching and developing as priorities.

Commodity Marketing Systems

In order to determine how to generate income for forest residents and other local producers, research must be undertaken on each potential commodity to identify the bottlenecks in the current system and the point where value can best be captured by the producers. Each commodity has a different production and marketing system. Copaíba oil is different from andiroba or babassu oil, and they are all different from Brazil nuts, cupuassu fruit, or honey. Traditionally each product has its own set of producers, traders, marketers, and processors.

Gathering such information is essential to determine where to intercede in the system so that more value can be added closer to the forest. With this information, local producers or harvesters can evaluate when it is profitable to process their products and when it is not worth the risk or capital investment, or when they do not have the skills.

Brazil nuts illustrate the point. In 1989, collectors were paid only 2 to 3 percent of the New York value of their nuts. (Some were not paid cash at all, but instead were kept in a constant state of indebtedness -- by a company store system -- by local traders.) Transporting their nuts to the regional market center doubles value. Shelling the nuts for export allows collectors to earn 20-40 times the in-forest value, because it adds value while reducing transport costs (shelled nuts are only one-third the weight and volume). In some instances local shelling makes it possible to sell Brazil nuts which in the shell are not worth the transport costs (at this time, it is estimated that only about half of the areas with Brazil nuts can be profitably harvested). Turning nuts into oil would double or even triple the shelled nut values. And so it goes. These are the types of data needed for each commodity.

Of course, this is just one commodity. A better way to increase the economic viability, or at least reduce risk to producers, of extractive economies is to diversify production and sources of income. Although this cannot be done overnight, each commodity can generate some of the money required to diversify income sources. For example, the export of Brazil nuts can be used to guarantee a loan to purchase equipment for processing a higher, more valuable grade of rubber, even though the rubber will only be marketed within Brazil. Copaíba, cupuassu, vanilla, vegetable ivory (***Phytelephas aequatorialis***), and other products can be added to the mix. Groups should strive to be less dependent on single products or purchasers, but such a strategy makes more sense on a regional basis rather than the level of an individual producer.

Processing and Technology Transfer/Development

One of the ways in which local groups can benefit from the sale of NWFPs is to add value locally. Some of the more general principles to be considered when thinking about investments in value-added initiatives are explored in this section.

In every instance, attempts should be made to determine ways to add value locally. In general, processing should be done to reduce post-harvest losses, reduce the weight and volume of raw products, increase their standardization, and guarantee consistent quality and acceptability into multiple markets. In general, local value added should increase the ability of NWFPs to enter multiple markets rather than restrict the number of markets that would accept them due to overprocessing.

Efforts to add value locally should not have built-in subsidies. While it may be acceptable to subsidize processing in the short term, in the long term plans would have to show that the subsidies would be eliminated or else such programs would not be options in the real world. Nor should programs to add value be ecologically unsound. For example, what is gained through sawing tropical timber locally if it is done so inefficiently that more trees must be harvested? Why not leave the processing to the most efficient processors? Or, why not invest in more efficient local plants?

Whether or not it makes sense to add value locally is a complex decision. Such decisions about if it is appropriate to add value and how much value should be added vary widely from group to group, commodity to commodity and region to region. The types of questions that should be considered when making such decisions include the following:

- What is the volume of the commodity in question?

- What is the seasonality of production?

- Could the facilities to add value be used in other ways during the off season?

- Is capital readily available?

- Is there sufficient labor?

- Would local people know how to manage a plant, both in technical and financial terms?

- What are the easiest ways to add the most value?

- Which forms of processing open the product to a wider market?

- Which forms restrict its markets?

- Which forms of adding value expose the producers to unnecessary risks?

Although adding value locally is important, with the exception of crafts and houseplants, attempting to produce end-user commodities is probably not a good idea. Rarely does an area have on hand the different ingredients that would be required. Furthermore, manufacturing takes energy and often results in products that are larger and less efficiently transported than either raw materials or semiprocessed goods. Thus, end products would require shipping not just the product, but the air and packaging, great distances at energy costs that could not justify the political impetus for local manufacture.

Initially, at least, groups should focus their efforts on production and sale in larger units. Quickly these efforts can be expanded into processing commodities into higher value, more efficiently transported commodities (e.g. shelled Brazil nuts, expelled oil, frozen fruit pulp). In fact, processing raw materials into more efficiently shipped, widely acceptable commodities generates considerable employment in its own right while allowing the commodities to penetrate more diverse markets.

In the following chapter, some value-adding initiatives will be presented along with an introduction to the species highlighted in this volume.

Marketing

Marketing of NWFPs is not easy; nor does it just happen on its own. A considerable amount of time and money must be invested to make it happen in a way that will return the most revenues to forest residents and the countries in which they live. As in the past, most development programs in the Amazon take a production-oriented approach. They focus on selling into the market rather than attempting to get higher value in the market or even changing the market entirely. Because of their production orientation, many development efforts have the net effect of creating increased supply of commodities and thus reducing prices, profitability and new income to producers. A marketing orientation increases demand and value, thus allowing more product to enter the market without reducing the overall price of the commodity.

Numerous constraints and guidelines for marketing NWFPs are mentioned throughout this chapter. Some of them, however, should be underscored at this point. Each community or regional association should attempt to market a number of different products and find a number of different markets for each product. Sometimes, groups may be able to market their own products in local, regional, national, or even international markets. At other times, local groups will want to limit and specialize their marketing efforts in certain areas and turn the rest of the marketing over to another group (or groups).

Support for NWFP production and processing initiatives should also insist that local groups actively consider the ultimate marketing of their goods, even if it takes years to get to that point. To be sure, such groups will probably always be able to sell their products; but if they want good markets they will have to work for them. Markets that benefit forest groups do not just emerge overnight; they are created only with considerable effort. CSE has found that it takes at least one full-time staff person for every commodity it trades. Marketing works best if that person has come on staff at least one year prior to the commencing of trade.

If Amazonian groups wish to market their own products, they will need to establish offices and warehouses in each market they intend to penetrate (e.g., the south of Brazil, New York, Europe, Japan). It would perhaps be better if many Amazonian forest groups worked through a single broker so as to spread the costs of such an operation over a large number of commodities. Based on CSE's experiences, setting up such offices will cost about US$1 million in Brazil until it becomes self-sufficient, and about US$4 million in the US and US$6 million each in Europe and Japan.

Whether or not local groups decide to open their own office, the more their representatives travel to the US and Europe to view such operations and understand their workings, the more informed they will be. In the short term, Amazonian groups will be forced to market their products through others. There is simply too much to be learned about harvesting and processing at this stage without adding another whole dimension of complexity. Nonetheless, Amazonian forest groups will need to prepare for this stage in their commercial development.

Creating Income-Generating Forests in Amazônia

Charles R. Clement

In order to conserve the Amazonian and other tropical-forest biomes, the standing forest must become more economically productive. The nondestructive harvesting of a larger number of existing species and the introduction of species with new uses into the standing forest or previously degraded fragments of it is one way of doing this. Norman Myers (1984) proposed the creation of "industrial forests" to conserve biodiversity within the tropical biome while obtaining economic returns from the forest. The term "income-generating" seems preferable to "industrial", since the latter has inescapable associations with pollution and servitude. Here, the terms "income" and "income-generating" are used to refer both to this idea and to the specific suggested strategies developed in this paper. The idea of "income-generating" forests seems viable but will require a significant research and development effort to integrate into Amazônia's rapidly evolving political and socio-economic matrix.

Amazonian deforestation is largely the result of social, political and economic pressures generated outside of the region (Anderson 1990). Large ranching projects, colonization schemes for small holders, mining of gold and other minerals, and timber high-grading initiatives were initially encouraged by Brazilian government planners to guarantee the occupation of Amazônia, but have largely escaped from their control and become the domain of private initiative, especially where subsidies are involved (Anderson 1990). Consequently any initiatives to develop a sustainable use of the forest must be acceptable to individual, cooperative and private corporate initiative, although to be viable, they must be devoid of subsidies. The fact that small-holder colonists, Amerindians, *caboclos* (mixed blood, long-term residents), extractivists and landless peasants are currently marginalized by most development initiatives in Brazilian Amazônia, suggests that options for these groups should receive priority attention.

Currently used agricultural and forestry practices generally originated outside the region. Many are poorly adapted to the Amazonian ecosystem (Fearnside 1983). The exception is forest management, which is technically viable but economically inviable in the current economic climate (Poore 1989). Many Amerindian practices are sustainable, especially when practiced as the Indians did, when population pressures are low and when markets are available. These practices include the shifting cultivation -- swidden agroforestry sequence and forest product extraction (Hecht & Cockburn 1990). Whether swidden agroforestry and with rapidly increasing population pressures remains to be seen.

From colonization by the Portuguese until the 1970's, the Amazonian economy was based upon forest-product extraction (Hecht & Cockburn 1990). The rubber boom of the early 20th century is best known, but other products were important before that period and have been since. Recently a "new" idea for sustainable development in Amazonia originated among the rubbertappers and has attracted considerable interest in the international conservation and development communities: extractive reserves. These reserves are designed to allow extractive peoples (rubbertappers, Amerindians, babassu (***Orbygnia phalerata***) harvesters, etc.) to maintain their forest-based way of life and to conserve the forest biome (Allegretti 1990, Anderson et al. 1991, Fearnside 1989, Schwartzman 1989). The latter objective has been responsible for the current fad, but must be considered critically (Browder 1992).

Unfortunately the extractive reserves as they now stand are economically inviable as independent commercial entities (Browder 1992, Fearnside 1989), as they relied upon Brazilian subsidies (the rubber price subsidies were canceled in 1990) and assistance from the international conservation community to market their Brazil nuts (***Bertholletia excelsa***) at more favorable prices. The number of products for which they have markets is extremely limited (Allegretti 1990, Fearnside 1989) and the marketing of these is problematic without external assistance. Profits realized by the extractivists are low because of the numerous middlemen between the producer in the forest and the consumer in major urban centers (Fearnside 1989, Hecht & Cockburn 1990), because rubber, and to some extent Brazil nuts, are commodities with inherently low unit values in the forest, and because little value is added by the producers or their associations. The same situation exists for all other forest or colonist peoples in Amazônia, which partially explains the collapse of extractivism there during this century. Another major reason for the collapse is that extractivist products have been taken into plantation in other areas where they can be produced more cheaply (eg rubber); they have been synthesized (also rubber); or where substitutes have been developed (eg quinine).

One of the possible improvements necessary to attain economic viability in extractive reserves, Amerindian and colonist areas is to increase the number of products offered to the local, national and world markets (Allegretti 1990, Fearnside 1989). These can be either alternative products obtained from existing species or new species introduced into their forests.

Myers' (1984) industrial forest fits the needs of the extractivists and can be readily adapted for use by small-holder colonists, Amerindians, *caboclos*, and even for the restoration of degraded sites, since it is designed to conserve or enhance biodiversity, while exploiting the economically useful fraction of this diversity. In Myers' conception, an income-generating forest would contain a large number of economic species with an equal or larger number of industrial uses, as well as an even larger number of species with no known current use. Myers suggested that species producing latex, resin, gum, oil, essential oil, alkaloid, or medicinal products could form the basis for these forests. Most of these could be harvested without destroying the forest's ability to provide ecological services, although the extent to which these may be partially impaired will require research (Browder 1992). Myers points out that only those species with established markets or with markets that could be developed by entrepreneurs would be harvested or planted, but the forest could contain numerous other species with potential for use at some point in the future. What Myers does not address is how to design and create an income-generating forest.

Several questions need to be addressed in order to design an income-generating forest that could enhance the economic viability of the sustainable use and management of the forest.

(1) How many economic species should be included? Today most extractive reserves depend upon only two (rubber and the Brazil nut), which is one of the reasons for their economic fragility. Colonists and *caboclos* tend to depend upon one or two "export" crops and a few subsistence crops. The Amerindians rarely have "export" crops, although they may be involved in rubber and Brazil nut extraction to some extent.

(2) How are these species to be chosen? Lists of candidate species include a minimum of 100 with known uses and several thousand with potential uses. A market orientation is required when selecting species, since only those with a market will contribute to the economic well-being of the forest producers. Another major criterion is species adaptation to the local humid tropical-forest ecosystem.

(3) Once chosen, how will the selected species be introduced into the forest ecosystem? Several silvicultural practices exist to enrich forests with timber species (Poore 1989). These practices could be used with other types of species also, but would probably require long lead times before starting to yield because of shading and intraspecific competition.

Agroforestry systems can also be used to create income forests from previously cleared lands, whether currently managed or already degraded, or from forest cleared for this reason. They offer the additional advantage of producing economic yields throughout the growth of the system. In fact, several examples of income forests created by the Amerindians probably started from their agroforestry systems (Balée 1989).

This chapter examines each of these questions more closely and outlines the research and development necessary to implement the income-generating forest idea in Amazônia. Although extractive reserves are currently at the center of discussions about sustainable development in Amazônia, the idea of income-generating forests is equally valid for small-holder colonists, Amerindians, *caboclos*, and even corporate entities.

What kinds of species?

There is no simple or single answer to this question, as numerous factors will effect the choice of species for any given locality. Information availability is the major limiting factor here, since no single source of data exists to supply a listing of potential species. Some databases are slowly evolving to fill this lacuna, however. The Royal Botanical Gardens at Kew, for example, is developing an economic-plant database for the Old World tropics (G.E. Wickens, Royal Botanical Gardens, Kew, pers. com. 1987). Nothing similar yet exists for the Neotropics but it is essential to this effort.

This does not imply that information does not exist. There is a large database on NWFPs, particularly oils, available from the first half of the 20th century that must be organized and computerized to make it easily accessible. Extensive research on phytochemical feed stocks, for example, was done in Brazil and elsewhere in the Neotropics before World War II and the subsequent multinational corporate options for petrochemicals. The results of this research are hidden away in industrial reports, research bulletins from institutes that no longer exist, and other difficult-to-find corners of Latin American government and private libraries. They probably also exist in the Northern hemisphere and in Africa and Asia. These data and other early information can suggest species or genera that are worth examining more closely.

While the selection of new options for any situation will be highly site specific, there are several criteria that these new crops will have to meet to become successful:

1) <u>The new crop should produce high unit value products</u> (Arkcoll & Clement 1989, Fearnside 1989). In other words, they must be valuable enough for the producer to collect them; for the middlemen to transport and commercialize them onto local, regional or international markets; and for the consumer to pay enough for them to support the earlier steps in the commercial chain. Perhaps the major disadvantage of rubber as an economic support for the extractivist reserves is its low unit value,

which makes it only marginally attractive as an extractivist forest product.

An example of how a low unit value is unattractive to the extractivists was observed recently. ***Copaiba multijuga*** produces an oil resin that can be sustainably tapped from the tree. In 1989-1990 it was tested as a raw material for cosmetics by several companies, including The Body Shop, PLC, based in London. The Body Shop found several potential uses for the oil resin and offered to pay a certain price per ton to the extractivists. Unfortunately this price was not attractive to the extractivists; it would cost them nearly as much to harvest the product and transport it to the regional market center as The Body Shop offered to pay them for it to be delivered to London (J.W. Clay, Cultural Survival, pers. com. 1990). The current glut in the international vegetable oil market and the ease with which the chemical industry can fractionate and mix oils for any end use is the reason for the low price offered. In 1991, however, the situation changed dramatically, when the new Brazilian government eliminated the rubber subsidies that had kept the rubbertappers working. Copaíba oil suddenly became attractive because there were few other alternatives, even though excessive harvesting immediately caused a 50 percent drop in prices (J.W. Clay, Cultural Survival, pers. com. 1992). This type of situation will inevitably be faced with other products as well.

2) <u>The new crop should have an easily processed or pre-processed product</u>. A processed product has a greater unit value than the raw material from which it was made. The processing of a product will help assure a greater return to the processor, in this case an extractivist in the forest or a small holder on the fringes of the forest. A current example of this is the Brazil nut market, where the shelled nut commands a higher price than the unshelled nut (Mori & Prance 1990). Cultural Survival has financed a Brazil nut processing plant in Acre, Brazil, which allows the extractivists to receive more for their product, thus enhancing the economic viability of this activity to them (Clay 1990).

3) <u>The new crop should have an easily stored product, either before or after processing</u>. This requirement is easily understood when the producer is several days journey from a collection point or local market. Fresh produce rots rapidly or otherwise degrades in the hot, humid environment of the rainforest. Brazil nuts in the shell, for example, accumulate aflotoxins if they become infested with certain types of fungi (Mori & Prance 1990). Processing and storage are clearly closely interrelated requirements.

Arkcoll & Clement (1989) suggested that many Amazonian fruit crops may also have potential as new crops. They can only be stored, however, if they are first processed or pre-processed (cleaned and frozen, for example). Most fruit crops meet the first criterion mentioned, but can only meet the second and third after an infrastructure for processing and storage is available. In other words, they will only be suitable for most areas in Amazônia in the future, when the income-forest practitioners have become better capitalized.

When a candidate species has been identified, either by researchers, entrepreneurs, enthusiasts or the extractivists themselves, the market potential of the candidate must be evaluated (Myers 1984, Wallis et al. 1989). Several questions must be answered to determine a species' market potential:

1) Does a market already exist for the product or a similar product? An example of this is rattan (*Calamus* spp), widely used for furniture construction in Southeast Asia (Dransfield 1988). Rattan could be introduced into the Neotropics, if the Southeast Asian sources of germplasm permit. In the Neotropics, however, *Desmoncus* spp have the same growth habit and occupy a similar ecological niche. The market for rattan is extremely strong and *Desmoncus* may have the characteristics necessary to substitute for some *Calamus* species.

2) If no market currently exists, did a market exist in the past? Can this market be reactivated? An example of this is the ivory nut palm (*Phytelephas* spp), which had an important market during the late 1800's and early 1900's as a source of vegetable ivory for buttons (Barfod 1989). With the advent of plastics, this market collapsed. The recent agreements to control the international market for elephant ivory and find alternatives has reinvigorated the ivory nut market, although it is still very small compared to the 1920's (R. Bernal & G. Galano, Univ. Nac. Colombia, pers. com. 1991).

3) If no market currently exists, are there consumers interested in buying the product? The "green consumer" groups that originated from the human rights and environmental movements in the late 1980's are actively assisting local Third World groups in marketing sustainably produced forest products (Clay 1990). These "green marketeers" can help find and test markets for new crops.

4) Are there competitive products that might be substituted by the new product? It may happen that an industrially created product can be substituted by a natural product, especially if marketed with a rainforest mystique.

5) Does a "crop champion" exist? A crop champion is an advocate for the species, who generates awareness amongst consumers and stimulates other entrepreneurs to get involved with the crop. For a little known species, like many that will come from the

rainforests, a crop champion can make the difference between success and failure in the marketing of the crop.

6) A model of yields, costs and the expected price structure associated with a new crop should be developed before attempting to market it. There is frequently some knowledge available that will allow projections to be made of a species' yield in the forest or local agroecosystem, commercial value on local markets, and idea of interest by extractivists, colonists and commercial entrepreneurs.

How many species?

Myers' (1984) conception of an income-generating forest is built around the idea of diversity, both of economic products and of tropical biodiversity in general. An income forest differs from an agroindustrial plantation in that biodiversity is permitted or even encouraged in the forest, while in a plantation only the economic species are permitted. Extractive reserves currently maintain considerable biodiversity, as do many other human-managed ecosystems (Pimentel et al. 1992). Extractive reserve subsistence economies are also diverse (Hecht & Cockburn 1990) but the number of products that penetrate the outside market are small. While colonist subsistence economies are generally less diverse than Amerindian and *caboclo* economies, most colonists realize the importance of increasing the diversity in their economies (Saragoussi et al. 1990).

Myers (1984) suggests that diversity is important for several reasons. Pest and disease outbreaks are reputed to be less serious in diverse systems than in simple ones (MacDicken & Vergara 1990), although a given species may suffer as much in the diverse system as in the simple one. As an example, rubber escapes from its parasites, especially leaf blight (***Microcyclus*** *ulei*), by being rare in its naturally diverse forest ecosystem. In monoculture plantations in Amazônia, however, it is devastated by this parasite (Hecht & Cockburn 1990). What is perhaps most important here is that the producer is buffered by diversity from the loss of economic return. The producer may lose yield from one species, but will have several others that remain healthy.

The presence of diversity is also claimed to buffer the producer, especially in agroforestry systems, from economic fluctuations in the markets for these products (MacDicken & Vergara 1990). The argument states that if a producer has 5 species on the farm and the price of one of these falls so drastically that it is not worthwhile to harvest it, the producer will still have 4 other species to harvest and market. While income will be foregone from the species with low prices, the producer may not have invested labor in harvesting it except for subsistence use and can rely on the other products to maintain family income.

Any extractivist species that becomes an attractive economic prospect, however, will immediately be taken into cultivation and become a new crop which can be more cheaply produced in cultivation somewhere else in the world (Homma 1989). The history of modern tropical agriculture gives clear support to this observation. Rubber was an extractive product in Amazônia until its value went high enough to encourage efforts to take it into cultivation in Southeast Asia (Baker 1970, Hecht & Cockburn 1990). Quinine (***Cinchona ledgeriana***) followed the same route in the late 1800s (Baker 1970).

South East Asia benefitted in both of the above mentioned cases for several reasons. 1) The Amazonian species escaped from its co-evolved pests and diseases during its transference. 2) It could therefore be planted in monoculture. 3) In plantation, the trees were tended to enhance yield, with fertilizers, elimination of competition, adequate management, etc. 4) With the trees closer together, harvesting was greatly facilitated. 5) The large quantities harvested could be processed uniformly and arrive at market with uniform quality. 6) Improvement programs were immediately initiated that resulted in continual yield and quality increases. The first five factors immediately lower costs of production, which allowed the SE Asian plantations to undercut the price of the wild harvested product from Amazônia. The last factor guaranteed the dominance of the plantations.

In order to develop the income-generating forest, the possibility of an extractivist candidate species going into plantation must be taken into account. The only solution is to find and develop a large number of species and to continue this process over time. The very long-term nature of this task has probably been underestimated by those starting to work with the development of new species for extractivists.

There are also limitations to working with highly diverse systems, three of which are:

1) <u>Limitations of knowledge about the species</u> - Some established crops from other continents can be introduced with a solid knowledge base and even markets. About others there is little more than limited empirical knowledge and some anecdotes (Arkcoll & Clement 1989, Fearnside 1989). This knowledge will have to be collected or developed for each new species, especially with respect to the interactions among species in the income forest.

2) <u>Limitations of the producer peoples' knowledge</u> - The Amerindians, *caboclos*, small-holder colonists, and extractivist peoples are excellent students of their environment but are generally unschooled. They will learn rapidly from example but

may learn less rapidly from other sources of information (Allegretti 1990). This is another reason for involving them in all phases of a project aimed at developing income forests.

3) Limitations of the labor force - The extractive reserves have very low population densities (1 family/200-500 ha) (Schwartzman 1989). *Caboclo* families are also relatively small for the area occupied. Small-holder colonists tend to be more concentrated, but generally have only limited labor available. Thus labor will be limited to plant new species, unless this is combined with existing activities. Labor may also limit the amount of management attention that can be devoted to any one species, so that species with high requirements may be viewed unfavorably unless they promise very high returns.

4) Limitations of capital - All forest peoples and most colonists live far from urban centers and financial resources. They are also uninteresting to banks because they are small holders (with high administrative costs to loan value), widely scattered (hence difficult to monitor), with few assets (to secure loans) and frequently without land titles (idem). Since many of the value-adding initiatives mentioned by J.W. Clay (chapter 2, this volume) will require start-up capital, this must frequently be furnished by outsiders, until such a time as local banks recognize the potential.

It is therefore impossible to say how many species will be necessary to ensure the economic well-being of an income-generating forest. In general, at the producer level, only a few species can be successfully managed by each family, given the limitations mentioned. At the community level, however, there should be an effort to expand the number considerably, although there will always be limitations in the ability of a group to market large numbers of different forest products. Even with a large number, however, there will be more than enough room to accommodate a large fraction of the local biodiversity, either intentionally or naturally.

Establishing the Income Forest

Caboclos, Amerindians, extractivists, and most small-holder colonists are also swidden agriculturalists, although Schwartzman (1989) comments that the Acre rubbertappers are poor practitioners of this agrotechnology. Each family therefore has varying amounts of previously deforested land and will deforest a little more each year for their subsistence requirements. Agroforestry offers numerous alternative practices that have potential to productively enrich these tracts. These can be roughly divided into low- versus high-diversity systems. Generally, each family also has a tract of forest, in various stages of degradation, that would be suitable for silvicultural or forest management interventions. Most of these practices can be considered as high-diversity systems also, because a large portion of the resident biodiversity will be maintained.

Low-Diversity Agroforestry - Numerous low-diversity agroforestry systems are widely used in the humid tropics. A lot is known about their establishment and yields. This knowledge base is obviously attractive, but may have limited value for the income-forest initiative because of the *a priori* requirement for diversity.

As Ewel (1986) and Myers (1986) point out, however, a mosaic of different agroecosystems and natural ecosystems is probably more viable than any single type of system for several reasons. 1) The producer can concentrate energies on the agroecosystems and allow the natural ecosystems to continue undisturbed. 2) Each agroecosystem has different labor requirements that can be distributed throughout the year, thus utilizing labor more efficiently. 3) Each agroecosystem will yield a different combination of products that can go to market at different times. Other advantages of diversity can probably be exploited through mosaics as well. Thus, several types of low-diversity systems can be combined within the productive unit to form a high-diversity mosaic acceptable to the producer.

1) The Cacao Under Coconut Model - Nair (1979) and numerous other authors have written on the value of this model in various parts of the humid tropics. Numerous species could substitute either the coconut or the cacao in this model. Johnson (1983) has shown that the larger palms, especially the single-stemmed ones, make good upper-story components in agroforestry systems. Cacao or coffee under leguminous trees is a similar model.

In this model, coconut or a similarly statured palm or tree with a canopy that transmits enough light for an understory crop to grow is planted at or near its ideal monoculture spacing. Cacao or coffee is then planted in the spaces between the upper-canopy species. Both cacao and coffee are moderately shade tolerant and yield well in this light shade. This model generally yields more than either species in monoculture (Nair 1979).

2) The Tamshiyacu Model - Padoch et al. (1988) report on the sequence used by the farmers of Tamshiyacu, Peru, to form near monoculture plantations of umari (*Poraquieba serecia*) from moderately high-diversity traditional swidden systems. A sequence of short-lived trees, shrubs and herbaceous plants are harvested early in the sequence and removed or die out before they compete seriously with the umari. The model yields a very low-diversity mature system but is interesting because the species tolerates pests and diseases and has a strong local market. The Brazil nut is occasionally used in Tamshiyacu

instead of umari and might be used similarly elsewhere. The number of species that can be planted at high density in Amazônia is limited, however. Peters et al. (1989) list several that naturally occur in nearly monospecific stands and therefore have potential for this type of model.

The question is: are these low-diversity models appropriate starting points for income-generating forests? In terms of producer acceptance, ease of installation and management, facility for marketing greater volumes of product, etc., these models are certainly appropriate, especially in already degraded areas. If biodiversity conservation is also a primary objective, however, then these models are less appropriate on a large scale. Consequently, they would be suitable as components of an income-forest, agroforest, subsistence swidden mosaic.

High-Diversity Agroforestry - Numerous high-diversity agroforestry systems are found throughout the humid tropics. Many of these are of ancient origin, others appear to be due to increased population pressures (Michon et al. 1986). They are apparently stable and economically viable, although their economic value is seldom easy to quantify (Alcorn 1989).

1) The Home Garden Model - MacDicken (1990), Soemaroto (1987) and many others have reported on the highly diverse home gardens found throughout the humid tropics. These may have 50-70 or more useful species in an area of less than a hectare. They supply a wide range of subsistence needs and frequently surpluses for market, thus supplying family needs that would otherwise cost money as well as generating a small income flow.

These gardens could be expanded away from the home, much as is done in Pohnpei, Micronesia (Raynor 1989), or among the Huastec Maya of southern Mexico (Alcorn 1989). Non-economic plants are tolerated and may even be encouraged to enhance "ecosystem services", such as shade, erosion control, micro-environment control, etc. (Alcorn 1989). This type of expanded home garden with some fallow characteristics appears to provide a solution acceptable to both producers and the conservation movements that are currently supporting sustainable development programs.

2) The Swidden-Fallow Model - Denevan & Treacy (1988), Flores Paitán (1988), and others have described the swidden-fallow system in Amazônia and elsewhere. Most extractivists already practice some form of this system, although it is frequently much less elaborate than is the case among the Bora and other Amazonian Indian groups. The more elaborate techniques used by the Amerindians enrich the economic-plant diversity in the fallow and tolerate volunteer non-economic plants as well. Balée (1989) has suggested that these systems are probably the origin of most high density stands of Brazil nut (called *castanhais*), many palms

(*babaçuzais, tucumãzais* (***Astrocaryum tucuma***), etc.), and other anthropogenic forest areas in Amazônia. This model, then, is definitely appropriate for the planting of income forests.

3) S. Flores Paitán's Sequential Experiments - Based upon the swidden-fallow model, these experiments are designed to yield subsistence and marketable products during several decades, until the timber species reach marketable size (S. Flores Paitán, Univ. Amazônia, pers. com. 1990). Plantation geometry is based on a 2 x 2 m or 3 x 3 m grid, with species having distinct growth habits, sizes, competition and pest tolerances occupying the 2 x 2 m, 4 x 4 m, 8 x 8 m, 12 x 12 m, 16 x 16 m or greater nodes.

The design is simple, flexible and easily understood and adapted by producers. Although the current experimentation is relatively new (< 15 years), it has been well accepted by several colonist and native communities around Iquitos, Peru. While current practice discourages non-economic volunteer plants and aims for a "climax" of timber species, this could easily be modified to attain the objectives desired for an income forest.

The agroforestry models mentioned, both high and low diversity, require the elimination of the forest as a starting point, and so are suitable for the swidden areas that each *caboclo*, Amerindian, small-holder colonist or extractivist prepares each year. The practices presented below start from the intact forest or from forests in various stages of degradation, but which still have some forest structure remaining.

Silviculture and Forest Management - Forestry has many practices that can be adapted from a timber production model to an income forest model. Also, timber may, in fact, be one of the numerous alternatives extracted from an income forest, as long as it is managed as a sustainable product, rather than being "mined". Poore (1989), however, point out that sustained-yield forest management is not currently practiced on more than an experimental scale in Amazônia, although many private and state businesses will argue violently that they are practicing it. Nonetheless, the technologies exist and have been used in various countries during the last century. As Palmer (1989) points out, the technologies themselves are biologically viable, although the socio-economic milieu in which they are used may not be conducive to an economically successful intervention. Of the numerous practices available, only two will be discussed here.

1) Enrichment planting - Numerous variations of this practice exist and have been experimented with in Amazônia and elsewhere. At the National Research Institute for Amazônia (INPA, Manaus), the Tropical Silviculture Department has used narrow trails cut in the forest or second growth areas to plant timber species at quite high densities. As an example, a trail is 4 m wide and separated from the next by 10-15 m of relatively undisturbed

forest. Economic species are planted along the trail at 2-4 m intervals. In order to assure adequate growth of the desired species, the trails must be maintained open, both at ground level and at canopy level, until the economic species reach the canopy level (N.P. Fernandes, INPA, pers. com. 1990). On poor ultisols near Manaus, INPA has observed moderate growth rates of andiroba (*Carapa guianensis*, Meliaceae, an income-forest candidate with oil-rich seeds), with low incidence of tip-borer (*Hipsiphylla grandella*), in this system (P.T.B. Sampaio, INPA, pers. com. 1990). Other timber species are also giving good results.

An ecologically attractive alternative is to use natural or created gaps in the forest to plant a selection of economic species. This has the attraction of using natural forest dynamics, i.e. gap creation and forest regeneration in them, to enrich the forest. This was tried by a company working in the Madeira River watershed south of Manaus, but did not succeed because they did not adequately manage the gaps until the economic species could compete successfully with the natural regeneration, which is always very vigorous in the native forest. Nonetheless, this alternative form of enrichment planting deserves further evaluation because it involves lower levels of intervention than other forms.

In a forest that has been partially degraded by selective logging, numerous gaps and extraction roads are left in the forest (de Graaf & Poels 1990). Enrichment schemes in these areas would significantly improve the regeneration of the forest with a higher level of economic species. Again, any interventions in this type of forest would require continued management of the area, especially to control vines and less desirable competitors.

Although timber has been the objective of all Amazonian experimentation with enrichment plantings to date, many of the species used have been multipurpose species, like the andiroba mentioned above. Enrichment plantings have the additional advantage of introducing high-quality germplasm into the forest, which is not generally practiced with the next alternative.

2) Natural regeneration - An example of this practice is provided by de Graaf & Poels (1990). The CELOS Management System combines careful harvesting technology with a significant silvicultural intervention to create a sustained-yield forest management system based upon natural regeneration of economic species. Natural regeneration is defined as the use of naturally occurring seeds, seedlings and saplings of the desired species, without introduction of outside germplasm, to repopulate the disturbed area. This is precisely the way a forest regenerates from a disturbance in the absence of humans. In the CELOS system, humans direct natural regeneration, however, so as to increase the abundance and the growth rate of desirable species. On poor

oxisols in Suriname, de Graaf & Poels (1990) report that a 20- to 25-year timber harvest cycle is possible. Although all experimentation to date with this and similar techniques has been with timber species, there is only one important limitation to adopting this practice directly for the creation of income forests.

The limitation is the genetic and market quality of the naturally regenerated population of the desired species. In forestry, the best quality trees are removed during harvest, leaving second-quality germplasm and juvenile material who's quality has not yet been examined. Over time, i.e. over several regeneration cycles, this results, inevitably and unintentionally, in the degeneration of the genetic base of the desired species. In forestry terms, the population will present fewer trees with straight stems and fast growth. This limitation will be directly felt with any of the multipurpose forest species used in income forests (eg with andiroba).

With species that are not also potential timber crops, such as palms or copaíba, for example, natural regeneration may not provide a sufficient number of plants within the population that yield well or have sufficiently high-quality products for market. If this is the case, poor-quality individuals can be selectively eliminated from the area, allowing for the slow increase in abundance of high-quality individuals. Over time, this will result in the genetic improvement of the desired species, which will almost always be necessary to supply growing markets.

Given the limitations in genetic and market quality that may be present in the initial populations in any given area, it would make sense to combine enrichment plantings with regeneration management. This will increase the abundance and market quality of the managed populations, facilitating harvest and guaranteeing reasonable prices because of good quality.

The high-diversity models discussed above are directly relevant to the income forest precisely because they are highly diverse and can contain significant biodiversity. Flores Paitán's experimental work, for example, shows that high-diversity agroforestry systems can be readily adopted by modern producers with a market orientation. The use of enrichment plantings and natural or managed regeneration should also be readily adopted by producers, because they are already generally practiced to a certain extent by most *caboclos*, Amerindians, and small-holder colonists and only require orientation to point them in the direction of the income-generating forest.

As Gregersen et al. (1989) point out, any set of plants and plantation designs offered to the public will have to be site specific, both in ecological and cultural terms. Thus, the whole gamut of models discussed in the above paragraphs, plus numerous others that exist elsewhere in the humid tropics, have a potential role to play in developing income-generating forests. Ewel's (1986) emphasis on mosaics can guide the adoption of these different models into a coherent whole.

The models selected must be attractive to the users, principally in terms of the economic returns that the user can expect, but also for esthetic or cultural reasons important to them (Alcorn 1989). As researchers and planners, we visualize the income forests as being compatible with the conservation of tropical biodiversity in general. But the users are interested more in economic returns. Consequently, we can recommend most intensively those models and management practices that are flexible enough to allow for the accumulation of non-economic species in the matrix or at least within a mosaic that leaves space for biodiversity.

Applying the Income Forest Idea

Once a list of candidate species and agroforestry or forestry models has been selected by an extractivist, colonist, Amerindian or other community, a research and development effort by state, national or international agencies and private conservation and entrepreneurial groups must be organized in collaboration with the community. This effort will include a genetic/agroforestry component, a marketing/entrepreneurial component, and an extension component. Some of the activities necessary are:

1) Product information availability - The importance of the market has been mentioned previously. Even before a product goes to market, however, information on its characteristics must be available to the commercial segments of the chain that will take it to market. The R&D institutes and agencies that support this program must prepare documentation that can be distributed to all segments of the producer/merchant/consumer chain. This information must include not only health and safety data, product quality characteristics (chemical/nutritive), but expected yields, harvest periods, ease of processing, storage and transport, etc., obtained either from the literature or from directed research.

2) Selling the idea to the producers - The forest peoples are well aware of what they need (Allegretti 1990), but they have already been deceived many times by governments and entrepreneurs. Therefore, the extension of the income-forest idea and its new crop and agroforestry/forestry systems R&D must be done openly and honestly. This is best done in detailed discussion with forest producer groups, who will be expected to suggest and approve candidate species, species combinations,

plantation layout, etc., based upon the best information that researchers, planners and the producers themselves can provide.

Once the idea is accepted, all stages of planning and execution of the research and development must be done in collaboration with the community. Rocheleau (1987) discusses the whys and hows of working directly with the community to be benefitted by any development project.

3) Provenance evaluation and germplasm selection - Wood (1990) outlines the process for agroforestry species and slight modifications of this process can easily be introduced to arrive at a full-fledged income forest. Arkcoll & Clement (1989) emphasize the importance of a wide genetic base, as most perennial species are outcrossing and thus highly variable. One outstanding provenance can make a species, while a dozen inferior ones are not worth pursuing. Once a wide genetic base has been obtained, selection for quality and yield is essential to develop high-quality plants and products for the consumers.

Germplasm collections, however, are expensive to develop, maintain, characterize and evaluate correctly. Since most forest communities will not have the resources to do this in the classical way, their individual home gardens and swidden plots can be used. Most Amazonians, and probably most other tropical peoples, use their home gardens for just this type of germplasm evaluation (Saragoussi et al. 1990). The R&D agents who work with the extractivists on developing new crops must maintain good records of germplasm location and assist the producers in evaluating those species unfamiliar to them. In this way, large amounts of germplasm can be evaluated and selections made with relatively low costs.

4) On-farm experimentation with selected models - Because an income forest may take 15-30 years to attain full stature, depending upon the route taken to establish it, the agroforestry/forestry experimentation must be done on farm. This is also necessary because large areas of Amazônia (> 100,000 km^2) are already degraded and require urgent action to become productive again and because this time frame is similar to that for worst-case projections for the elimination of the Amazonian biome from most of its current area.

Flores Paitán's sequential and geometric designs have proven to be acceptable to producers in Peru and can be easily understood and implemented by producers elsewhere. They yield abundantly and continually throughout their development, which is a major reason for their attractiveness. They are also inherently attractive to university-trained R&D staff for the same reasons, and because they are perceived to be more "scientific" than the apparently random location of plants in Amerindian swidden plots. Where Amerindian knowledge and experience is available, however, this should be exploited. All on-farm experimentation should be done within a mosaic pattern, since this is a way to increase diversity at the farm level and thus reduce the risk of failure for the producer.

5) Entrepreneurial development - Most new crops or products require an active entrepreneurial participation to develop lucrative markets. Entrepreneurial capability is often lacking in Amazônia and elsewhere in the humid tropics, however, not only among the forest peoples but among the researchers and conservationists who are attempting to assist these peoples. Cultural Survival Enterprise's Rainforest Marketing Project has run into this barrier at the local level (J.W. Clay, Cultural Survival, pers. com.).

The development of local and regional entrepreneurs must be fostered in order to guarantee the success of this type of venture. In Brazil there are several agencies that support the small and medium entrepreneur, as well as cooperative ventures. Some international foundations specialize in training Third World groups through consultancies and courses organized with retired entrepreneurial and managerial experts from the developed world. A combination of these ideas with current efforts to market forest products can help develop the required know-how.

6) Getting long-term financial support for R&D - The international research and development agencies should be receptive to this idea since it includes both new crop development and agroforestry, both of which are "hot" areas for funding. This financial support for research and development should not be confused with the development of the commercial chain that will take the products from the forest to the consumer. This chain must remain free from subsidies that can distort the true economic value of a product or species. Most forest peoples desire a helping hand to become independent, not a hand-out to remain dependent.

Conclusion: Is It A Viable Alternative?

The income-generating forest idea is extremely attractive, both for forest conservation and for sustainable development in the tropics. As outlined above, its implementation is feasible in agroecological terms. Agroforestry systems and forest management practices can play important roles in developing income forests, as they are known and will be easily accepted by the forest peoples. The agroforestry systems, especially, will provide an economic return during the years that they take to mature, and they are flexible enough to accommodate a great number of species.

If the species are chosen with care and if marketing channels and local entrepreneurs can be fostered, they will be economically viable. Nonetheless, once the necessary research starts it will be never-ending, since successful new extractivist products will be taken into plantation in other tropical areas and newer ones will be necessary to replace them.

Given the idea's potential for tropical-forest conservation and sustainably improving the quality of life of the forest peoples, the research and development necessary to design, plant and manage income-generating forests is well worth the investment.

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Some Amazonian Forest Products and Initiatives for Adding Value to Them

J. W. Clay & C. R. Clement

Virtually every product that comes from the forest is first processed within the forest, as well as in nearby urban areas. This value added is what makes the commodity initially marketable, in the sense that it could not be sold without such processing. This is true of rubber, Brazil nuts, babassu, assaí and the other most commonly traded commodities. How and where additional processing could occur to add value locally will vary by commodity.

In this report 19 Amazonian species are discussed that have potential on local, regional, national and international markets, as well as being potential components for agroforestry or forest management systems. In addition, various ways of adding value to these and other types of commodities are suggested. Each example is intended to allow the reader to understand the range of possibilities, in order to think of ways to add value to products not discussed in this report.

Unfortunately, the implementation of these ideas could be difficult for at least three reasons. (1) The politics of who owns the infrastructure, processing plants, etc. that are suggested here will be a political issue. To the extent that states guarantee the loans, they may want to retain ownership. Likewise, local collector and producer groups are not the same as processor groups and both might have legitimate claims to ownership. (2) Cooperatives or other local groups often have no history of cooperative financial endeavors. (3) At this time few local groups have the skills necessary to run such ventures. Thus, any investment in processing or value-added initiatives will succeed only if issues of ownership are thought out ahead of time and if technical assistance is made available to local groups from the beginning.

The species discussed in detail in this report are listed in Table 1, which also provides some basic information on each of the species. Most of the species have multiple uses. Consequently there may be several ways to add value between the tree and the market.

All of these species are used to some degree in Amazônia today. Most have markets on at least a family subsistence basis, the exception being ucuúba, which was once an important oil species but today is only used to make plywood. At the other end of the market spectrum, some of the species already have international markets that could be expanded (eg Brazil nut, Cupuassu fruit pulp, Cumaru and Rosewood essential oils, Assaí palm hearts, Copaíba oil, vegetable ivory nuts.

Table 1. Multipurpose Amazonian species with present and future market potential to serve as components of agroforestry and income-forest management systems.

Common and specific name	Yields[a] (kg/tree)	Uses[b]	Current Markets[c]
Assaí (*Euterpe oleracea*)	24F,0.1Ph	F,B,Ph,H	F,L,N,I
Buriti (*Mauritia flexuosa*)	200F	F,B,H	F,L
Patauá (*Jessenia bataua*)	16F,1.3Ol	F,B,O	F
Pejibaye (*Bactris gasipaes*)	15F,0.2Ph	F,B,O,Ph	F,L
Piqui (*Caryocar villosum*)	60F,1.8N,2Ol	F,O,T,Ch	F
Brazil Nut (*Bertholletia excelsa*)	50N	N,O,T,Ch,H	F,L,N,I
Pendula Nut (*Couepia longipendula*)	?	N	F
Bacuri (*Platonia insignis*)	93F,16N	F,N,T,Ch	F,L
Camu-camu (*Myrciaria dubia*)	12F	F	F,L
Cupuassu (*Theobroma grandiflorum*)	16F,1.4Ol	F,O,C	F,L,R,N,I
Copaíba (*Copaifera multijuga*)	0.5-1Ol	O,P,M	F,L,R,I
Jatobá (*Hymenaea courbaril*)	<15R	F,R,T	F
Andiroba (*Carapa guianensis*)	90Ol	O,M,T	F,R
Babassu (*Orbignya phalerata*)	1Ol	O,Ch	F,L,R,N
Ucuúba (*Virola surinamensis*)	42Ol	T,O	?
Cumaru (*Dipteryx odorata*)	0.1+Ol	O,E,P,T	F,L,I
Rosewood (*Aniba duckei*)	9Ol	E,P,T,H	I
Sacaca (*Croton cajucara*)	0.1Ol	M,E	F,L
Tagua (*Phytelephas aequatorialis*)	15N	N,H	F,N,I

a - Yields (of unimproved, unfertilized plants): F - fruit, N - nuts, Ol - oil, Ph - palm heart, R - resin.
b - Uses: B - beverage, C - cosmetic, Ch - charcoal, E - essential oil, F - fruit, H - handicrafts, M - medicinal, N - nut, P - perfume, Ph - palm heart, R - resin, T - timber.
c - Current markets: F - family, L - local, R - regional, N - national, I - international

Nuts

The Amazonian forest product that is best known is the Brazil nut. Adding value can start by cooperation among collectors. Collector cooperatives which buy and then sell in large volume can increase the value of the nuts from the 2-3% of the New York price to ≈10%. The skills that are needed to run such cooperatives are the same that are needed to provide members with less expensive necessities that are purchased in bulk and then sold to members. Eventually, these skills can be used to set up and run local processing facilities, which may allow collectors to increase their gross revenues to ≈60% of the New York price for the nuts they gather.

Another alternative way to add value locally is to process or semi-process the product locally. For example, in 1990, the first Brazil nut shelling factory owned by nut collectors in Brazil was financed. The initial cost of the Xapuri plant was US$30,000. Subsequent modifications have brought the cost up to ≈US$60,000. In addition to the cost of the plant, the local co-op was provided with the US$12,000 annual salary of the plant manager and considerable technical assistance. Since 1990, technical assistance to the plant has exceeded the financial investment in plant infrastructure. [NB: Building plants and processing facilities, regardless of the commodity produced, will often cost less than the technical and financial assistance and training that must accompany them if they are to succeed.] In 1993, the plant could become profitable for the first time if it reaches its overall production goal of 200 metric tons (MT) of nuts and 12 kg of shelled nuts/worker/day.

The return on this investment has been quite impressive. To date, the factory has shipped 112 MT of nuts to the US. The factory employs some 100 people in Xapuri, making it both the largest employer and the largest taxpayer in the town. The factory loses, through spoilage, only about 15% of the nuts it purchases each year compared to the 25-35% loss by commercial shellers in Manaus and Belém. Perhaps most importantly, the factory has increased the price paid to collectors for nuts in the shell by 40% in 1990 and 100% in 1991. Word of the doubling of the price in 1991 spread quickly in Acre, leading to other gatherers demanding the same price. Consequently, in that year alone, the price paid to all collectors in the state for their nuts increased from an estimated US$600,000 to US$1.2 million.

Decentralized shelling is another way to add value in the forest, reduce post-harvest losses and reduce transport costs of nuts to market. Decentralized shelling systems are appealing because they cost even less than the small Xapuri-type plants and because they generate income in the forest itself. The main problem with decentralized shelling is maintaining quality control. For this reason, it is essential that a centralized facility be established with <u>each</u> decentralized system to maintain quality control and sort, dry and package for export. Provided a central processing plant exists, small groups can be brought into the system for an investment of only a few thousand US dollars each. A rubbertapper group in Cachoeira, Acre, is working to evaluate this decentralized model.

Amazônia contains numerous other species that furnish edible seeds. Even within the Lecythidaceae there are several as good as the Brazil nut and one (*Lecythis pisonis*) that is frequently considered to be superior. The piquiá (Clement, this volume) and other *Caryocar* species provide an edible seed within a spiny endocarp, which is generally enveloped in an edible oily/starchy mesocarp. All of the palms provide edible seeds as well, although these are not commonly used today. The pendula nut (Sampaio, this volume) and other *Couepia* species are also edible and of high quality. Even the bacuri is reputed to have an edible seed (Clement, this volume). Any of these could become a new alternative in some part of Amazônia and would be relatively easy to introduce into the world nut market because of similarities with other nuts.

Oils

During the first 3 decades of this century, and again during World War II, Brazil exported some 40 different vegetable oils from Amazônia. These exports declined precipitously with the advent of electricity (and the elimination of candles) and the extensive cultivation of corn and soybeans, which became the most commonly traded vegetable oils on the world market. During World War II, the US and the UK pushed Brazil to encourage the collection of wild rubber in Amazônia at the expense of all other forest products. Consequently, many of the small Brazil nut shelling operations and oil purchasing centers which had dominated local economies since the end of the rubber boom were forced out of business.

Today there is an increased global interest in vegetable oils, particularly those with exotic properties or that can be produced without degrading the environment. Palm oil (*Elaeis guineensis*), for example, which had been embraced by a number of personal care manufacturers, has begun to lose its appeal as they realize that most palm oil is produced from plantations that have been carved out of rainforests (eg The Body Shop, pers. com.).

The only oil in Brazilian Amazônia that is being produced in quantities sufficient for high volume trade is babassu. Today some 400,000 families in Maranhao and Pará depend on babassu for most of their income during six months of the year. Babassu competes with coconut oil in Brazil for about six months of the year, but it is always at least 25% more expensive than palm kernel oil. Babassu's costs come from the amount of hand labor associated with extracting the oil seed from its shell. Wages are miserably low for shellers -- probably not even 25% of the minimum wage.

A prototype mechanical sheller has been developed that produces not only the oil seed, but a number of useful by-products: flour for human consumption; fiber and flour for animal rations; and the hard shell, which makes an extremely low sulphur charcoal. With only a little more development, shelling machines could be produced at about US$25,000 with each serving a handful of communities. The machines would cut down on the shelling time and free family members to spend more time collecting babassu. Current estimates indicate that only 20-30% of all babassu is collected each year. With current prices, harvesters could collect in 4 hours what they spent 8 hours collecting and shelling in the past. The net effect would be to reduce labor requirements, reduce overall costs of the oil seeds, and consequently reduce the price for oil itself while increasing overall production and income. Thus, the mechanical sheller would generate employment in gathering and related industries while reducing the price of the finished product, thus making babassu more competitive in national and international markets. See Balick & Pinheiro (this volume) for further details on this initiative.

Another way to add value and generate more income locally with babassu would be to introduce village-level oil presses, each at a cost of about US$5,000 to US$10,000. Such technology would more than triple the value of the product while reducing its overall weight, volume, and transportation costs. In addition, a by-product would be the cake left after pressing the seed, that could provide good rations locally for chickens and pigs, thus improving the diet of local residents. Currently, the cake that is left after expelling the oil is sold to commercial livestock producers.

Another Amazonian oil crop that could benefit from village-level oil presses is patauá. As Balick (this volume) points out, during World War II this oil was marketed as a substitute for olive oil. With the current interest in unsaturated oils, patauá could find a receptive market. There are thousands of hectares of *patauazais* in diverse parts of Amazônia which could be sustainably harvested.

Other potential oil crops are andiroba, Brazil nut, copaíba, and ucuúba. Copaíba and andiroba have long been exported from the region. During the 1920's, copaíba was exported primarily for the perfume industry, where it still has a steady but dwindling market (Sampaio, this volume). Andiroba oil reached 350 MT of exports in the 1920's; today, it is not exported, and andiroba trees are being cut for timber because they have no other value (Sampaio, this volume). Ucuúba was important as an industrial oil, especially for soap making. Today it is planted as a timber crop and its annual oil-seed harvest is wasted (Sampaio, this volume).

Essential Oils

Anyone who has been to the Ver-O-Peso public market in Belém becomes immediately aware of the wide number of essences and essential oils in Amazônia. Nonetheless, with the exception of a few rosewood products, all personal care products (cosmetics, soaps, perfumes, etc) made from Amazonian essential oils are imported into the region. Some are imported from São Paulo, but most actually come from or via Europe. Thus Amazônia, and Brazil in general, are in the strange situation of producing the raw material, exporting it cheaply, and importing the finished product, usually at great expense.

A vapor essence or essential oil extraction plant would cost about US$1 million to set up. Research should be undertaken on the existing essence manufacturing capacity in Brazil and other Amazonian countries to determine what could be done to increase capacity and to improve the quality of the products. This is one area where it may well pay to add value locally by preparing the final product and exporting it as a sustainably produced Amazonian perfume or other personal care product.

There is a huge market for essences, particularly ones that are new and exotic. The cheapest perfume that one might buy contains at least 40 essences; the more expensive ones are even more complex. Essential oils of many of the fruits in the region would find markets in soaps, shampoos, and other personal care products. Likewise, oil extracts from fruits or their seeds would also find markets (e.g., passionfruit, avocado, mango, and a whole host of more exotic, lesser-known species). Companies have taken considerable interest in other seeds as well (eg puxuri and cumaru). Flowers, such as propagated orchids, and various plants could also be used to produce essential oils.

Rosewood is the only essential oil that is now produced for export from Brazil. A good source of linalool, which is used as a fixative by the French perfume industry, rosewood was in such demand that it nearly depleted the species (Sampaio, this volume). Consequently its production costs increased and high prices finally led to its substitution by synthetic linalool for most uses.

Two other Amazonian plants, sacaca and pimenta longa, are good sources of linalool. Sacaca, a bush that grows 2-5 m in height, has leaves that can be harvested after 6-8 months. After drying, the leaves produce 0.8% essential oil by weight. The leaves of sacaca are currently dried and shipped from Manaus directly to Japan where they are processed; no value is being added in Brazil (Venturieri & Ribeiro, this volume). Pimenta longa, a low-growing plant, is not currently exploited commercially. These two could be cultivated rather than harvested from the wild.

Flours

With the exception of manioc or cassava flour, flours are not major traded commodities in Amazônia today. Yet markets for manioc flour could be expanded considerably and other flours could offer considerable revenues to specific groups, diversify sources of income, and make use of presently neglected products or by-products. Pejibaye (peach palm) flour is quite nutritious and has been used as a food staple by indigenous peoples in Amazônia for thousands of years. There is evidence to suggest that peach palm was, in fact, the first domesticated food crop in the Americas (before maize, beans, or manioc).

Peach palm field trials demonstrate that it produces six times as much edible fruit biomass as maize. The ground fruit, which may also be high in oils, makes excellent animal rations (maize and sorghum for chickens and pigs in the region is currently trucked in from the south of the country at high energy costs). In Costa Rica there is a rapidly growing demand for peach palm flour for bread, pasta, cakes, rolls, and so on. At the very least peach palm could be used in Brazil as a highly nutritious substitute for manioc farinha, and since it is a tree crop it does not require the same clearing, planting, and digging up as manioc (Clement, this volume). [In addition to flour, peach palm also has market potential for fresh fruit and for sustainably harvested palm heart or rainforest chips made from the soft heartwood below the palm heart (about twice the volume and weight of the palm heart).]

Jatobá has long been an emergency food in Amazônia. Its large, distinctive seed pods contain a flour that is the consistency of oat flour, and is unique for its aromatic qualities, although this varies somewhat between the three species (Ferreira & Sampaio, this volume). Although its scent would indicate good potential in the personal care products industry, it would probably detract from its acceptability as a food product (it smells a little like carob tastes). If the seeds are collected in a timely fashion, the flour is in good condition -- otherwise, it begins to mold. To sell the product in ton or container quantities, more health and safety data would have to be compiled. Despite these factors, there is currently market interest in the product.

Brazil nuts have long been consumed by forest peoples, generally as nuts or pounded into a milky substance to cook vegetables, fish, chicken or meat. Now markets for Brazil nut oil can be developed as well. When the oil is extracted from good nuts, a highly nutritious Brazil nut cake remains (about 50% the weight of the original nut). The cake is about 50% protein, and when mixed with flour it could be used to make bread and pasta higher in protein than meat. (Perhaps it could be used in regional school lunch programs.) The protein in Brazil nuts also appears to be easily digested. Recent studies suggest that it may be particularly good for people who have difficulty digesting protein, such as patients undergoing chemotherapy or those with AIDS. The advantage of the cake over the whole nuts is that most oils have been removed.

Fruits

Tropical fruits, probably more than any other single food category, are associated with Amazônia in the minds of Western consumers. In addition, the tropical fruit juice category is the most rapidly expanding juice market in the US. As the US population ages, more sophisticated non-alcoholic adult drinks are developing large market niches. It is therefore odd that with all these marketing angles, there is only one functioning fruit processing plant in the entire Brazilian Amazon -- the factory at Tome Açu, Pará, built with the assistance of the Japanese government. This initiative exports most of its product to Japanese companies.

To date, fruit processing in Amazônia, whether by hand or machine, has consisted of freezing fruit pulp. Given the high cost of energy needed for freezing and the high costs associated with transporting products that are mostly water, other methods of processing Amazonian fruit should be examined carefully. While frozen fruit pulp is of interest to most manufacturers, the high costs associated with transporting such products from Amazônia have deterred most from their initial desire to produce juices, jams, ice creams, yogurts, and so on.

Three new technologies should be examined and perhaps introduced in Amazônia to overcome the current problems associated with creating markets for the region's fruit.

1) The method of processing frozen fruits should be changed. Instead of only processing the fruits that have the strongest flavors (eg acerola and cupuassu) and thereby obtaining higher prices because they can be diluted more, efforts should be focussed on processing fruit juices with higher brix concentrations (a measurement of natural sugar percentage). For example, by doubling the brix levels, the water content is reduced by half and thus the overall weight and volume is less. In short, it makes no sense to ship frozen water halfway around the world.

2) With aseptic packaging, fruit can be packaged without freezing it. This type of packaging would be good in combination with a fruit processing plant that produces concentrates. Aseptic packaging plants could run 24 hours per day, an especially useful framework for the short, intense fruiting

season of many Amazonian species. It could also produce individual containers as large as 300 gallons (about one ton; these are the collapsible pallet containers with metal/plastic bags that are used to ship oil). Alternatively, an aseptic plant that produces individual drink boxes could be built. Neither plant requires sterile water during operation, only potable water to clean the equipment during downtime.

Aseptic packaging units have been used all over the world, even off semitrailers in China. MAPS (mobile aseptic processing systems) might be the perfect solution in Amazônia, particularly if they could be mounted onto barges (with a water purification unit) and floated to the sources of the fruit, rather than having the fruits, which often spoil very quickly, taken to the factory. In this scenario, it would be possible to put a container right on the same barge so that it could be filled as the fruit is processed, then taken off by crane at the dock for direct export by boat or tractor-trailer to other parts of the country.

3) Drying. There are ever-increasing markets for dried fruits as well as fruit leathers (dried fruit products made from pulp). The advantage of these items, too, is that they have relatively high values per weight and volume and customers are not paying to ship water. Village-level drying technology is well known. The main necessity for drying fruit is air movement rather than heat. Black plastic, plastic screens, and other inexpensive materials have revolutionized the industry. Village-level dryers in Honduras are capable of producing 10-20 MT of dried fruit per season. They cost US$5,000 to US$10,000 to construct. Adequately maintained systems can last ten years.

In Amazônia and its buffer areas, five fruits could be processed immediately: assaí, buriti, camu-camu, cupuassu, and bacuri. Each of these fruits illustrates the importance of one or more of the above-described processing systems, and each represents both the problems and prospects with development and conservation in the region.

Assaí is found in nearly monocrop stands, both naturally occurring and created, near the mouth of Amazônia and in varying densities along the river all the way to Bolivia (Bovi & Castro, this volume). In 1990, the market for assaí fruit, which was entirely domestic, was nearly US$100 million. The main market for the fruit is in Belém, where as many as 50,000 liters of unprocessed fruit are sold daily. Harvesters in the area can earn as much as US$10 to US$15 per hour.

Unfortunately, the Belém market can be supplied only with fruit that is no further away than a single night's boat trip because after 24 hours the fruit spoils. Within an evening's ride of Belém, then, assaí fruit is very valuable. Outside of this radius, however, assaí stands are decimated and sold for palm heart. Attempts to process the fruit locally, with sugar to preserve it, work well technically but do not appear to be acceptable in taste for the Belém market.

A floating processing plant would provide a perfect solution to the processing/transport problem. However, simply introducing the technology without expanding the market would reduce the price currently paid to collectors, and more likely than not would make the currently productive assaí areas less valuable and thus more likely to be developed for housing and vacation spots due to their proximity to the metropolitan area of Belém.

Like assaí in Belém, buriti is the most popular palm fruit in the Iquitos market (Castro, this volume). Most of it is processed into a thick juice. A floating processing plant would be an excellent option to open new areas for exploitation, if the plant actively educated its local collectors about how to harvest buriti non-destructively. Well-processed buriti juice might also have export potential, but only if harvested sustainably.

Camu-camu is extremely high in vitamin C. It, too, is found in monocrop densities in vast areas of the Peruvian Amazon and could be processed in a floating processing plant. However, camu-camu does not currently have a large regional market, although the local Iquitos market is large and expanding rapidly (Chávez, this volume). Again, a floating processing plant could expand production and prepare camu-camu for penetration of other markets, starting with Manaus and Belém, later the rest of Brazil and South America.

Cupuassu represents yet a different challenge and potential for Amazon residents. A close relative of cacao, cupuassu has long been known as a source of cocoa butter, which is particularly high in white chocolate. What is most attractive about cupuassu, however, is the distinctive flavored pulp that surrounds the seeds (Venturieri, this volume). Because it is a strong flavor it is mixed into ice cream at a ratio of 1-to-20. Thus, although the fruit is expensive, a little goes a long way.

The fact that cupuassu is a valuable crop and that demand within Brazil is growing rapidly explains why so many government officials are promoting its planting and why so many forest residents, colonists, and mid-sized landowners are planting it throughout Amazônia. Unfortunately, no one is as yet actively funding processing plants or the creation of markets for the crop. While most plants begin to produce in 3-5 years, only one centrifugal processing plant exists to process the fruit. Most of the areas with large plantings have no processing capacity, and although the fruit will last several days after harvesting, it is likely that a few wealthy individuals will gain control of the processing and thus the fruit's market. This scenario is likely to keep forest residents impoverished and forests endangered.

Cupuassu represents a problem typical of planting-based development programs. Too little attention is given to processing and marketing (other crops with similar problems are coffee, cacao, cashew and annatto/urucuum). A village-level aseptic processing plant would cost about US$30,000; larger, regional plants could cost more than US$500,000.

Like cupuassu, bacuri has a strong, distinctively flavored pulp around the seeds (Clement, this volume). Frequently one or more of the seeds will abort, but the pulp will still be produced. This seedless section is highly prized in Amazônia and has potential for drying and more ample marketing. The rest of the pulp could be treated aseptically for shipping.

Handicrafts

Handicrafts are a form of adding value to any raw material. In this report, tagua [or vegetable ivory (Bernal & Galeano)] is the only species treated as a pure handicraft material. Interest in using vegetable ivory for semi-industrial uses (eg buttons) is also reviving but is less likely to provide significant income for forest peoples unless the industries are located in or near areas that produce this raw material.

Many of the other species mentioned is this report also furnish raw materials to local and regional handicraft industries. Aside from vegetable ivory, all of the other palms can also furnish wood for handicrafts. Pejibaye, for example, has a dark brown fibrous matrix with yellow or beige rays running lengthwise through it, forming a very pleasing design that is highly prized for many small articles. The other palms have a distinct, but pleasing appearance also. The leaf petiole of buriti is exceptionally large and its pith is quite similar to balsa wood and can be used for many of the same handicrafts, although this is not current.

The fruit of the Brazil nut is a spherical woody structure, called an *ouriço* in Brazil. The *ouriço* is widely used for handicrafts in eastern Amazônia, with little to significant modification of its natural form. It is easily turned on a lathe and yields a very pleasing grain design when well finished. It is also frequently carved with Amerindian floral or faunal motifs.

Because of its pleasant perfume, rosewood is also used in the manufacture of handicrafts, especially small jewelry boxes or chests for miscellaneous objects. All of the dicots can furnish wood for handicrafts and carpentry also.

The species detailed in this report and the value-added initiatives outlined are merely a sample of what could be done with Amazonian forest products. Imagination is one of the prerequisites for developing or expanding markets for any of these products and ideas, as well as for others not discussed here.

In the following chapters more information is provided on the species mentioned above. These chapters show the limits to current knowledge and point the way to obtaining the type of information that will be necessary to develop each species. As mentioned by Clay (this volume), this information is another of the prerequisites for developing these species further.

Assaí

Marilene L. A. Bovi & Aline de Castro

There are at least two different palm species known as assaí in Brazilian Amazônia: ***Euterpe oleracea*** Mart., called açaí-do-Pará, an extremely abundant, multistemmed palm, that occurs in the *varzeas* (annually flooded white water river terraces) and in the Amazon River estuary, where it frequently forms monospecific populations; and ***Euterpe precatoria*** Mart., called açaí-da-terra-firma, a single-stemmed palm (solitary), common in Central and Western Amazônia, that occurs along the valley edges on the *terra firma* (non-flooded, upland plateaus), in areas without permanent flooding. This chapter will deal with both of these species.

Family: Arecaceae (Palmae)

Species: *Euterpe oleracea* Mart. and *Euterpe precatoria* Mart. (Glassman 1972).

Common names: *E. oleracea* - açaí, assaí, açaizeiro, açaí-do-Pará, açaí-da-várzea, açaí-do-baixo-Amazonas (Brazil); uassi, morroke (Venezuela); manicole (Guyana); pina, pinau (French Guiana); palisade pina, prasara, manaka, wasei, wapoe (Suriname); manac (Trinidad).

E. precatoria - açaí, assaí, açaí-do-terra-firma, açaí-do-Amazonas, açaí-do-alto-Amazonas, açaí-do-mato, açaí mirim, palmito mole, guassai, jissara (Brazil); huasai, chonta (Peru); palmo, manaco, guasay (Colombia); palma do rosario (Bolivia); rahoo, wahoo, wahoo, weenamori, waboyaka, manicole (Guyana); guassai (Venezuela); monki-monki pina, baboen pina, wapoeiema (Suriname); manac (Trinidad).

Related species

There are numerous other *Euterpe* species, many of which are of doubtful validity, also known as assaí. Their common names are açaí branco, açaí espada, etc. There are also marked differences between the açaí-do-igapó and the açaí-da-várzea, although they are all classified as *E. oleracea*. In other parts of Brazil and South America other *Euterpe* species are used as sources of palm heart: *E. edulis* was especially important in southern Brazil before its populations were decimated.

Description and phenology

Euterpe oleracea

E. oleracea is a slender, multistemmed, monoecious palm that can attain 25+ m. It can have more than 45 stems in different stages of growth and fructification, depending on insolation. In natural stands 4-8 well-developed stems per mature plant are common.

The green to yellowish crown shaft is composed of the leaf sheaths (about 1.2 m long) of the 9-15 pinnate leaves. The mature leaf has a rachis 2.5 m long and 50-62 leaflets, each measuring 39-77 cm. The leaves are well-adapted to high light levels: those exposed to full sunlight are smaller and have a larger number of leaflets hanging vertically, reducing to a minimum the area exposed to direct sunlight.

The slender stems are light gray, measuring 9-16 cm in diameter at breast high (DBH). Rings formed by the scars from old detached leaves appear from the base to the crown shaft. Six to eight leaves, on average, senesce per year. Although flexible, the stem is very resistant.

Adventitious roots are formed continually at the swollen base of the stem. They form a ring of thick (1.5 cm), bright purple aerial roots around the base of the stem that can reach to 80 cm above soil level. The root system is very large and quite superficial, with a radius of 6 m or more. Eighty percent of the total root volume is found in the first 20 cm of soil. The plant is well adapted to periodically waterlogged soils. Special root structures, called pneumatophores, help the root system respire in waterlogged soils. In low lying areas, soil and organic particles trapped on the root system slowly construct a mound around the plant.

Inflorescences are present most of the time in the *varzea*, singly or multiply, in up to 6 different maturity stages. They develop from the axil of the leaves, and, after the oldest leaf senesces, the inflorescence can be seen, protected by its sheaths. Initially it arises at an erect angle, later dropping to a more horizontal position. When opened, it has a light brown color (beige). The inflorescence is composed of a central stiff rachis about 56 cm long, with an average of 54 rachillae. Each rachillae bears clusters of two lateral staminate (male) flowers and one central pistilate (female) flower, except on the end portion, where there are only staminate flowers. The flowers are quite small (4.5 x 2.7 mm male; 3.2 x 2.6 mm female). Male flowers are purplish, with purple anthers as well. Pollen viability ranges from 30 to 83%. Female flowers are purple to light brown.

Fruits are globose, 1.1-1.5 cm in diameter, green when young and usually ripening to a darkish purple. There are some assaí populations that have green fruits even when mature and these are locally called açaí branco (white açaí). The fruit is one-seeded. The seed is surrounded by stringy fibrous sheaths and a thin dryish but slightly oily coating. The seeds have a solid and ruminated endosperm and a small, but completely developed, embryo. The seedlings have two or three profils and the first complete leaf is bifid (divided into two leaflets).

E. oleracea is monoecious, with each inflorescence bearing numerous sessile staminate and pistilate flowers. It is protandrous, with the staminate flowers open and shedding pollen before the pistilate flowers are receptive. Thus, the species is predominantly allogamous (outbreeding), but various degrees of autogamy can occur depending on the synchronization of phases between inflorescences in the same or different stems of the same clump (geitonogamy). Pollination is done mainly by small bees and flies. Flowering can start as earlier as 4 years if it is grown in full sunlight. Inside the rainforest, however, flowering starts later as it is directly related to insolation.

E. oleracea flowers throughout the year, with an inflorescence appearing in the axil of each leaf (Jardim & Anderson 1987). Leaf turnover may be as high as 10 new leaves per year. Nutrient stress during the dry period may cause inflorescence abortion (ibid).

The number of fruit bunches per plant can reach 8, although 3-4 is more common. In any stem, each bunch is at a different stage of development, varying from inflorescences enclosed in the bracts to bunches with ripe fruits. Fruiting occurs throughout the year, with the dry season, July to December, being the period of greatest abundance.

Euterpe precatoria

E. precatoria is a single-stemmed (solitary) palm, growing to a maximum of 20-22 m in height. The crown shaft is composed of 14-19 leaves, each reaching 3.5-4.5 m in length. A large number of pendent leaflets confer a unique, ornamental appearance to this palm. The stem and root system are similar to those of *E. oleracea*.

The inflorescences are larger than those of *E. oleracea*, bearing a larger number of rachillae (70-76) and staminate and pistilate flowers. The flowers are lighter in color, usually a pale yellowish-pink (male) and light brown (female).

The fruits are globose, 1.0-1.8 cm in diameter, dark purple when mature, with a thin (0.5-1.5 mm thick) and juicy mesocarp.

There is also one seed per fruit, with a solid and homogeneous endosperm. The seedlings have initially 2 or 3 profils and a complete leaf divided in 6 leaflets.

E. precatoria has a similar floral biology and reproductive system to that of *E. oleracea*. In this species, geitonogamy is also possible due to synchronization of male and female phases in different inflorescences on the same stem.

The period of greatest abundance of fruits is December to August, although there is a geographic gradient, earlier (January to June) in Western Amazônia (Coarí to Codajás, Amazonas), intermediate (April to August) in the region of Manaquiri, Amazonas, and later and shorter (middle June to middle September) between Manaus and Itacoatiara, Amazonas.

Cytological data

Chromosome numbers of x=18 (2n=36) were observed in *E. oleracea* and in some other *Euterpe* species. A marked similarity in chromosome size and shape was observed in all the species studied (Maglio, pers. com.). This would be expected, since inter-specific fertility has been demonstrated through crosses between most species (Bovi et al. 1987a, 1988).

Distribution, abundance and ecology

E. oleracea is widely distributed in northern South America but attain their greatest coverage and economic importance in Pará state, Brazil, where it is found in nearly the entire state. The major occurrence is in the Amazon River estuary, an area estimated of 25,000 km^2 (Lima 1956). Calzavara (1972) conservatively estimated the coverage of assaí in the Amazon estuary to be 10,000 km^2. It is especially common on *varzeas*, slightly less so in the *igapós* (perennially flooded, black or clear water forest swamps) and less so still on the *terra firma*.

Plants from these three edaphic conditions look quite different. At times the palms are found in almost pure stands (*açaizais*), representing, along with buriti (*Mauritia flexuosa*), the most prominent feature of the vegetation landscape (Peters et al. 1989).

E. precatoria occurs almost exclusively on the *terra firma* and along the slopes leading to the *igapós* and *varzeas*. This species is common in Central and Western Amazônia, including the Peru-Brazil-Colombia borders (Kahn 1988).

Population density of *E. oleracea* in the Amazon River estuary is high and variable, depending mostly on soil conditions. On average, the plant population is between 230 and 600 clumps/ha, considering only clumps with stems higher than 2 m (Jardim 1991 & pers. com.). Total population ranges from 2,500 to 7,500 plants/ha, most of them (50%) in the first seedling stage (one to two leaves and about 20 to 25 cm tall).

Population density of *E. precatoria* varies from 50 to 250 plants/ha in the forest ecosystems of Peruvian Amazônia (Kahn 1988). Higher population densities were found in Manaquiri, Amazonas, Brazil (100 km from Manaus). A field survey showed population densities varying from 5,740 to 13,396 plants/ha [2.24-4.88% adult, 1.52-14.00% stemmed juveniles, 22.22-50.00% stemless juveniles and 71.43-91.22% seedlings (one-leaf stage)] (A. Castro, unpublished).

E. oleracea and *E. precatoria* can both be classified as species of the climax forest by the following characteristics: slow growth, high moisture requirement, low light needed for seedling growth, low plant survival rate and long seedling stage.

The germination process of both species begins soon after the seeds fall, as they are without any mechanisms for long-term dormancy. The fruit epicarp is readily eliminated by natural decomposition, aided by microorganisms, insects or passing through the digestive tract of some birds. Germination lasts 3-11 months, with the bulk of seeds germinating in the first 30-60 days. Although the germination percentage is high in laboratory conditions, reaching 90% (Bovi et al. 1991), in nature it may reach 50-60%. Microorganisms and predators (some insects and especially rodents), contribute to reduce it in nature. Initial water content of the seeds is 51%, and they lose viability quickly in unfavorable conditions.

Seed dispersal over short distances is done by rats and other rodents. Long distance seed dispersal is done by birds [toucans (Ramphastidae)], jacus (Cracinae), arapongas (Cotingidae), and sabias (Turdus) (Zimmermamm 1991) and by water (floods), mainly along stream banks.

Seedling survival is low, especially from the one-leaf stage until the plants are about 50 cm in height. Competition for light is the main factor limiting survival and seedling growth.

Plant growth rate is slow, especially as compared to some of its forest competitors, and in the first three years. Small seedlings (one-leaf stage) are able to survive without much growth, awaiting more favorable conditions, especially light. Stem growth is usually seen 2-3 years from seedling stage, when the plant is at about 1 m in height. After that, growth in height increases rapidly, which can be easily observed by the distance between leaf scars. Normally it takes 4-6 years for the main stem to reach the minimum size for economically viable palm heart harvest. Once the palm reaches the canopy, stem growth is slower and constant and the leaves show changes in morphology as they adapt to new ecological conditions. Their size is reduced and more leaflets appear, with the interval between leaflets shorter than before.

Suckering starts within one year after germination and the number of suckers is a function of insolation. Under shaded conditions *E. oleracea* has fewer suckers than in full sunlight (Bovi 1987). Plant height is also function of insolation levels and increment in stem diameter is inversely correlated with it.

Uses and economic potential

Principal uses

E. oleracea produces a wide variety of market and subsistence products (Anderson 1988). This author listed 22 different uses for all plant parts, from the leaves to the roots.

By far, its principal use of both *E. oleracea* and *E. precatoria* to local people is for the preparation of a thick, dark purple liquid obtained by maceration of the pulp of the ripe fruits. The liquid, locally called açaí or *vinho de açaí* (although it is not a fermented or distilled beverage), is not particularly nutritious. The nutrient content reported by Altman (1956), Campos (1951) and Mota (1946) is as follows: 1.25-4.34% (dry weight) protein; 7.6-11.0% fats; 1-25% sugar, 0.050% calcium; 0.033% phosphorous; and 0.0009% iron. It also has some sulphur, traces of vitamin B1 and some vitamin A. Caloric content ranges from 88 to 265 calories per 100 grams, depending upon the dilution and on the complement. Yet the liquid is extremely filling, especially when mixed with manioc (*Manihot esculenta*) flour. It is usually not drunk, but eaten with a spoon, and forms a major and basic part of the diet of most of the inhabitants of the lower Amazon River. An individual daily consumption of up to 2 liters has been reported. It has a metallic, somewhat nutty flavor, with a texture roughly creamy and appearance slightly oily.

The assaí liquid is so popular that there are special establishments (called açaílandia) in small and large towns which make and sell it in plastic bags. Although a basic part of the diet of the poor, assaí liquid is popular throughout all socio-economic levels. Details of assaí liquid making, consumption and marketing are well described by Strudwick & Sobel (1988).

Assaí liquid is extremely perishable and this factor has restricted its consumption to a purely regional level. Attempts have being made to dehydrate the liquid to preserve it (Melo et al. 1988). The dehydrated product is suitable for consumption up to 115 days after packing. With this product, assaí could be made available throughout the year and could be exported to other national and international markets.

The other main product from both *E. oleracea* and *E. precatoria* is palm heart. It consists of the tender, whitish, immature leaves of the palm, found just above the growing point on each stem. Once removed, it is a flexible cylinder about 45 cm long and 2-3 cm wide. It has almost no nutritious value (Ferreira & Yokomizo 1978, Ferreira et al. 1982), but it is widely appreciated in a variety of dishes. Although regional (Amazonian) consumption of palm heart is minimal, there is a large internal Brazilian market for palm heart, especially in the southeastern states, where a wide variety of dishes can be found in the restaurants.

Commercial extraction of assaí palm heart began in the Amazon River estuary by 1960, as a consequence of the decimation of native stands of *E. edulis* (a single-stemmed palm very similar to *E. precatoria*) in southeastern Brazil, caused by heavy exploitation of the natural palm populations (Renesto & Vieira 1977). *E. oleracea* is currently the world's main source of palm heart, with the Amazon River estuary being the principal producing region. At present there are 120 registered processing industries in the region, most of them situated at the edges of the rivers. Innumerous smaller factories exist based on family labor and associated with or selling their product to the larger ones. The degree of sophistication of those industries varies, but most of them are very precarious and process a low quality product.

Canned heart of palm production per processing plant is variable, ranging from 6 to 30 tons per month. There is already a shortage of the raw material in many locations in the Amazon River estuary, due to over harvesting and lack of management of the native stands, and some processing plants run only 2-3 days per week. This shortage has also spurred the migration of some floating processing plants from the estuary in Pará to *varzea* areas in Amazonas, where they exploit (again destructively) both local populations of *E. oleracea* and previously unexploited (for palm heart) populations of *E. precatoria*, thus denying an important resource to local residences.

Secondary uses

Increased profit from this regional product could also be achieved by extracting its pigment (anthocyanin) in order to provide natural red dyes for the food industry. Iaderoza et al. (1992) showed that *E. oleracea*, as well as *E. edulis*, is a potential source of this natural pigment.

Economic data

Anderson (1988) studied the commercial products sold in one year's time by a single family living on the Ilha das Onças, near Belém, Pará, Brazil. He found that some 35,000 hearts of *E. oleracea* were extracted during this period, representing an income of $US2,916. At the same time, the family harvested $US15,532 worth of fruits (78,885 kg of product). Together these two products accounted for 75% of the forest products sold by the family. Anderson (1988) pointed out, the fragility of the system. An increase in demand and in the number of palm heart processing industries can pose a threat to the unstable economic balance of the estuary. A sudden rise in prices for the palm heart could mean the cutting of the stems meant for fruit production and result in general scarcity of fruit for a number of years.

World trade in heart of palm in 1990 exceeded $US 65 million and 85+% of it came from the exploitation of primary forest stands, principally *E. oleracea*. World consumption is much greater, however. Brazil is both the major world producer (100,000+ MT) and largest consumer. This country is responsible for 70% of the world trade in palm hearts, exporting 10,000+ MT, but consumes nearly 10 times the amount exported. Due to the highly perishable character of the *Euterpe* species, especially discoloration due to enzyme mediated oxidation, at least 85% of the total internal consumption of heart of palm is in a processed form (cans or jars) and retail prices are almost the same as for export.

Collection methods and yields

Harvesting the fruit bunches is an arduous and frequently dangerous task, done by individuals accustomed to climbing the assaí palms. After scaling a palm, a practiced harvester moves easily from one stem to another, without descending, collecting all the ripe fruit bunches from a clump.

E. oleracea produces 4-8 bunches a year, each one yielding, on average, 4 kg of fruit. Thus, one stem can provide 16-32 kg of fruit, mean 24 kg, per year. *E. precatoria* is somewhat less productive, producing 2-3 bunches a year, each yielding, on average, 6.5 kg of fruit. Thus, one stem can provide 13-20 kg of fruit per year.

To harvest the palm heart the entire stem must be cut down with an axe, or the harvester may climb the stem with the aid of a device made with palm leaf (called a *pecunha*) and cut through the base of the crown shaft with a machete in order to bring down the entire crown. A man can harvest as much as 300 palm hearts per day and will be paid about US$0.05 for each heart of palm harvested and delivered to the factory. This contrasts with a final consumer price of US$5 to US$6 per pound in New York.

Uncontrolled extraction of palm hearts has been practiced in the Amazon River estuary since exploitation began and it still continues in many areas, with extremely negative consequences for the regeneration of the natural assaí stands and also for the large segment of the rural population that depends upon the harvest of assaí fruits for subsistence and sale. In the case of palm hearts, independent collectors frequently cut every stem of sufficient size to yield a saleable heart. Currently, a plantation or dense natural stand produces about 3 MT of rough palm hearts per hectare, 20% of which is export quality.

Management

In order to maintain a steady supply of palm hearts from one area, selective cutting of only a certain number of stems per individual is preferable. This system has been used by some Amazon River estuary small holders. Intuitively they developed a management system that allows for the sustainable harvest of palm heart in this region. By practicing a combination of selective harvesting of assaí suckers for each clump, with selective thinning of forest competitors, the small holder can not only make cash from the direct sale of the heart of palm, but also enhances fruit production on the remaining stems.

This alternative management practice, that permits both fruit harvest and palm heart extraction, appears to be increasingly implemented by rural inhabitants in the Amazon River estuary. Although it may reduce estuarian biodiversity in the long run, this practice can sustainably supply income to its practitioners while conserving vital ecosystem service in the area.

There is a need to develop systems for large-scale sustainable exploitation and renewal of populations. In this area, agroforestry systems may be feasible, as well as pure crop plantations, in order to make the product more affordable and support increasing demand. However, as almost all assaí palm heart production comes from natural or managed forest, there is some doubt as to whether the higher yields from a plantation can compensate for the extra cost of management, fertilizing, etc. Nowadays, considering all the costs involved in the processing of heart of palm (raw material, processing, overhead and marketing, amortization and taxes) the raw material represents only 23-25% of the final export value of the product. Nonetheless, if current exploitation practices continue, natural stands will be decimated.

In the Amazon, agroforestry systems, combined with the sustainable management of existing stands, is a major need. On the other hand, heart of palm plantations will probably become a regular feature of the estuarian landscape in the future, as increasing world demand, together with more rigid environmental regulations, limits illogical forest resource exploitation, such as that currently practiced.

Nowadays, assaí and other "new" palms, such as pejibaye (*Bactris gasipaes*), gariroba (*Syagrus oleracea*), assaí hybrids, etc., are being cultivated in disturbed areas. With research being carried out in different countries and the introduction of new technologies, the results of plant breeding and cultural management will soon be available for each palm species and for distinct edaphic and climatic conditions. With the new technologies being developed, heart of palm plantations could be more productive and lucrative and the price of the product reduced.

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Buriti

Aline de Castro

Family: Arecaceae (Palmae)

Species: *Mauritia flexuosa* Linnaeus filius, Supplementum Plantarum 70, 454. 1781. (Glassman 1972)

Synonyms: *Mauritia vinifera* Martius, *M. setigera* Grisebach & Wendland, *M. sphaerocarpa* Burret, *M. minor* Burret, *M. flexuosa* var. *venezuela* Steyermark (Glassman 1972).

Observation: Previously, two species were distinguished, buriti (*M. vinifera*) and miriti or buriti-do-brejo (*M. flexuosa*), by the size of the male inflorescences and the fruits, and by habitat. *M. vinifera* was defined to occur along river banks and in low-lying acid soils on the plateaus of central Brazil. *M. flexuosa* occurs in flooded soils in low-lying areas of the north of South America. Currently, these are considered to be ecotypes of the same species.

Common names: Buriti (from the Tupi Indian language: mburi'ti), buriti-do-brejo, coqueiro-buriti, buritizeiro, miriti, muriti, muritim, muritizeiro, muruti, palmeira-dos-brejos, carandaguaçu, carandaiguaçu (Brazil); moriche (Venezuela, Trinidad); ita (Guyana); palmier bâche (French Guiana); achual, aguaje, auashi, bimón, buritisol, mariti, muriti, moriche (Peru); caranday-guazu, ideuí (Bolivia); cananguche, chomiya, ideuí, mariti, miriti, muriti, moriche (Colombia) (Bohorquez 1976, Borgtoft-Pedersen & Balslev 1990, Dugand 1972, 1976, Ferreira 1975, Glassman 1972).

Related species

Mauritia carana Wallace. This palm, commonly called caraná, is similar to buriti in size (stem 20-30 cm in diameter, with a mature height of 15-22 m), but each leaflet is united to the next for one-third of its length and is much more curved at the tips. After the leaf blade falls from the petiole, the leaf sheaths persist on the stem. As happens with the piassava fiber palm (*Leopoldinia piassaba*), a large quantity of fiber frays from the leaf sheaths under the crown, although less densely than is the case with piassava. The spadices grow and mature among the leaves and are a little more erect and much smaller than those of the buriti. Fruits are also less abundant, smaller and oval shaped. Caraná occurs only in the Negro River basin and the upper Orinoco River basin, being unknown in the rest of Amazônia. Its leaves are used as thatch, considered one of the best Amazonian thatches because of the more entire leaf blade and because it is extremely durable, lasting 8 to 10 years, where others last 3 to 5. Although it is very similar to buriti in most respects and is richly endowed with fiber, rope is not made from its epiderm (Wallace 1853).

Mauritiella armata (Mart.) Burret. This species is widely known as caranaí, buritirana or buriti-mirim (the first and last being the diminutive of caraná and buriti, respectively). It grows in clumps, has much thinner stems (12-15 cm in diameter), but attains up 20 m in height. Its leaves are smaller, with more rigidly held leaflet tips, and spineless petioles. The fruit are elliptical, 2-3 cm in length, with a thin, oily, orange-colored mesocarp, enveloping a thin, spongy endocarp and a single seed. The endosperm is white and tough. Like buriti, it is found in flooded areas, both on the *terra firma* and in the *varzea*, being especially common in the Amazonas River estuary. Its fruit is processed and consumed as a juice (called vinho), similar to that of buriti (see below). Fruiting occurs from January to June and fresh fruit occasionally appear in local markets (Cavalcante 1988).

Observation: Although Balick (1981) recently combined the genera ***Mauritia*** and ***Mauritiella***, Uhl & Dransfield (1987) consider them to be distinct, due to consistent differences in growth habit and the arrangement of the flowers. ***Mauritia*** spp. are all single-stemmed, with smooth unarmed trunks, their pistilate flowers are solitary or occur on very short branches, and their staminate flowers occur in pairs. ***Mauritiella*** spp. are multistemmed, with spiny stems, their pistilate flowers occur on short branches, and their staminate flowers are solitary.

Description and phenology

The buriti is a robust, single-stemmed palm, that may attain 30 m in height. Its crown is composed of 10-14 large costa-palmate leaves, 5-6 m in total length. The arrangement of the leaves confers a spherical crown form, with dead leaves hanging below the crown for a considerable period before falling. The buriti is a dioecious species, without vegetative differences to distinguish the male and female individuals.

The 3-7 axillar male and female inflorescences arise among the lower leaves and are similar in size and shape. The inflorescence peduncle measures 60-100 cm in length, with approximately 10 empty bracts; the rachis, with 25-40 oppositely arranged rachillae, measures 70-140 cm in length. The staminate rachillae have a "cat's tail" shape, with floral bracts hugging the two staminate flowers, arranged in a spiral along the rachillae. The pistilate rachillae are very short, with floral bracts hugging the single pistilate flowers, arranged nearly opposite along the rachillae.

The fruit are nearly spherical to elliptical in shape, varying from 4-5 cm in diameter by 5-7 cm in length, covered with brownish-red scales, 6-7 mm in diameter. The soft mesocarp is orange to reddish-orange in color. The endocarp (seed coat) is soft, rich in cellulose, and poorly differentiated. The seeds (1-2 per fruit) are nearly spherical, covered with a brownish testa, with a solid, homogeneous, white albumen, and a sub-basal to laterally placed embryon (see Wessels-Boer (1965) and Uhl & Dransfield (1987) for further description).

The buriti has a root system adapted to its hydrophyllous habitat. The primary roots arise at the base of the stem, occasionally above the level of the soil. Initially they present a positive geotropism (they grow down) until they reach a certain depth, which varies in function of the nature and degree of hydromorphism of the soil (generally about 60 cm), at which point they grow horizontally, attaining up to 40 m in length. On the superior face of these roots, secondary, perpendicular roots arise, with negative geotropism (they grow up), with diameters smaller than 5 mm. These secondary roots have two distinct parts: one subterranean, on which arise smaller horizontal roots, active in water and nutrient absorption; the other aerial, occasionally with vertically oriented branching. The aerial parts have characteristic pneumatozones, where the root epidermis becomes an aerenquimatic structure formed by 2-3 layers of elongated cells slightly separated from each other so that air can circulate freely. These pneumatozones function like air tubes and are extremely important for root respiration during periods of flooding (Granville 1974).

Flowering and fruiting in buriti are irregularly distributed during the year, but both occur yearly. In eastern Amazônia, in Belém, Cavalcante (1988) reports that mature fruit appear in the markets from January to July. In central Amazônia, flowering occurs at the end of the rainy season to the beginning of the dry season, May to August (A. de Castro, not published). The fruits mature during the following rainy season and are found in the market from December to June. Urrego (1987) found a similar phenology in the Colombian Amazon. In Iquitos, Peru, mature fruits are abundant in the markets from February to August, with a distinct shortage from September to November, due to seasonal fluctuations (Padoch 1988). Heinen & Ruddle (1974) observed two flowering seasons in the Orinoco River delta in Venezuela: the first, composed principally of male inflorescences, is stimulated by the increased rainfall at the beginning of the rainy season;

the second occurs in December, stimulated by the more continuous rains of the rainy season itself, and is composed principally of female inflorescences. Mature fruits are found year round, with a noticeable peak from August to October, and a minor peak from February to April.

Distribution, abundance and ecology

The buriti's geographic distribution covers all of ecological Amazônia, reaching its northern limits in the Orinoco River valley of Venezuela, including Trinidad and Tobago (Bailey 1947), French Guiana and the northern coast of Amapá state, Brazil. In the west, the Colombian, Ecuadorian, Peruvian and Bolivian Andean foothills limit its range. In the east and southeast, it occurs widely throughout the Brazilian Northeast, from Maranhão to Bahia. In the south, it extends through the *cerrado* (central Brazil's sparsely forested savanna) along the river banks as far as Minas Gerais and Mato Grosso do Sul. Throughout the *cerrado* and the northeast it is represented by the *M. vinifera* ecotype (Cavalcante 1988).

The buriti appears in small groups along the streams that bisect the *terra firma* (non-flooded upland) forests, where the soils are predominantly sandy to hydromorphic humic gleys. Descending the streams towards their mouths, the buriti becomes more abundant, finally being found in large stands, frequently monospecific, which are especially evident in the estuaries of the major Amazonian tributaries (Peters et al. 1989).

In the central-south of Brazil, where the *cerrado* vegetation predominates, the buriti is found in formations called *veredas*, which extend along the river banks and anywhere with soils that retain enough humidity (Bondar 1964).

With respect to abundance, it must be remembered that the buriti is restricted to permanently or seasonally flooded soils, which may comprise 4-6% of Brazilian Amazônia. Castro & Lescure (1990) counted 52 plants (with 15 mature) in a 0.96 ha plot in *terra firma* low forest along a stream near Manaus. The same authors found 684 plants (with 7 mature) in a 0.16 ha plot of degraded (by human activity) vegetation along a nearby stream. Kahn (1988) found, in a 1 ha *aguajale* (as a nearly monospecific stand is called in Peru) in the lower Ucayali River basin, 645 plants ≥ 1 m in height, of which 138 were mature. These *aguajales* or *buriti zones* are frequent in the Amazon valley, always on humid soils (Peters et al. 1989). In western Amazônia, especially, the buriti zones cover thousands of hectares along the floodplains.

The buriti is a predominantly sun species. In natural conditions in the forest, germination and the first stages of development occur in the shade. Further development, however, and especially sexual maturity, requires sun, the more the better. In the low and open forests along streams, where relatively fewer species are well adapted, the forest is frequently disturbed by falling branches and trees, which form gaps of up to 600 m^2. In these gaps, buriti can develop to maturity, attaining its commonly observed position in the upper canopy of these forests (Castro & Lescure, in prep.).

Uses and economic potential

Principal use

The buriti's edible mesocarp is the most widely used part of the plant. From this fresh pulp a very popular juice is prepared, called "buriti wine" or "vinho de buriti". The fruit are prepared by softening them in warm water for several hours or leaving them covered by leaves for 3 or 4 days, so as to accelerate their maturation, since the fruit fall from the trees or are collected before they are fully ripened. Covering them with leaves for a few days is preferred, as it is reputed to enhance flavor. When ready, the pulp is separated from the seeds by hand and mixed with water. It is then strained to separate the seeds and exocarp scales. The buriti wine is consumed fresh, with sugar, or mixed with cassava flour, as is done with assaí (*Euterpe oleracea*) wine.

The fresh pulp is also used to prepare "buriti sweets" or *doce de buriti*, as a flavoring for ice creams (excellent!), and made into a sweetened thin juice that is frozen in small plastic bags and sold like popsicles (called *dim-dim* in Brazil, *curichi* in Peru). All of these products are extremely popular and form the basis of an important segment of the local economies of the Amazonas River basin (Cavalcante 1988, Padoch 1988).

Doce de buriti is also being used in the Brazilian Northeast to treat or to prevent vitamin A deficiency. Lima (1987) reported on the use of *doce de buriti* as a food supplement for a group of children, aged 43-144 months, that presented hypovitaminosis A symptoms. A 20-day treatment was sufficient to eliminate all clinical and analytical symptoms in this group of children. Given the abundance of buriti in lowland northern South America, there is no biological reason to continue to accept the high levels of hypovitaminosis A so prevalent in many parts of this region.

In the Orinoco River delta, in Venezuela, the natives toast the pulp of the fruit and consume it as a type of bread (Braun 1968).

In the same region, Spruce (1908) reported that a mash of fresh pulp is wrapped in leaves of "platanillo" (Marantaceae), stored in a barrel made from boards of the palm *Iriartella setigera*, and left to ferment for several weeks. The fermented mash is then mixed with water to make an agreeably flavored beverage with a strong alcoholic content. The fermentation of starchy fruit pulps or other starchy products, like cassava or corn, is quite common in tropical America. *Caissuma* (Brazil) or *masato* (Peru) is a similar beverage prepared from the pejibaye palm (*Bactris gasipaes*); it is very nutritious, as well as intoxicating.

Table 1 presents a listing of analytical results on the composition of the fruit and the food value of the pulp of buriti, obtained from several sources. Although the pulp is only 12-13% of the fruit dry weight, it is an important source of calories, proteins and vitamins.

Interestingly, Wu Leung's (1961) and Bohorquez' (1977) data translate into approximately 11% protein by dry weight, which is on the level of that of maize. Beckerman (1979), evaluating the availability of vegetal proteins consumed by the Amerindian populations of Amazônia, commented on the fruit of buriti, "although the protein is a rather small fraction of the dry weight (of the 'whole pulp', data from Altman & Cordeiro 1964) -- only 5% -- it cannot be rejected as insignificant in a diet in which (a) large quantities of the food are consumed; (b) the food actually consumed may be considerably higher in protein content than the raw fruit because of removal of fiber and other non-nutrients; and (c) fermentation may actually increase the absolute amount of protein contained in the processed food". The great importance of buriti in the diet of several populations of Amazônia (fruit: Padoch 1988) and the Orinoco River delta (fruit and trunk starch: Suarez 1966, Heinen & Ruddle 1974) is well known, and for Beckerman (1979) this palm could assure them the major part of their dietary protein, with minor addition of other sources, such as meat and fish.

Potentially there may be economic interest in the carotene dissolved in the buriti's mesocarp oil (Table 2), mentioned by several authors as one of the largest reserves of carotenes known in the plant kingdom. Chaves & Pechnik (1949) reported 5,000 International Units of pro-vitamin A/g of oil, a level five times that of the African oil palm (*Elaeis guineensis*). Rizzini & Mors (1976) reported 300 mg of β-carotene per 100 g of dry mesocarp, which is three times greater than that found in African oil palm. These data, and those of Aguiar et al. (1980), highlight the variability observed in buriti, which could certainly be exploited in mass selection improvement of natural populations. More detailed analyses are necessary to better identify the intra- and inter-populational variation in mesocarp composition and nutritional value to better guide its use and improvement.

Table 1. A. Components of the fruit (fresh weight).
B. Nutritional value of 100 g of mesocarp*.

	Chaves & Pechnik (1946, 1949)	Bohorquez (1977) @	FAO (1986)	Altman & Cordeiro (1964)	Wu Leung (1961)
A.					
fruit weight (g)	50	-	50	40-55	-
exocarp (%)	30		23	23	-
		>49<			
mesocarp (%)	10		21	20.5	-
endocarp (%)	20		12	12	-
		>51<			
endosperm (%)	40		44	44.5	-
B.	f.wt**	f.wt	d.wt	d.wt	f.wt
energy (cal)	120.0	143.0	-	-	265.0
humidity (%)	71.8	72.8	-	68.0	72.8
proteins (g)	2.9	3.0	5.5	5.2	3.0
fats (g)	10.5	10.5	31.0	26.2	10.5
N-free extract (g)	2.2	12.5	38.0	38.2	12.5
fiber (g)	11.4	11.4	23.0	27.5	11.4
ash (g)	1.2	1.2	2.4	2.9	1.2
Ca (mg)	158.0	113.0	-	-	-
P (mg)	44.0	19.0	-	-	-
Fe (mg)	5.0	3.5	-	-	-
vitamin A (mg)	30.0	12.0	30.0	-	-
thiamine (mg)	-	0.3	0.1	-	-
riboflavine (mg)	-	0.23	-	-	-
niacin (mg)	-	0.7	-	-	-
Vitamin C (mg)	50.5	26.0	52.5	-	-

*Chaves & Pechnik (1946, 1949), Bohorquez (1976) and Wu Leung (1961) based upon 100 g of fresh edible pulp, while FAO (1986) and Altman & Cordeiro (1964) based upon 100 g of dry edible pulp.
@ Bohorquez combined exocarp w/mesocarp, endocarp w/endosperm.
** f.wt = fresh weight, d.wt = dry weight.

Table 2. Vitamin A, as retinol equivalents ($\mu g/100g$) in buriti.

	Chaves & Pechnik (1949)	IBGE (1977)	Rizzini & Mors (1976)	Franco (1982)	Lima (1987)
in mesocarp	5.000	6.000	-	6.000	-
in mesocarp oil	50.000	-	50.000	50.000	50.667
doce de buriti	-	-	-	-	1.116
oil from doce de buriti	-	-	-	-	17.167

Unfortunately, buriti never attracted agricultural research attention as a perennial edible oil crop. This is probably due to the small quantity of oil in the mesocarp and to its ecological requirements. Pesce (1941) commented on this and suggested the utilization of its seeds (40-50% of fruit weight) for the production of alcohol for energy, by transforming the manocellulose in manose, followed by fermentation. Altman & Cordeiro (1964) extended and elaborated on this suggestion and proposed a scheme for the integral utilization of the whole fruit through a series of simple processes, which could be carried out by small processing plants located adjacent to natural concentrations of buriti. These processing plants would produce (1) juice (34% of fresh weight), to be sold as "vinho"; (2) vegetable oil (4.5%), which contains 0.013% pure carotene; (3) extraction residue (14.6%) rich in carbohydrates (52%) that could be used for animal feed or as a feed stock for alcohol production; (4) charcoal (9.1%), pirolenic acid (7.4%) which can substitute acetic acid, and pitch (1.2%). These processing plants could attend local and regional markets and provide raw materials for other industries.

Lleras & Coradin (1988) showed that palms in general yield two types of vegetable oil with numerous uses in the food and chemical industries: the oleic oils -- obtained from the fruit pulp and generally similar to vegetable oils obtained from most annual crops in terms of fatty acid composition; the lauric oils -- obtained almost exclusively from palm seeds. These authors estimate that buriti can attain yields of 3.6 T/ha of oleic oils (assuming a density of 150 female plants/ha), significantly above current yields of most annual oil crops, such as soybean (*Glycine max*), sunflower (*Helianthus annuus*) and peanut (*Arachis hypogaea*), although lower than that of African oil palm.

The full potential of the buriti fruit has not yet been exploited anywhere in its range. Since it occupies ecological habitats that are not suitable for most other agricultural options, the full exploitation of natural populations of buriti could play a major role in Amazonian development without contributing to further environmental degradation (Peters et al. 1989).

Secondary uses

The young inflorescence can be cut or tapped to collect the sweet sap, which can be consumed directly, fermented to obtain an alcoholic beverage, or boiled to obtain sugar (Corner 1966). Pesce (1941) reports on the chemical composition of this sugar: 92.7% sacarose, 2.3% reducing sugars, 1.9% ash and 3.1% unidentified. In some areas, the harvest of the sap is a predatory process, involving the felling of the palm, followed by defoliation and stimulation of the sap flow with fire (Corner 1966). If the harvest is managed correctly, buriti could supply large quantities of palm wine sustainably, as occurs in parts of Africa and Asia (Corner 1966).

The terminal meristem is the heart of palm, which is locally exploited in some parts of Amazônia (Bohorquez 1976).

The starchy pith of the buriti stem can be processed to yield an edible flour (nearly pure starch), similar to that obtained from the Asian palm ***Metroxylon sagu***. This flour is an essential part of the diet of the Warao Indians, of the Orinoco River delta, in Venezuela. To extract the starchy pith, the female buriti palm is cut, its trunk is split, and the pith removed with a small hand hoe, frequently made from the wood of the trunk itself. The pith is placed on a circular screen above the excavated trunk, which serves as a receptacle for the starch. The pith is washed and mashed by hand, and the starch is leached out and accumulates in the trunk. The water is removed and the starch is dried in the sun. It is then stored as dried flour or baked into large round breads (Suarez 1966, Heinen & Ruddle 1974).

Two starch samples, taken at 1 and 13 m in height from a male buriti palm, and therefore possibly not representative of the female starch, yielded the following analysis (dry weight): ramnose - 0.2% and 0.1%; arabinose - 1.3% and 2.2%; xilose - 5.6% and 4.4%; galacturonic acid - 3.2% and 2.5%; galactose - 0.8% and 1.4%; and glucose - 12.0% and 9% (Borgtoft-Pedersen & Balslev 1990).

Amongst many indigenous populations in South America, the starch of the buriti is also used medicinally as a cure for diarrhea (Plotkin & Balick 1984).

Larvae of ***Rhynchophorus palmarum*** (Curculioniodae), a large palm trunk borer, proliferate in the rotting trunk of cut palms.

They are widely consumed raw or cooked by the indigenous populations of the Orinoco River delta (Suarez 1966), Ecuadorian (Borgtoft-Pedersen & Balslev 1990) and Peruvian Amazônia (Padoch 1988).

The leaves of the buriti are used to thatch houses and manufacture numerous household items in Amazônia, including hats, baskets, fishing traps, rope, and hammocks. From the edges of young tender leaves a very fine, pale yellow fiber is extracted. These are tied in bunches to dry, after which they can be twisted by hand to make fine threads or ropes. This fiber is especially fine and supple and suited for hammocks and other fine handicrafts. The petioles furnish a spongy light pith, similar to balsa wood, and used to make corks for bottles, handicrafted toys, or even mattresses for chairs and beds (Balick 1984, Borgtoft-Pedersen & Balslev 1990, Cavalcante 1988, Correa 1926, Schultes 1977, Suarez 1966, Wallace 1853).

Collection methods and yields

When the fruit mature they are dark red in color and fall from the infructescences. At this point they deteriorate rapidly. If they are to be transported, they should be collected just before they are ripe. In the wild, individual plants start to bear at a height of about 6 m above the soil at 7-8 years of age. Trees yield for several decades, with reduced harvests after 40-50 years (Bohorquez 1976, FAO 1986).

The occurrence of large natural buriti zones and the lack of interest in rational management and exploitation of the species, has inhibited detailed studies of buriti production. Up to a certain height, the infructescence can be harvested with a machete or a curved blade tied on the tip of a long pole, but as the palm grows it becomes increasingly difficult because the infructescences are interfoliar and difficult to reach. Consequently, the felling of the trees is frequent. Near Iquitos, Peru, a majority of the female plants have already been cut, leaving *aguajales* with only male plants. Today buriti merchants bring fruit from 2-3 days away by boat (Padoch 1988).

"Climbing bicycles" and other similar technologies could easily be used, since there are no branches to impede the climb, although it may be necessary to regulate the trunk bands as the buriti trunk increases and decreases in diameter due to starch reserves in the trunk parenchymatic tissue. The use of this technology would eliminate the felling of female plants and would make sustainable harvesting a reality in Peru. The extension services could provide plans for constructing simplified technologies or the local development agencies could provide access to capital to locally build or buy higher technology climbing bicycles.

The harvest of palm heart and sagu from the trunk require the felling of the plant, as buriti only has one meristem. Harvested by the Warao Indians, of the Orinoco River delta, sagu production is sustainable, but only because of the low population density of these people. Consequently, harvesting for a wider market would be unsustainable. Harvest of buriti sap, however, could be sustainable if entrance of *Rhynchophorus palmarum* into the trunk were avoided.

Lleras & Coradin (1988) estimate that an individual plant could yield 200 kg of fruit per year, which could yield 24 kg of oil from the pulp. At a density of 150 plants/ha, which is possible for almost all Neotropical palms of large growth habit, this could result in a harvest of 3,600 kg of mesocarp oil per year. Bohorquez (1976) reports yields of 19 MT of fruit/ha/year in plantations with 100 palms/ha in Peru, which corresponds to 190 kg fruit/plant.

In the Peruvian *aguajale* described by Kahn (1988), Peters et al. (1989) estimated a yield of 6.1 MT/ha/yr of fresh fruit, with an Iquitos market value of US$1,525. It is probable that the majority of Amazonian buriti zones could yield similar quantities of fruit. Although no estimate of the total area occupied by buriti zones in Amazônia is available at this time, it is probable that there are at least 1,000 km^2. This estimate suggests that the annual yield of buriti in Amazônia is close to 600,000 MT, the great majority of which is consumed by fish and other wildlife.

Based on Bohorquez' (1976) analysis of the chemical composition of 100 g of fruit mesocarp, Borgtoft-Pedersen & Balslev (1990) estimated that the nutrient loss to the ecosystem by the harvest of buriti fruit is approximately 42 kg of nitrogen, 9.9 kg of calcium, 1.7 kg of phosphorus and 0.3 kg of iron. This suggests that the buriti zones along nutrient-poor black water rivers might diminish with intensive exploitation through the years, unless fertilizers were used or long periods of fallow were permitted. In the buriti zones along the *varzeas* (periodically flooded river terraces) of the white water rivers this would not be a problem.

The yield of trunk starch is estimated at 60 kg/trunk (Ruddle et al. 1978, Borgtoft-Pedersen & Balslev 1990). Reported leaf fiber production in Brazil was 1155 MT in 1987, with Pará and Maranhão the major producing regions (IBGE 1989).

Propagation and cultivation methods

Little published information is available on this subject. Bohorquez (1976) reports germination of 100% after 75 days, for seed collected 1-10 days before sowing; 20-30 days after harvest germination falls to 55% even after 120 days.

In Manaus, germination tests, performed with 8-day old seed, showed that seed from single-seeded fruit started to germinate after 92 days, with 48% of the seeds germinating between 120 and 150 days, and a final germination of 52%. Seeds from double-seeded fruit started to germinate after 55 days, with 41% germinating between 120 and 150 days and a final germination of 64%. Pretreatment of seed in 29°C running water for 5 days and immersion in a solution of gibberellic acid (100 ppm) for 72 hours, increased final germination to 58% and 68%, respectively, but did not alter germination frequencies (Storti et al. 1989).

Little is known about initial seedling development and size and age of seedling transplant (Bohorquez 1976). Observations to accompany seedling development in different levels of shade during 15 months (Castro et al., in prep.) indicate that:

- in full sun, seedlings develop an average of 9.1 leaves, 7% of the plants were diseased at the end of the period, and average petiole and leaf blade dry weight was 4.9 g and 12.4 g, respectively;

- in 50% shade, seedlings develop an average of 7.7 leaves, none of the plants were diseased at the end of the period, and average petiole and leaf blade dry weight was 7.4 g and 14.2 g, respectively; and

- in 70% shade, seedling develop an average of 8.1 leaves, none were diseased, and average petiole and leaf blade dry weight was 13.0 g and 18.9 g, respectively.

The leaf dry weight of individuals growing in 70% shade was, on average, two times greater than that of individuals growing in full sun. These results confirm the observation that, at least in the initial stages of development, the species requires shade. Once "establishment growth" (Tomlinson 1970) is finished, this species, like other Neotropical forest palms (Kahn 1988), requires considerable light (at or near full sunlight) to grow in height and attain sexual maturity, which is also confirmed by the distribution of adult palms in the forest in relation to light (Castro & Lescure, in prep.).

The buriti can be planted in temporarily or permanently flooded soils, if its pneumatophores can reach the air, but will die if these are submersed for too long a period.

Cultivation of buriti for fruit must take into account the dioecious nature of the species. It is currently impossible to determine the sex of a plant before first flowering. Buriti reproductive biology is also poorly understood, so that it is impossible today to estimate the number of male plants that must be maintained to pollinate the females and thus assure satisfactory yields. In Colombia, Urrego (1987) found some natural populations dominated by females (83%), while others were dominated by males (77%), with no apparent yield reduction in the first case. The destructive harvesting of female plants in Peru is rapidly destroying economically active natural populations, and Kahn (1988) found female:male ratios of 3:15 and 23:100 in some 1 ha plots in the lower Ucayali River. Relative production of these females was unreported but could supply some of the requisite information.

Management of the buriti zones appears to be a simple process. Some suggestions are presented for research and development:

1. Female plants should not be cut. Climbing bicycles or similar technologies should be made available to buriti collectors.

2. Male plants can be thinned to leave 15-20% males in the population, based upon Urrego's (1987) observations.

3. Nonuseful dicots or other palms can also be thinned or eliminated, leaving only other useful dicots or palms (eg. ***Euterpe oleracea*, *Jessenia bataua*, *Virola surinamensis***, etc). This would open space for buriti, thus probably enhancing fruit yields.

4. Mass selected seed from the best quality buriti in each buriti zone should be sown directly or prepared in nurseries and transplanted into open areas in the buriti zone to improve the quality of the population. When these plants start to fruit, the males can be thinned to attain the 15-20% mentioned above.

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Patauá

Michael J. Balick

During the last decade there has been a great deal of study on the *Oenocarpus-Jessenia* palm complex. Widely used by people in lowland South America, it is the source of an important oil, beverage, and raw material for construction and handicrafts. Initial work on this palm was through collaborative activities between the Centro "Las Gaviotas" in Colombia, and the Botanical Museum of Harvard University in the US, commencing in 1975. Subsequently, numerous projects were begun at numerous sites in the Neotropics. This chapter focuses on *Jessenia bataua* subsp. *bataua*, the most widely used of the complex. Other species are also mentioned. The two major references on this group include a monograph (Balick 1986) and a domestication study (Balick 1988).

Family: Palmae

Species: *Jessenia bataua* (Martius) Burret

Synonyms: *Oenocarpus bataua* Martius, *J. polycarpa* Karsten, *J. repanda* Engel, *J. oligocarpa* Grisebach & Wendland. The three first synonyms are of *J. bataua* subsp. *bataua*, while the last is of *J. bataua* subsp. *oligocarpa* (Balick 1986).

Common names: patauá (Brazil, Suriname); milpesos, seje, palma de leche (Colombia); chapil (Ecuador); palma patavona (French Guiana); batawa (from the Carib, hence the specific name) (Guyana); ungurauy (Peru); jagua, yagua (Trinidad); seje, jagua (Venezuela) (Balick 1986).

Patauá's importance to the people of northern South America is attested by the number of common names attributed to it by the Amerindians, and rural and urban populations in this region. Balick (1986) lists 87 names, most from indigenous groups, and there are probably many more.

Related species

Oenocarpus bacaba Martius (bacaba: Brazil). Widely used in northern South America as a source of *vinho de bacaba*, a thick, somewhat oily juice prepared from the slurry of mesocarp and water. The bacaba is a large, single-stemmed palm growing both in flooded and in non-flooded areas in rainforest ecosystems. In the latter ecosystem, bacaba may form high-density stands, called *bacabais*, referred to as oligarchic stands (eg dominated by a few species) by Peters et al. (1989). In fact, ***Oenocarpus bacaba*, *O. distichus*** and ***J. bataua*** all naturally form oligarchic forests, but their over harvest in the past and in recent decades has led to the destruction or severe reduction in stand density or the complete elimination of the stands.

Oenocarpus balickii F. Kahn (sinamillo: Peru). This recently described species (Kahn 1990) is found in Amazonian Peru, Brazil, Colombia and perhaps elsewhere. It is distinguished from ***O. mapora*** by its solitary habit, greater number of pinnae and smaller fruit. It is common in well-drained sites in primary forest, where it can be found in great abundance. Its fruit is used to make a beverage, similar to that made from patauá.

Oenocarpus distichus Martius (bacaba-do-leque: Brazil). This species is the source of *vinho de bacaba*, a commonly consumed drink in southeastern Amazônia. The *bacaba-do-leque* is distinguished from the bacaba by the striking profile formed by its opposite leaves; the latter species has a spiral leaf arrangement typical of most palms. This species is common on sandier, though humid soils in the seasonally dry forest areas of southeastern Amazônia.

Oenocarpus makeru Bernal, Galeano & Henderson (makeru: Colombia). This species was recently described from the Caquetá River, Colombia (Bernal et al. 1991). It is especially interesting because it has some characteristics of ***Jessenia*** and this suggests that the generic concept of Martius (1823), lumping the two genera under ***Oenocarpus***, may be more appropriate. More complete collections are needed to confirm this, however. In the type locality ("Rio Caquetá, near the Chorro Córdoba, trail to the savanna") it is "abundant in the forest bordering an area of caatinga" (Bernal et al. 1991).

Oenocarpus mapora Karsten (bacabinha: Brazil). A common and widely used species in northwestern South America to southern Central America (to Costa Rica), this palm is a source of *vinho de bacaba* and palm hearts. This species is smaller and generally multistemmed. It is found as scattered individuals in upland or seasonally flooded sites. The wood is used in house construction and for handicrafts.

Two apparent hybrids exist in the wild, including ***O. bacaba*** x ***J. bataua*** and ***O. bacaba*** x ***O. minor***. The presence of natural hybridization bodes well for future breeding programs designed to improve yields, tolerance to stress, reduced time to maturity, etc.

Distribution, abundance and ecology

Patauá (*Jessenia bataua* subspecies *bataua*) is found throughout lowland northern South America, from Bolivia in the south, to Panama in the north, and from Belém (Brazil) in the east to the Chocó (Colombia) in the west.

Balick (1986, 1988) and Kahn (1988) report that patauá occurs both on well-drained upland soils (*terra firma*) and in seasonally or perennially flooded swamps (*igapó* and *varzea*). In the former ecosystem, patauá occurs as scattered individuals, frequently very numerous, although most of these are juvenile, acaulescent individuals (Kahn 1988). Mature palms may only occur at a rate of 1-2 individuals/ha. No botanical collections are reported above 950 m altitude (Balick 1986). In the latter ecosystem, patauá may be the dominant species over hundreds of hectares and forms the classic oligarchic forest described by Peters et al. (1989). Balick (1986, 1988) suggests that patauá, and palms in general, are more efficient at exploiting these high water stress ecosystems than are most dicots, due to their ability to adapt to such conditions. Peters et al. (1989) report as many as 100 mature and 900 immature palms/ha in some areas of Peru and Brazil, while Sirotti & Malagutti (1950) report up to 500 mature palms and an equal number of immature ones. Balick (1988), however, doubts that *sejales* of this density can produce fruit in quantities that would be comparable to yields derived from individual trees (see below).

While it appears that patauá prefers the poorly drained, but more nutrient-rich soils of the *igapós* and *varzeas* of Amazônia, they probably are most abundant there because the palms get substantial amounts of light and less competition from surrounding vegetation. These soils are either very sandy, with relatively high organic matter contents (*igapó*) or humic gleys, with high silt, nutrients and organic matter (*varzea*). On the *terra firma* they are frequently shaded significantly, which probably explains the rarity of mature palms in most areas. In fact, Kahn (1988) states that patauá requires high light levels to fruit. Nonetheless, patauá does extremely well on the terra firma if released from competition with the surrounding vegetation. This is confirmed by observations of high-density stands remaining in pastures in the Colombian Chocó (Balick et al. 1988).

Description & phenology

The patauá is a large (15-25 m), single-stemmed palm, with a 15-25 cm stem diameter at breast height. The 8-16 spirally arranged leaves are 3-10 m long, of which the leaf sheath is 0.5-1.4 m, the petiole 0.2-1 m, the rachis 3-8 m. The pinnae number 120-220 and are inserted at regular intervals in a single plane along the rachis. The inflorescence has a distinctive horsetail shape, called a panicle, with 135-350 rachillae, each 70-120 cm long, and bears from 500-4000 fruit, each weighing from 4-15 g, for a total weight 2-32 kg/bunch. The small round to ovoid fruit have a dark purple rind when ripe, containing a 1-3 mm thick, juicy/oily, white or green or pink/purple mesocarp. The single seed contains a ruminate endosperm (Balick 1986, 1988).

Leaves are produced year round. A single inflorescence is produced in the axil of each leaf (Balick 1986). Only 1-3 inflorescences reach maturity during any one year, as developing inflorescences can abort due to unfavorable nutrient status, photoassimilate reserves, or other physiological factors. This inflorescence abortion often occurs during unfavorable periods for fruit set and development. Collazos & Mejia (1988) found that patauá flowers and fruits during periods of lower rainfall in western Colombia and that the fruit take 10-14 months to ripen after pollination.

Uses and economic potential

As with most palms, patauá has multiple uses (Balick 1986, 1988). This discussion considers its major potential -- oil-- its principal use. More complete discussions can be found in the previously cited references.

Principal use: mesocarp oil

Patauá's mesocarp oil is almost identical to that of olive oil (*Olea europaea*) in its physical appearance and fatty acid composition (Balick 1986, 1988) (see below, Table 2). The Amerindians have used the patauá extensively since well before contact and consider it to be the finest oil available from a forest plant. Since Latin America produces very little olive oil and, in fact, this production is decreasing, patauá has the potential to substitute for Latin America's imports of this high-quality oil that is so much in demand. FAO (1985) reports that Latin America produced less than 1% of the world's olive oil in 1978, or about 13,000 MT. At least 40,000 MT were used in the region in 1974. This disparity in production versus consumption of olive oil, equivalent to about 27,000 MT, has probably expanded since those data were collected, so the potential market may be much larger.

Since patauá oil is virtually identical to olive oil, it is likely that patauá oil could substitute for olive oil in most uses. There was a world shortage of olive oil during World War II and Brazil exported as much as 210 MT/year of patauá oil (Pereira Pinto 1951). Unfortunately, the harvesting of this oil resulted in the wholesale destruction of numerous massive oligarchic stands, which resulted in severe genetic and commercial erosion of patauá populations.

Unlike most palm mesocarp oils, patauá oil is highly unsaturated, with 78±3% monounsaturated fatty acids and 3±1% polyunsaturated fatty acids. This contrasts with olive oil's 77-80% monounsaturated and 7-8% polyunsaturated fatty acids. With the modern emphasis on unsaturated vegetable oils, patauá may even find a ready market in the developed countries.

Secondary uses: food/beverage, medicinal, fiber

Throughout Amazônia and northern South America, the Amerindians prepare patauá "wine", actually a thick non-alcoholic juice with a nutty flavor made from the fruit mesocarp crushed in water and sieved, similar to *vinho de bacaba*. This is a highly nutritious and energy-rich beverage. Balick (1988) observed that the Amerindians put on weight and are healthier during the patauá fruiting season than at other times of the year and attributed this to consumption of the patauá drink. The protein in this drink was shown to be of excellent quality (see below, Table 3), which, combined with the oil and some minerals, makes it an exceedingly nutritious, well-balanced beverage (Balick & Gershoff 1981).

There are several Amerindian medicinal uses for the palm, some of which are worth further investigation. Alone or mixed with honey and lemon, patauá oil is considered a cure for minor bronchial and pulmonary infections. There was some work in Colombia that showed it's efficacy as a treatment for tuberculosis. The oil is also said to prevent hair loss, but this activity is unsubstantiated (Balick 1986).

The leaf sheath and petiole have two types of fibers along their edge: a strong stiff fiber used for blowgun darts and other hunting equipment, and a soft, hair-like brown fiber that might be used for ropes and weaving. These fibers could become an important sub-product from patauá plantations or management areas (see below).

Chemical-nutritive and industrial analysis

An average patauá yields two bunches, each weighing about 15 kg. Trees yielding up to 5 bunches have been observed in favorable agroecosystems (Balick 1988). Blaak (1988) points out that patauá has a high fruit/bunch ratio of 76-83% but a low oil/fruit ratio of 6.5-8% (Table 1). This gives an oil/bunch ratio of 5-6.5%.

Table 1. Patauá fresh fruit components (Blaak 1988)

Component	mean±SD	min.	max.
Fruit weight (g)	8.0±2.7	5.1	13.5
% pulp/fruit	41.4±3.2	35.6	44.7
% oil/fruit	7.4±0.7	6.6	8.1

Table 2 contrasts patauá oil with olive oil, which are both from the mesocarp. Note especially the high levels of unsaturated fatty acids. Note also the variation in fatty acid composition. Overall, these two oils show great chemical similarity.

Table 2. Fatty acid composition of patauá mesocarp oil and a comparison with olive oil (in % total oil).

# C	Fatty acid	pataua Jamieson (1943)	pataua Balick & Gershoff (1981)*	olive oil Jamieson (1943)	olive oil Balick & Gershoff (1981)
C14:0	- myristic	-	-	1.0	-
C16:0	- palmitic	8.8	13.2±2.1	9.4	11.2
C16:1	- palmitoleic	-	0.6±0.2	-	1.5
C18:0	- stearic	5.6	3.6±1.1	1.4	2.0
C18:1	- oleic	76.5	77.7±3.1	80.5	76.0
C18:2	- linoleic	3.4	2.7±1.0	6.9	8.5
C18:3	- linolenic	-	0.6±0.4	-	0.5
% unsaturated		79.9	81.6±4.7	87.4	86.5

* mean±SD of 12 samples.

The dry patauá mesocarp contains about 7.4% protein, with an excellent balance of amino acids. Table 3 presents Balick & Gershoff's (1981) amino acid profile and a comparison of patauá with FAO/WHO's (1973) approximation of the essential amino acid profile of an ideal protein source. Patauá is high for several essential amino acids and only a little low for tryptophan and lysine. Patauá is, therefore, a protein with one of the highest biological values in the plant kingdom, and comparable to animal meat or human milk.

Table 3. Amino acid composition of patauá mesocarp protein* and a comparison with the FAO/WHO (1973) amino acid scoring pattern (Balick & Gershoff 1981).

Non-essential amino acids	mg/g prot.	Essential amino acids	mg/g prot.	FAO/WHO score	FAO/WHO % of score
Aspartic acid	122±8	Isoleucine	47±4	40	118
Serine	54±3	Leucine	78±4	70	111
Glutamic acid	96±5	Lysine	53±3	55	96
Proline	75±8	Methionine	18±6\		
Glycine	69±4		44±9	35	126
Alanine	58±4	Cystine	26±6/		
Histidine	29±4	Phenylaline	62±3\		
Arginine	56±2		105±7	60	175
		Tyrosine	43±5/		
		Threonine	69±6	40	173
		Valine	68±4	50	136
		Tryptophan	9±1	10	90

* mean±SD from 7 samples, except Tryptophan from 3 samples.

Historical production data

Pereira Pinto (1951) presents data on Brazilian exports of patauá oil immediately before, during and after World War II. These are represented in Figure 1. Patauá is not listed in the CACEX register of Brazilian exports during the 1980's (CACEX 1981-88).

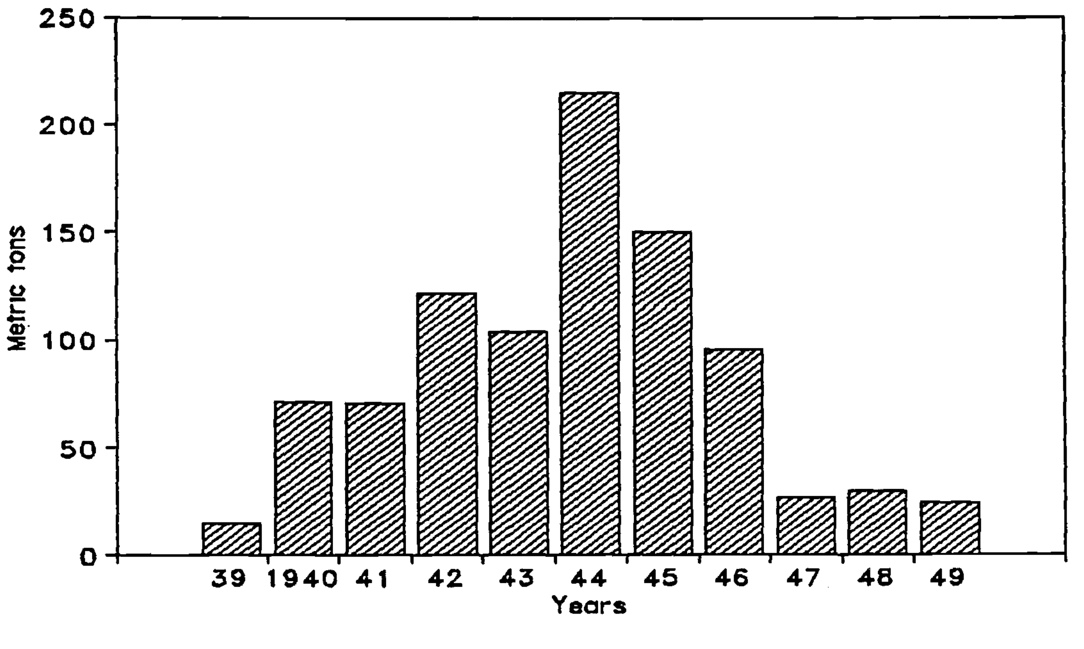

Figure 1. Brazilian exports of pataua oil during the decade including World War II. No exports have occurred since then.

Yields and collection and processing methods

Although pataúá has been widely recommended as an interesting and potentially valuable crop, with potential to become an extractivist-industrial species, there is surprisingly little information available about yields. Sirotti & Malagutti (1950) estimated yields from a natural population of pataúá in Venezuela. These authors analyzed an oligarchic population, called a *sejal* in Venezuela, and reported between 400 and 500 potentially fruit-bearing plants/ha. Balick (1988) considers this to be too high to obtain maximum yields, since it is equivalent to a monoculture spacing of 5 x 5 m (= 400 plants/ha) to 4.5 x 4.5 m (= 494 plants/ha). A mature pataúá tree would probably require a monoculture spacing of 7 x 7 m square (= 204 plants/ha) or triangular (= 216 plants/ha).

Sirotti & Malagutti found that 72% of the mature plants bore fruit during the season, of which 30% bore only one bunch, 42% bore two and 38% bore three bunches (mean bunch number = 2.28). Average bunch weight was 14.5 kg, of which 10.4 kg was fruit (fruit/bunch ratio = 72%). Although Sirotti & Malagutti did not estimate yields, their numbers suggest a yield between 9.5 and 11.8 MT/ha, which is much higher than improved oil palm and extremely unlikely to occur in the wild or in cultivation.

Balick (1988) estimated the yield of 100 fruiting plants at 155 bunches containing 1.6 metric tons of fruit. Peters et al. (1989) estimated a yield of 3.5 MT in their study of 104 plants/ha, slightly more than double Balick's (1988) estimated yield for 100 plants, due either to larger bunches (probable) or more bunches/tree (less probable) or a combination of both (most probable).

Thus, from a hectare of natural oligarchic palm forest, yields vary from 1.6 to 3.5 MT of fresh fruit. This is equivalent to 112-260 kg of pataúá oil/ha or 1.1-2.6 kg/plant. If 204 plants/ha is an appropriate density for a plantation, yields of 3.2-7 MT of fresh fruit could be expected with no further agronomic practices. This is equivalent to 240-525 kg of pataúá oil.

In the early decades of this century, the African oil palm (*Elaeis guineensis*) yielded only 1.9-4.5 kg of oil/plant (@ 205 plants/ha, oil yields were 400-900 kg/ha). Today this species yields 4-5 MT of oil/ha, due principally to improved agronomic practices and better germplasm (Hartley 1977). An equivalent period (about 50 years) of genetic and agronomic improvement could raise pataúá yields to the 2-3 MT/ha range with little difficulty (Balick 1988). In fact, modern improvement techniques, combined with an extensive germplasm prospecting, could allow equivalent progress to be made in one-half the time. This range is 2-3 times the yield of the olive tree, suggesting that patauá has the yield potential to take a share of that market through lower prices due to more efficient production.

If the patauá fruit bunch is not cut from the tree when ripe, fruit will fall over a period of a week or more. Unfortunately, much of the exploitation of the natural populations to supply patauá oil during World War II was done by cutting the tree, rather than the bunch (Balick 1986). There are, however, numerous easy ways of climbing a patauá palm to collect the bunch. It is also possible to harvest it from the ground, as is done with pejibaye (*Bactris gasipaes*).

Traditionally Amerindians extracted oil by heating the mashed mesocarp and pressing it in a *tipitipi*, a long woven tube that shrinks in diameter as it is stretched in length. This method is described in detail by Balick (1986, 1988) but is only about 35% efficient (Blaak 1988).

G. Blaak, of the Royal Tropical Institute, Amsterdam, and now at FAO Plant Production and Protection Division, developed the pilot project for a small-scale, village-level processing plant for patauá, located at Las Gaviotas, Colombia, in the Llanos region. Blaak (1988) details this experimental project, which is not presently operating, despite the fact that Blaak's analysis was very positive. Undercapitalization of the project and a small supply of mature patauá stands in the immediate vicinity contributed to the decision to halt the project at Las Gaviotas.

Oil extraction efficiency of this pilot plant was on the order of 85-89%. The equipment and buildings cost US$29,000 in 1980. This could handle 1 MT of fruit per day, which, during one harvest season is the equivalent of 4500-5000 plants, a 45-50 ha oligarchic population. This plant would need a working capital of US$25,000 a year to turn a profit of US$7,000/yr (29% on investment). Las Gaviotas sold clarified patauá oil at the processing plant gate for US$3.75/kg, approximately equal to the wholesale price of olive oil on the US market in the same period.

It is exactly this type of processing plant that would allow the wider use of the numerous oligarchic patauá populations found throughout Amazônia. A village-level processing plant, similar to that at Las Gaviotas, combined with market contacts, could be a viable component of a forest community or extractivist reserve in Amazônia.

Propagation and cultivation methods

The fresh seed should have the pulp removed and be soaked in warm water (≈50°C) for 30-60 minutes. Alternatively, seeds used to make vinho de patauá (if they have not been boiled) can be sown, as they will have received approximately the same treatment. When pre-treated this way, 90-98% of fresh seed will germinate within 50-60 days (Balick 1988). Seed viability is lost rapidly, with significant reductions occurring in 4-6 weeks. Germination should be carried out in partial shade.

Although no research on preparation of patauá seedlings for planting has been published, a few general comments can be made from empirical observations on patauá. As soon after germination as possible, the seedling should be transplanted to a black plastic nursery bag containing a substrate with 1 part sandy loam, 2 parts clay loam and 1 part organic matter, preferably well-rotted animal manure. Seedlings should be maintained in partial shade (≈50%) during the initial nursery growth period.

St. John (1988) has shown that patauá seedlings inoculated with mycorrhiza produce more leaves and a greater leaf biomass than those not inoculated. If the nursery substrate is obtained from forest soils, as would be the case if Amazonian farmers prepared the seedlings, sufficient mycorrhizal inoculum should be present. If artificial substrates or treated soils are used, the substrate should be inoculated.

If the seedlings will be used for enrichment plantings, either in partially forested or second growth areas, they can be planted directly from the nursery to the field. If they are to go into full sun, as in a monoculture plantation, they should be hardened-off first. When transplanted, they should be semi-shaded with a cut leaf of an adult palm folded over.

Kahn's (1988) work suggests, however, that juvenile material like this may have problems adapting to full sun at an early age, not unexpected in a species adapted to the forest environment. This may partially explain why several patauá seedlings planted in full sun at INPA, Manaus, did not grow satisfactorily. Research should be carried out to determine at what age plants can be transplanted to full sun, since, theoretically, they should grow more vigorously in this environment than in forest enrichment plantings.

Since the patauá is a large palm, it can not be planted at extremely high population densities without reducing yields. Blaak (1988) suggests a 7 x 7 m spacing, used in yield calculation above. This suggestion is based on empirical evidence and would be worth testing. Different genotypes might accept higher or demand lower densities.

Some authors have reported that patauá takes 10-15 years to fruit (Balick 1988). As with most palms, however, this time may be reduced by modifications in the agroecosystem, especially by reducing competition and enriching the nutrient content of the soil. Blaak (1988) comments that 1.5 kg of fertilizer/plant should double yields. Balick (1986) observed a plant in Ecuador that fruited very precociously, at less than two meters from the ground. The patauá germplasm bank being organized at the Centro de Pesquisas Agropecuárias do Trópico Umido, in Belém, Pará, will provide information on the precocity of different genotypes in plantations. This trait generally has a moderate to high heritability and can be selected for in an improvement program.

Many economically important palms are frequently spared in forest clearing and become part of diversified agroforestry systems in the region. Patauá is no exception, as patauá fruit are very popular. There are no reports of patauá being planted into Amazonian agroforestry systems, but this practice is to be expected, even though there is a long juvenile stage before fruiting. Balick et al. (1988) note that palms in agroforestry systems studied in Colombia have larger bunches (fruit:flower ratio) than those studied in primary forest. This suggests that lessened competition and increased availability of light, nutrients and pollinators could result in immediate yield increases.

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Pejibaye

Charles R. Clement

Family: Palmae (Arecaceae)

Species: *Bactris gasipaes* Kunth

Synonyms: *Bactris gasipaes* H.B.K., *Guilielma speciosa* Martius, *G. utilis* Oersted, *G. chontaduro* Triana, *G. gasipaes* (HBK) L.H. Bailey.

Common names: pejibaye (Costa Rica), pupunha (Brazil), chontaduro, cachipay (Colombia), chontaruro (Ecuador), pijuayo (Peru), gachipaes (Venezuela), peach palm, pewa nut (Trinidad).

Related species

The genus *Bactris* contains roughly 200 species. Numerous *Bactris* sp are occasionally used as edible fruit in northern South America, although none of them attain the importance of pejibaye.

Description and phenology

The pejibaye is a caespitose (multistemmed) palm that may attain 20+ m in height. Stem diameter varies from 15 to 30 cm and internode length from 2 to 30 cm. The internodes are armed with numerous black, brittle spines, although spineless mutants occur and have been selected for in several areas. The stem is topped by a crown of 15 to 25 pinnate fronds, with the leaflets inserted at different angles; the tender unexpanded leaves in the center of the crown form the palm heart, an important economic product. Among the axils of the senescent fronds the monoecious inflorescences develop. After pollinization the bunch may contain between 50 and 1000 fruits and weigh between 1-25 kg. Numerous factors can cause fruit abortion: poor plant nutrition, poor pollinization, drought, crowding, insects and diseases -- which also contribute to low average bunch weights. Table 1 presents bunch composition data. The fruit that ripen have a starchy to oily, humid mesocarp; a fibrous red, orange or yellow epicarp; and a single endocarp with a fibrous, oily white endosperm. Individual fruit may weigh between 10 and 250 g and are potentially and traditionally the most important economic product. Table 2 presents fruit composition data.

Mora Urpí & Clement (1988) classified 8 landraces (primitive varieties) of pejibaye in Amazônia and Clement (1986) classified one more and classified the Occidental pejibayes as a race. Fruit mesocarp composition vary considerably among the races, as occurs with other plant, bunch and fruit characters.

In central Amazônia the pejibaye flowers between August and October, with the main harvest between December and March. There is frequently a minor harvest, with flowering in May-June and fruiting in August-September. In the Costa Rican Atlantic coast the main fruiting season is between August and November (Mora Urpí 1984).

Table 1. Average bunch composition data from several sources.

Author	Race	Bunch weight (kg)	Fruit number	Fruit/bunch ratio (%)
Piedrahita & Velez, 1982	Occidental	3.3	61	87
Arkcoll & Aguiar, 1984	Pará, Solimões	3.6	96	93
Clement & Mora Urpí, 1988	all Amazônia	7.9	149	96
Clement, 1986a	Occidental	4.8	106	91

Table 2. Average fruit composition data from several sources.

Author	Fruit weight (g)	Seed Weight (g)	Mesocarp %	Pulp %
Piedrahita & Velez, 1982	50	3.6	80.8	92.8
Arkcoll & Aguiar, 1984	35	2.9	76.1	90.3
Clement & Mora Urpí, 1988	58	4.1	-	91.7
Clement, 1986a	42	4.6	-	88.5

Distribution, abundance and ecology

The pejibaye was distributed by the Amerindians in the pre-Colombian period, from its probable center of origin in south-western Amazônia and its undoubted center of domestication in western Amazônia (Clement 1988). At contact (1500 AD) it was found from southeastern Honduras in the north, down through Central America and around the Caribbean shores (with a small disjunction east of the mouth of the Magdalena River, where conditions are too dry) to the Atlantic port of São Luiz de Maranhão (Brazil), from where its distribution turns inland along the middle reaches of the eastern Amazon River tributaries, then up the Madeira River into Bolivia and reaches its southern most point near Santa Cruz de la Sierra, from where it extends northward along the Andes. On the Pacific coast it first appears in southwestern Costa Rica and extends down to extreme northern Peru. It thus has a disjunct distribution: Central America and the Pacific coast of South America, with a small area between Darien (Panamá) and the Magdalena River (Colombia); northern South America and Amazônia, with some small areas of non-occurrence due to local edapho-climatic conditions, principally dryness (Clement 1988).

The pejibaye is a truly domesticated species (Clement 1988). As such, it only occurs where man has planted it, although its phylogenetic relationships with other species are starting to be worked out and this research may identify one of the wild species as the original pejibaye. Until this is resolved, it can be considered a cultigen, i.e. with no positively identified wild ancestor in the local flora. Abundance therefore depends upon its local importance to man. Where it has a long history of use, for example in western Amazônia and southern Central America, it can be extremely abundant, i.e. several thousand palms in the fields around Amerindian villages. Patiño (1963) reports on its importance in southern Costa Rica shortly after contact (1500 AD), when some Spanish mercenaries cut 50,000 stems of pejibaye at one site, for which they were later punished by the recently installed royal judicial system.

Because it is a domesticated species its ecological tolerance is much wider than that of any probable ancestor. It fruits in the following conditions: from 2 m above sea level to more than 1,200 m; with rainfall from 1800 to 5000 mm (although drought of more than 3 months reduces fruiting, therefore, rainfall distribution patterns are important); in moderately sandy to very clayey soils if these are well drained (bad drainage is unacceptable), even where nutrient levels are poor, although it obviously yields better on richer soils; in full sun, since it does not tolerate shading. Because of rapid stem growth, however, it can be combined with other species, especially shade-tolerant, smaller statured ones.

Uses and economic potential

Clement & Mora Urpí (1987) and Clement & Arkcoll (1989) have discussed 5 products obtained from pejibaye with potential in the modern tropical market economy. Several of these uses are directly related to fruit mesocarp composition (Tables 3, 4). What follows is condensed from the above mentioned references.

Principal uses

Fruit for direct human consumption

This is the traditional use for the pejibaye fruit and is the only one known in most places. The whole fruit is separated from the bunch and boiled in salted water for 30 to 60 minutes, to improve flavor and eliminate the irritating oxalate crystals (Arkcoll & Aguiar 1984) and trypsin inhibitor (Murillo et al. 1983). Piedrahita & Velez (1982) report that cooking for 15 to 20 minutes deactivates the peroxidase enzyme activity. The fruit are then peeled, halved and pitted, and are ready for consumption. Pejibaye fruit are frequently consumed at breakfast, or as an appetizer before later meals. When the fruit are dry, starchy and low in oil, they are tastier when accompanied by mayonnaise or a sauce. The cooked fruit can also be used whole in stews, or ground to a flour for use in a variety of preparations and pastries. About 40 pejibaye recipes have been collected by Calvo (1981).

Table 3. Average mesocarp composition data from several sources. (% dry weight)

Author Race	Humidity	Protein	Oils	N-free extract	Fiber	Ash
Piedrahita & Velez, 1982 **Occidental**	49.8	9.8	11.5	73.7	2.8	2.4
Arkcoll & Aguiar, 1984 **Pará & Solimões**	55.7	6.9	23.0	59.5	9.3	1.3
CIPRONA, 1986 **Occidental**	56.7	6.1	8.3	79.9	3.6	2.1

While the flavor of fruit is quite variable, the typical pejibaye has a distinctive bland to strong flavor (depending upon carotenoid and oil content) of its own. A liking for this is acquired fairly easily but it is not exciting enough to generate new markets without good quality control and clever marketing (FAO 1986). Several authors have mentioned that pejibaye may taste like European chestnut (*Castanea sativa*) (Popenoe & Jimenez 1921; NAS 1975). Arkcoll & Aguiar (1984) found fruit with flavors similar to potato, maize and cassava and some which were sweet.

Table 4. Vitamins present in pejibaye mesocarp, from several sources. (in 100 g fresh mesocarp)

Author/Vitamin	β-carotene	Niacin (mcg)	Vit. C (mcg)	Riboflavin (mcg)	Thiamine (mcg)
Johannessen (1967)	315 mcg	0.12	1.19		
I.N.N. (1959)	7300 I.U.	0.9	20.0	0.11	0.04
Leung (INCAP) (1961)	670 mcg	1.4	35.0	0.16	0.05
Arkcoll & Aguiar (1984)	0-70 mg				

Mesocarp texture is also variable, ranging from that of a soggy potato to that of a good raw cashew (*Anacardium occidentale*). Texture is determined by water, starch, fiber and oil content, with watery, low starch types being soggy and starchy, low water types being floury to crunchy, even after cooking. Preferences vary from region to region. In Costa Rica the "best" fruit are dry, high-starch ones with a nutty texture; in Manaus the "best" fruit are moderately starchy, somewhat oily and humid, with a less nutty, though still firm, texture.

In Costa Rica whole or halved, pitted or unpitted, peeled or unpeeled fruit are marketed in brine in 500 and 1000 g jars or cans. Quality is extremely variable but they sell well when fresh fruit are unavailable. In Colombia dehydrated fruit have been prepared for market.

Fruit for animal ration

This is the major alternative use being studied at the moment. Because its dried fruit can partially or completely substitute maize for many uses, the pejibaye may be considered a tree cereal. This is especially true for animal rations, as pejibaye flour can substitute for the maize base that is generally used. Costa Rican researchers are currently leading this effort and Murillo & Zumbado (1986) have reviewed recent work with chicken feeds. Their team (Soto 1983, Zumbado & Murillo 1984, Cooz 1984, Loynaz 1985, Facuseh 1986, Espinoza 1986) has studied pejibaye preparation (autoclaving, extrusion, sun drying, etc.) and maize substitution levels for starter and primary rations for layers and broilers.

Using second-quality fruit (first-quality having high market value) their results showed that pejibaye can be used as the principal energy source in primary rations, but should be used less intensively in starter rations. Heat treatment is essential, especially for starter rations, to deactivate the trypsin inhibitor (Murillo et al. 1983). Heat treatment by extrusion is cheaper than other methods tested and is recommended. Moderate to high levels (30-100% substitution of maize) also allows the production of a cheaper meal (both for starter and for primary rations), at Costa Rican costs for maize and second-quality pejibaye.

One attractive option, that avoids drying and heat treatments, is to ensile the fruit on the farm and feed it directly to stock, possibly with a protein supplement. There is some suggestion that acid ferment may break down the anti-nutritional factors (Sangil 1985) and is appreciated by pigs (I. Araújo, pers. com.). Ensiling would also be an excellent way to cheaply store pejibaye fruit for animal feeds.

Fruit for flour

To avoid saturating the high-value fresh fruit market, it is interesting to consider the potential for developing other products for human consumption. Among Calvo's (1981) 40 recipes are several for making breads, cakes and other pastries from pejibaye flour. Tracy (1986, 1987) tested pejibaye flour, mixed with wheat flour, for bread in Costa Rica. Ninety percent wheat and 10 percent pejibaye gave bread dough with excellent baking characteristics, slightly less protein, more energy (from the oil) and more vitamin A (β-carotene). Eighty-five percent wheat and 15 percent pejibaye gave a slightly heavier dough, similar to whole wheat bread. Both were acceptable to a small group of consumers. This product might develop well in the "natural foods" market.

Tracy (1986) also tested several cake recipes with good results, both in the kitchen and on the market. Pejibaye flour must be mixed with wheat flour to make a good cake in Costa Rica. In the Manaus region, however, some pejibayes can be used pure, with excellent results. This may be due to the higher oil content.

Clement & Mora Urpí (1987) point out that pejibaye flour is quite similar to yellow cassava or maize flour and could substitute for these in many areas, with nutritional advantages over the cassava flour. This was one of the alternative products developed by the Amerindians, who appear to have domesticated the Putumayo and Vaupés "macrocarpa" landraces specifically for this purpose (Clement 1988). These landraces have extremely high starch and low oil levels in large fruit, excellent for making flour that stores well for long periods. This flour can also be fermented to make *caissuma* (Brazil) or *masato* (Peru), a soupy-gruel with a peachy flavor and mild alcoholic level. Flours can also be extruded to make a variety of attractive snacks that might find a large market.

<u>Fruit for oil</u>

Arkcoll & Aguiar (1984) were the first to point out pejibaye's oil potential. By searching for high oil fruit these authors eventually found fruit with 62% oil in the dry mesocarp and 34% oil on bunch weight. Clement & Arkcoll (1985) later pointed out that the oily fruit are more frequent in the more primitive (i.e. less selected) populations, especially in the "microcarpa" racial group. This seems to be due to Amerindian selection for starch, which, being negatively correlated with oil, means that the more selected landraces have low oil levels in the mesocarp. While per hectare oil yields [extrapolated from the best plants and assuming *in vitro* cloning (Clement & Arkcoll 1991)] are lower than established crops [ex. African oil palm (*Eleais guineensis*) yields 5 T/ha/yr of vegetable oil], they are higher than these were at a similar stage of development, suggesting that modern breeding and biotechnology methods could produce a new oil crop quickly (Clement & Arkcoll 1991).

Although there already are excellent oil crops for the wet tropics (i.e. *E. guineensis* and *Cocos nucifera*), the need for greater crop diversity is well demonstrated by the diseases and pests that limit or prevent their use in several countries (Meunier 1976). Pejibaye has an advantage over these two in that it will also provide a significant quantity of a high quality meal after oil extraction, suitable for humans and animals.

Unsaturated fatty acids are more common in pejibaye mesocarp oil than in African oil palm (Table 5), although the caiaué (*Elaeis oleifera*) has similar oils and is now being introgressed with oil palm to improve oil quality in that species (Hartley 1977). The fact remains, however, that unsaturated fats have a good market value at present, and are interesting from both a nutritional and industrial point of view.

As pointed out by Arkcoll & Aguiar (1984) and emphasized by Clement & Arkcoll (1985, 1991), most pejibayes have oil-separation problems when pressure is extracted. The oil, starch and water form an emulsion that must be solvent extracted. There are plants that have good separation characteristics, but using only these would severely reduce the genetic base of any improvement program. The oiliest pejibayes are relatively dry, however, so that separation may not be a severe problem with improved materials.

Table 5. Fatty acid composition data of pejibaye mesocarp oils from several sources (% oil)

F.A.\Author	Zapata (1972)	Hammond et al. (1982)	Silva & Amelotti (1983)	CIPRONA (1986)	Oil palm Noiret & Wuidart '76
Palmitic	40.2	29.6	44.8	32.2	42.2
Estearic	0.4	trace	1.5	1.5	4.9
Totl Saturated	40.6	29.6	46.3	33.7	47.1
Palmitoleic	10.5	5.3	6.5	8.3	-
Oleic	47.5	50.3	41.0	45.5	40.6
Linoleic	1.4	12.5	4.8	11.6	11.2
Linolenic	-	1.8	1.0	2.0	-
Totl Unsatur.	59.4	69.9	53.3	67.4	51.8

Heart of palm

Palmito, or palm hearts, are the only product for which pejibaye is currently grown on a commercial scale. There are more than 2000 ha planted in Costa Rica (Clement & Mora Urpí 1987) and already 300 ha in Amazônia (Acre state). The palmito market is very volatile because of quality control in the main palmito species, the assaí palm (*Euterpe oleracea*). This is extracted nearly free of cost from enormous natural populations in the Amazonas River estuary, which are being severely devastated by most companies. Quality control varies considerably from company to company; those practicing management rather than devastation having better control. Both of these factors may open a larger market for pejibaye, as plantation quality control has been good and plantations are managed rather than devastated.

Processing technology for the pejibaye palmito has been developed in Costa Rica and in Brazil. The most detailed studies are by Ferreira et al. (1982ab) at the Instituto de Tecnologia de Alimentos (ITAL), in Campinas, São Paulo, Brazil. Recently the

University of Costa Rica Food Technology Research Center (CITA), in conjunction with a French research institute, has started working on technology to package, ship and commercialize fresh palmito (J. Mora Urpí, pers. com.), which should significantly expand the palmito market, as there are many more uses for fresh palmito than for the currently processed product.

Most pejibayes are spiny, both on the trunk and on the leaf petiole and rachis, which complicates extraction of the palmito. Several spineless populations have been found in western Amazônia, especially around Yurimaguas, Peru (Clement et al. 1988). Many other western Amazonian populations show variable frequencies of spinelessness or reduced spininess. There is also a spineless population in Costa Rica. This germplasm forms the genetic base for the improvement programs currently planned in Brazil and Costa Rica.

Both the apical and basal residue from palmito extraction have some potential use and require more intensive research to find new uses. The basal residue, just below the plant's apical meristem, is very tender and has a crispy texture. This could be made into a cream soup or be thin-sliced (transversally) as a substitute for bamboo shoots or deep fried to make chips. The apical residue is slightly fibrous leaf and petiole material, which can serve as a vegetable.

Secondary uses

Mora Urpí (1984) reports that the wood from the outer stem (the inner part is pith) is an attractive black with yellow fibers, strong, durable, easy to work and takes a good polish and suggests its use as parquet. Patiño (1963) reports numerous Amerindian uses for this wood, some of which are adapted for the local handicrafts industry. Because pejibaye grows so tall so quickly, plantations must periodically be renewed from stem off-shoots. The wood obtained from these periodic renewals could supply these use options without endangering fruit production.

Collection methods and yields

High yields have only been projected from small plots or population data. Mora Urpí (1984) reports 25 T/ha/yr of fresh bunches from non-selected, fertilized germplasm ("mesocarpa" Occidental landrace) growing in good edapho-climatic conditions in Costa Rica. Clement (1987) projected 6-10 T/ha/yr from population data ("microcarpa" Pará landrace) near Manaus, for unselected, unfertilized germplasm on poor soils with three months drought. Moreira Gomes et al. (1987) estimated yields of 24 T/ha/yr from the Fonte Boa ("mesocarpa" Solimões landrace) population for unselected, unfertilized germplasm on poor soils with a favorable climate. Clement & Mora Urpí (1987) state that much higher yields (50 T/ha/yr) can be attained within a cycle or two of any improvement program, although factors causing fruit drop must be eliminated, especially on poor soils.

Given these yields and strong market acceptance where it is well known, there are good prospects for producing good quality fruit for the local and regional markets. Market saturation levels are, however, unknown. Excessive supply would lower prices from the current US$0.50 to US$1.00 per kilogram range for best quality fruit. This might increase consumption somewhat, but could lower farm income, unless alternative uses are developed.

Potential yields for animal ration should be similar to those for fresh fruit, especially if used in silage. For use in chicken feeds, the fruit would have to be dried, thus reducing the final product to 50% of the initial yield. A breeding program for fruit for animal ration would select for starchy, low oil fruit and should yield in excess of 25-30 T/ha/yr of fresh bunches (Clement 1988).

In many areas of the humid tropics cereals do not yield well without considerable amounts of inputs and know-how. For example, on the nutrient poor oxisols near Manaus, maize small holders rarely obtain more than 800-1000 kg/ha/yr. This suggests that pejibaye might develop a market as a component of animal rations, if it can be produced cheaper than imported maize. Tracy (1985) was able to obtain a small profit when using sun-power to dry second-quality pejibaye for animal ration in a rainy climate. A more efficient, low-cost drying method should improve profits.

As Tracy (1985) pointed out, in regions that do not produce bread cereals, like the humid tropics, even 10% substitution of wheat can have a favorable effect on the local balance of payments, by reducing imports. Yields of 10-12 T/ha/yr of dry flour are thought to be possible, if pests and diseases are controlled (Clement & Mora Urpí 1987) and would probably be economically viable. Phytosanitary quality control would be extremely important [re Piedrahita & Velez's (1982) 30 percent unacceptable fruit quality levels; as this flour would go to human consumption it must be of high quality].

Clement & Arkcoll (1985, 1991) suggest that yields of 2-3 MT/ha/yr of oil are immediately feasible with *in vitro* cloning and could easily be raised to 5+ MT in an improvement program. The germplasm is available (Clement & Arkcoll 1985) and trial crosses have been made, but long-term financing is required for this breeding program. The problem of fruit drop must also be resolved before this product can become commercially viable.

Current pejibaye collection technology is a long pole with a hook or curved knife on the point to pull or cut the bunch from the stem, with a bag or pad to stop the bunch from shattering on the ground. Needless to say this is extremely inefficient but small holders rarely have the economic resources necessary to develop or buy better technology. Some work has been done at the University of Costa Rica, with mixed results, i.e. the technology looks good in the laboratory but has not been accepted by farmers. During the 1983 US AID-sponsored collecting trips, a farmer was observed in Coari, Amazonas, Brazil, using a basket on his knife-tipped pole; the cut bunch would (generally) fall into the basket, which would slide down the pole. This is a simple, promising technology which deserves further study.

Moreira Gomes & Arkcoll (1988) reported first harvest yields (2 years) of 1.2 MT/ha of export-quality palmito on fertilized oxisols in Manaus, falling to between 600 and 900 kg/ha at subsequent harvests. This decline is probably due to poor plantation management, rather than biological factors, as it has not been reported in Costa Rica. Zamora (1985) reported 3 MT/ha/yr of field harvested palmito in Costa Rica, of which 20 to 30% is export quality. Zamora (1985) also reported on a density trial whose highest yields were above 3.5 MT/ha/yr. With selected germplasm and good agronomic practices it may be possible to attain nearly 2 MT/ha/yr of export-quality palmito. The useable-residues yields are usually calculated at triple export-quality yields.

The mature palmito is obtained by cutting the stem just under the apical meristem (base of the palmito) with a machete and removing the outer leaves and petioles. Because pejibaye is a caespitose palm (i.e. it suckers from the base) it is not killed by this harvesting and new stems are managed to replace the cut stem.

Propagation and cultivation methods

<u>General</u>

The following simplified propagation and cultivation methodology may be followed by small farmers with little capital (Clement 1989). More elaborate systems are obviously possible.

In areas where pejibaye is indigenous, seed should be obtained from plants selected for desirable fruit characters, high yield and spinelessness. In other areas the local agronomic research institute could obtain selected material from one of the research contacts listed below. The seeds could be germinated in loam or composted sawdust substrate beds; if local soil pathogens are a problem, pure sand, mulched with sawdust, can be used. Germination under these conditions takes 60-120 days. Mora Urpí (1984) gives details for seed germination in plastic bags, where germination percentage is usually higher but practice is required.

At the two-leaf stage, the seedlings should be transplanted to 2 kg black plastic nursery bags or similar containers, because root damage from bare-root planting or other root disturbance at final transplant results in poor field establishment. Fifty percent shade is recommended during germination and early nursery growth. (Palm thatching makes an excellent shade as long as light recommendations are followed.) With a loamy, manured substrate, seedling growth is rapid; the plantlets should be hardened-off when about 40-50 cm tall, 4-6 months after transplanting.

A good planting pit is important for successful field establishment: a minimum size is 40 cm in all dimensions. This should be partially filled with animal manure, organic refuse and about 100 g of phospherous (P) and well mixed with the topsoil from the pit a month or so before planting out. The subsoil can be used to form a catch basin on the downhill side of the planting pit. The seedlings should be planted about 10 cm below the soil surface, without filling the planting pit to bury them, so that adventitious roots can take hold and develop as new primary roots.

Planting out should be done at the start of the rainy season. The pejibaye is extremely hardy, however, and has survived the Manaus dry season with only one month of rainy weather; this is not recommended, however! If the plants have been correctly hardened-off at the end of the nursery stage, little or no growth pause will occur after planting out. Weed control is important during the first two rainy seasons in order to allow the young plants to get above their competitors; the cut weeds can be used as mulch. This should be done without túrning the soil, as pejibaye roots are distributed superficially (Ferreira et al. 1980) and easily damaged. Herbicides should be avoided, as these damage root growth also.

The young plants should receive a dressing of nitrogen (N) during the first two seasons after planting out. In poor soils this should be about 25 g of N at the beginning, middle and end of the rainy season. In year-round rain areas, this can be appropriately modified. Mineral N can be substituted by animal manure or well-managed leguminous ground covers. Peréz (1987) recommends *Pouraria phasealoids* and *Desmodium ovatifolium* as ground covers; the former is a climber which must be adequately managed at all times, the latter is shrubby and must be cut back at the beginning of the dry season to serve as mulch and to avoid competition for water. Poor nutrition leaves the plants weakened and less resistent to pests, such as leaf mites that can reduce growth. The pejibaye is resistant to most leaf herbivores, but even spiny types are avidly consumed by cattle, goats, horses and donkeys.

As the plants attain reproductive age, between 2 and 4 years after field planting (if adequately fertilized and managed), they require more nutrients to yield well. This is because the fruits are mineral-rich and these nutrients are exported during harvest. On the nutrient-poor oxisols near Manaus a single-stemmed plant requires approximately 200 g P, 150 g N and potassium (K) and about 50 g magnesium (Mg) -- the P and Mg applied at the beginning of the rainy season and the others applied at intervals of two or three months. Again, manure can supply most of the K and leguminous covers the N. Other organic wastes (including bunch waste) can supply more of these and other minerals. Phosphorus must be used, as this is the major limiting element (Arkcoll 1982). Micro-nutrient deficiencies are becoming evident in Amazônia, after several years of NPK+Mg fertilization. The use of manures, other organic wastes and leguminous covers should delay micro-nutrient deficiency symptoms in most areas.

Monoculture

Detailed agronomic instructions and costs for monoculture plantations have been presented (Mora Urpí 1984, Mora Urpí et al. 1984).

For monoculture fruit plantations, 5 x 5 m spacing is recommended on poor soils and 6 x 6 m on rich soils. Contour planting is recommended and steep slopes should be avoided. Large-scale monocultures are not recommended for Amazônia because of probable pest and disease attack. Small-scale monocultures (0.5-2 ha) are an appropriate farm component.

Long-term management of the plantation will require occasional plantation renewal, when the plants become too tall for economic harvesting of the fruit (Mora Urpí 1984). Plants should be managed to have one principal fruiting stem and a single off-shoot for renewal. The off-shoot will grow vigorously during the first years and can be eliminated when its palmito is harvestable. An off-shoot from this off-shoot can then be maintained to replace the principal stem when it is too tall. Upon cutting the principal stem, generally at 10-15 years, its palmito can be extracted and its wood exploited. This form of management will give periodic harvests of palmito and wood to supplement the farmer's diet and income, and will occur in both monoculture and agroforestry systems. After renewal, the new reproductive stem will take 2-3 years to start fruiting.

Until recently the pejibaye has been relatively free of pests and diseases, principally because it has been a low-density agroforestry component rather than a monoculture. As even small-scale monocultures have spread in Costa Rica and Brazil, "new" pests and diseases are being identified; the "catalog" of economic pests and diseases is expanding rapidly. As pejibaye spreads around the world it will probably enjoy a decade or two of relative freedom from attack in new areas, followed by an increasing pest and disease load.

Several diseases attack the fruit (Mora Urpí 1984), generally after an initial insect-caused lesion. ***Phytophtera*** has been identified as an occasional problem in Costa Rica (E. Vargas, pers. com. 1986) and may be expected to spread, especially in poorly managed and fertilized plantations. Leaf mites attack certain genotypes in some areas (Mora Urpí 1984). Coleoptera and diptera fruit and seed borers are frequently found, although seldom serious to date (Mora Urpí 1984). A coleoptera seed borer has recently been found in Rondônia (Brazil) that eliminated nearly 100% of the yield in one area. In Manaus, poor plant nutrition and a prolonged drought weakened the plants and opened the way for several coleoptera, diptera and hemiptera which eliminated 85-90% of the expected harvest in the INPA plantations in 1988.

If pejibaye is intended for palmito production, it should be planted at 2 x 1 m, with the same planting pit and N dressing as used for fruit production. The first harvest should start after 18 months in the field. When ready for harvesting the trunk should have a visible internode. The numerous off-shoots must be managed continuously (Mora Urpí 1984): for maximum palmito yield in subsequent harvests leave 3-4 shoots after pruning back most of the older leaves to reduce sun-scorch; for maximum palmito size leave only one shoot, also pruned back. All waste from rough palmito extraction should be left in the field and all waste from export-quality extraction should be returned to the field to serve as mulch and to reduce mineral exports.

Further expansion of pejibaye culture can be expected by stimulating popular consumption of palmito, currently considered a luxury export product and mostly consumed on holidays. In Peru, where palmito consumption is more common, this expansion should be easier (INIPA 1987). Small-sçale palmito monocultures (0.5-2 ha) are thought to be a viable option in most of Peruvian Amazônia because of this tradition and could easily be introduced in other areas.

Agroforestry

The pejibaye is a component of most Amerindian swiddens in western Amazônia and parts of northern South America and southern Central America. There are ethnohistorical reports of near monoculture stands in southern Central America (Patiño 1963), but most reports show that it is a common element at low density. In traditional Amazonian agroforestry, the pejibaye density can probably be raised from the current 3-20 plants/ha to 20-50 plants/ha without much cost or increased risk of pest and disease attack. It can be introduced to new immigrants as components of their home gardens and new perennial plantations. The limiting factor is expansion of human and animal consumption of the fruit, in order to raise demand and justify the increased density.

Clement (1986b) discussed the Costa Rican agroforestry uses of pejibaye and the Brazilian institutional experimentation with this species. The Executive Commission for the Promotion of Cacao (CEPLAC) now recommends pejibaye as a productive shade for cacao (*Theobroma cacao*) in Amazônia (P.T. Alvim, pers. com. 1988). Use of pejibaye as a productive shade should be considered throughout the humid tropics as an alternative to coconut shade in cacao and coffee plantations. In these areas it can be planted in a uniform lattice or in single or multiple rows running with or across the sun's path, depending upon the light requirements of the associated species. When planted in rows, pejibaye can be a border for any field or fruit crop, although it should not be considered as a wind break if high yields are desired.

In multistrata systems, the pejibaye should be considered as a component of the upper stratum, as it will not produce well if shaded by taller trees. Having been domesticated in an agroforestry environment, the pejibaye appears to be tolerant of competition from shorter statured plants, except Graminae. Several experiments have been conducted that show that pejibaye monocultures can be economically initiated with understories of rice, beans, maize or cassava; some experiments have been conducted with semi-perennial fruits species, such as pineapple (*Ananas comusus*), papaya (*Carica papaya*) and passionfruit (*Passiflora edulis*).

Agro-silvi-pastoral systems have been suggested for pejibaye, but may not yield well if large animals are allowed to disturb the root system. Cattle trample and destroy the superficial root mat, which accounts for 60-70% of the root absorptive surface; they are also avid consumers of pejibaye leaves from the off-shoots and even of the adventitious roots that develop from the first few internodes. Swine are also destructive of the root system and should not be turned loose, except if abundant fruit bunches are available on the ground. Pejibaye should, however, be considered as a component of agro-silvi-pastoral systems where the fruit, preferably ensiled, are taken to animals in another part of the farm and the manure returned to the plants.

"Income Forests"

The pejibaye cannot be considered a climax component of an income forest because it would not fruit in the shade of taller dicots. It could be used, however, as a successional component in an agroforestry system designed to mature into an income forest.

Salvador Paitán (Univ. Amazônia Peruana, pers. com., 1991) has used pejibaye in this way, although his agroforestry systems are designed to mature into tree lots destined for export-quality timber. This follows from its widespread Amerindian use in swidden-fallow systems, where it provides fruit until shaded by returning secondary or primary forest species.

Research contacts

Dr. Jorge Mora Urpí, Escuela de Biologia, Universidad de Costa Rica, San José, Costa Rica. Dr. Mora Urpí is the world specialist on the species.

Dr. Mario Murillo, Facultad de Agronomia, Universidad de Costa Rica. Dr. Murillo coordinates studies on pejibaye for animal feeds.

Dr. Jose Ciccío, Centro de Investigación en Productos Naturales - CIPRONA, Universidad de Costa Rica. Dr. Ciccío coordinates studies on composition and uses.

Dr. Victor Patiño, Apdo Aereo 21-54, Cali, Colombia. Dr. Patiño is Colombia's specialist on the species and has done the most detailed ethnohistorical surveys.

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Piquiá

Charles R. Clement

Family: Caryocaraceae

Species: *Caryocar villosum* (Aubl.) Pers.

Synonym: *Caryocar butyrosum* (Aubl.) Willd.

Common names: Piquiá, pequiá, piquiá verdadeiro, amêndoa de espinho (Brazil); arbre à beurre (French Guiana); suari, soari (Suriname); bats sauari (Guyana) (Cavalcante 1988); piqui-a, pekea (Malaysia) (Lane 1957).

Related species

Caryocar nuciferum L. - The souari or butter nut of the Guianas (often confused with the piquiá in southern Suriname) has occasionally entered the world market (mostly Europe) as an edible nut, almost exclusively from wild collected trees. Although a larger fruit, it has a lower mesocarp to endocarp ratio than the piquiá, which makes the seed (nut) more important. The souari nut has a flavor like sweet almonds (Rosengarten 1984). It occurs in Suriname, Guyana and Venezuela, where it is also reputed to be cultivated (León 1987).

Caryocar brasiliense Gam. - The pequí or piquí has a smaller fruit, with a similar mesocarp to endocarp ratio as the piquiá. It is widely distributed in the Brazilian *cerrado* (sparsely forested savannas) and adjacent transition zones, where it is extremely popular and occasionally cultivated. It is used principally as a flavoring for other dishes, especially rice, although it may also be consumed cooked or made into a liquor. The seed (nut), although edible, is seldom used (FAO 1986).

Caryocar glabrum (Aubl.) Pers. - the piquia-rana (Brazil) or almendro (Peru) has very little mesocarp but is widely used for its seed (nut) in Peru, where it is frequently commercialized. There is no record of cultivation (FAO 1986).

Description and phenology

The piquiá is one of the largest forest trees in most of its distribution, frequently attaining 40-50 m when occurring as an

Brasília highway in southeastern Pará. Its distribution suggests that the Amerindians may have helped disperse the species, although they appear not to have created the concentrated stands that they did with the Brazil nut (***Bertholletia excelsa***), except in the case noted by Wickham. More detailed study of the species' distribution may turn up other cases of exceptional abundance.

The piquiá is adapted to the heavy, nutrient-poor but well-structured, well-drained clay soils (oxisols and ultisols) of the non-flooded Amazonian plateaus (*terra firma*). The species is most common in Köppen's "Am" climatic zone, with 1700-2500 mm of rainfall and a 1-2 month dry season; it also occurs in "Aw" climate areas, with 1200-1700 mm and a 3-4 month dry season and in "Af" climate areas, with 2500+ mm and no dry season.

The species is a prominent component of the high forest, frequently found as an emergent (similar to Brazil nut). Pereira & Pedroso (1972a) suggest that it does not regenerate well in the shade of the high forest, a common characteristic of canopy and emergent species. In full sun, growth is rapid (Clement 1982, Loureiro et al. 1979).

Uses and economic potential

Principal uses

The principal commercial use of the piquiá is its wood. In 1972, piquiá represented 1.1% (26,540 m^3) of the timber commercialized in Manaus [Volatron (1976), cited by Corrêa & Corrêa 1979]. Loureiro et al. (1979) describe the wood: heavy (0.8-0.85 g/cm^3); light whitish- to yellowish-beige color; rough grain because of compact interwoven fibers; medium texture, moderately easy to work and finish; rot resistent; and good quality for ship-building, civil construction, and general carpentry [although susceptible to warping if not dried correctly (Clement, personal observation)].

The principal popular use of the piquiá is its fruit. Henry Wickham commented on the avidity with which the Amerindians near the mouth of the Tapajós River collected these (Lane 1957). Throughout its distribution, the caboclos know the location of most trees and visit them frequently during harvest season.

The fruit are boiled for about one hour in salted (if available) water. The pericarp becomes loosened and is discarded. The hard, oily mesocarp is gnawed or cut-off with a knife and the endocarp and kernel are generally discarded because of the difficulty of removing the seed (nut) with primitive tools (Cavalcante 1988, FAO 1986). Aguiar et al. (1980) report 72% oil, 3% protein, 14% fiber and 11% other carbohydrates [dry weight basis (50% water)] in the mesocarp, which make it a good source of energy but poor in protein.

Secondary uses

The piquiá's major potential is as an oil crop, although this is currently only a very minor use. Lane (1957) explained that Henry Wickham [famous for having taken Pará rubber (*Hevea brasiliensis*) to British Asia] spent a significant part of his life trying to promote the development of piquiá as an oil crop in Asia.

Numerous authors have studied the oil of the mesocarp and the seed, but the piquiá never attracted the attention of the agricultural research community as a potential oil crop. Table 1 gives several physical-chemical analyses of these oils and Table 2 gives available fatty acid data.

Table 1. Physical-chemical characteristics of piquiá mesocarp and seed oils. LeCointe (1927) and Pesce (1941) analyzed samples from eastern Amazônia, while Georgi (1929) and Eckey (1954) analyzed samples from Malaysia, whose germplasm originated in eastern Amazônia.

characteristic	mesocarp			
	LeCointe 1927	Georgi 1929	Pesce 1941	Eckey 1954
Oil % (dry wt. basis)	76.8	72.3	67.0	72.3
Melting point (°C)	29.0	27-28	29.0	32.0
Saponification value	192.7	204.9	196.0	205.0
Iodine value	53.7	46.6	53.7	46.6
characteristic	**seed**			
	LeCointe 1927	Georgi 1929	Pesce 1941	Eckey 1954
Oil % (dry wt. basis)	70.4	61.4	70.4	61.4
Melting point (°C)	28-30	31-32	29-30	32.0
Saponification value	198-200	202.9	197.6	203.0
Iodine value	26.4	52.0	41.9	52.0

In general, the piquiá mesocarp and seed oils are very similar to oil palm (*Eleais guineensis*) mesocarp oil (Eckey 1954). Pesce (1941), however, recommended the piquiá seed oil for use in the cosmetic industry. If this oil turns out to be especially useful for this market it will command a higher price than the mesocarp oil, which can serve as a substitute for palm mesocarp oil, although this market is currently saturated.

Table 2. Fatty acid composition of piquiá mesocarp and seed oils. Both samples obtained from Malayan plantations, whose germplasm originated in eastern Amazônia.

Fatty acid	mesocarp		seed	
	Eckey 1954	Lane 1957	Eckey 1954	Lane 1957
Myristic	1.5	1.5	1.4	1.4
Palmitic	45.1	41.2	48.4	48.4
Stearic	1.8	0.8	0.9	0.9
Oleic	49.6	53.9	46.0	46.0
Linoleic	2.0	2.6	3.3	3.3

Just after World War I, the piquiá was finally taken to Malaya, where the Birkhall Estate plantation (Kuala Ketil, Kedah) was created (Lane 1957). Growth of the piquiá seedlings was rapid and they started to yield within 7 years. Yields, however, were lower than expected. The germplasm available was unselected and, obviously, from generally unproductive plants. This venture failed because of this and low world prices for vegetable oils. It was the only attempt ever made to plant piquiá commercially.

The seed (nut) is also a secondary product, mostly because it is so difficult to remove from the endocarp. It has a good flavor, slightly sweet, and could surely find a market. The souari nut market is currently small, but piquiá could enter this as an alternative source of this slightly better-known nut. It would not be difficult to develop a machine to break-off the endocarp spines and then crack the remaining endocarp to liberate the seed in good condition. Toasting or dehydration would be necessary to inactivate enzymes that would otherwise rancify the seed oils and causes free fatty acids to develop in storage (Lane 1957).

The pericarp is rich in tannins [34% dry wt. basis (Georgi 1929)] of the pyrogallol type. This type of tannin was imported into the US in the 1960's in large quantities for use in leather tanning (Thorenstensen 1969). Tannins of diverse types are also being used for making adhesives for use in the wood products industry; based on current available information, piquiá tannins have not yet been researched. Because of the large quantity of pericarp, this could become an important by-product of any piquiá processing project.

Loureiro et al. (1979) mention a popular medicinal use of a tea made from the bark for relieving fevers and as a diuretic, however, there is no supporting evidence to prove medicinal values.

Collection methods and yields

The fruit falls from the tree when ripe and needs only to be collected from the ground. Because it is rich in oils, it is necessary to collect and process the fruit as soon as possible to avoid rancidity. The Birkhall Estate (Malaya) developed a machine to remove the mesocarp from the endocarp (Lane 1957). Similar machinery is easily available today and could be modified to work at the community level.

Le Cointe (1947) reported a single tree producing 6,000 fruit near Belém, but yields are generally between 100 and 300 fruit on the nutrient-poor soils near Manaus. A yield projection may be made from the Manaus data, using the following assumptions: 100 trees per hectare; unselected germplasm; no agronomic treatments; 300 g per fruit; 50% humidity in fruit. This projection yields 3-9 tons of fresh fruit per hectare, from which can be obtained 90-270 kg of seeds (nuts) and 1-3 tons of fresh mesocarp/endocarp stone for direct human consumption, *or* 330-990 kg of tannins, 105-315 kg of mesocarp oil and 30-90 kg seed oil. Even if yields were twice as good in Malaya, it is easy to see why their effort failed: oil palm produced 2 tons per hectare of mesocarp oil in those days and produces 5 tons today (Hartley 1977). To be a valid option in either monoculture or agroforestry systems, these yields must be increased dramatically. Nonetheless, if Le Cointe's (1947) report is correct, it would not be difficult to find good germplasm and, combined with grafting and good agronomy, raise yields.

Propagation and cultivation methods

Pereira & Pedroso (1972b) obtained 60% germination in 25 weeks when the cleaned stone was sown at a depth of 10 cm in sandy loam, although CTM (1979) reports a similar percentage in only 3-4 months. At 30 weeks from sowing, the seedlings averaged 75 cm in height (Pereira & Pedroso 1972b).

Barbosa, Vastão & Clement (unpublished) found that piquiá grafts easily, especially with the modified forkert method as used in rubber. Grafting would make selection and propagation of elite material extremely easy and could significantly raise yields in plantations, either monoculture or agroforestry.

In silvicultural trials in full sun, growth is rapid: 1.0 m per year at 5 x 5 m in Manaus (Clement 1982) and 1.14 m in Pará (CTM 1979). CTM (1979) also report an average volumetric increment of 10.7 m^3 per hectare per year in Pará, although spacing is not given. For a hardwood species, these growth rates are extremely high. Clement (1982) reports slightly lower growth rates at 10 x 10 m after 5 years and attributes this to crown expansion, which seems to be the Malaysian experience also (Lane 1957).

Pereira & Pedroso (1972a) and CTM (1979) suggest that natural regeneration of piquiá is difficult, which means that seedlings grow slowly in the shade of the forest. If piquiá were to be used in a forest enrichment scheme, it would require relatively large gaps or east-west oriented roads in the forest to grow quickly enough to provide a return to the planter.

Given these rapid growth rates and the piquiá's popularity in most of Amazônia, it would appear feasible to include this species as a multipurpose agroforestry component or forest management component. All the research remains to be done, however.

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Brazil Nut

Charles R. Clement

Family: Lecythidaceae

Species: *Bertholletia excelsa* Humb. & Bonpl.

Synonyms: *B. nobilis* Miers.

Common names: Castanha do Pará, castanha do Brasil, castanheira (Brazil); castaña Brasileña, castaña (Bolivia, Peru); Brazil nut (English).

Related species

Bertholletia is a monospecific genus. The closely related genus *Lecythis* contains several edible species, notably the sapucaia or paradise nut group of species, the most widespread of which is *L. pisonis* = *L. usitata* (Mori & Prance 1990a,b).

Lecythis pisonis Cambess. The sapucaia is a large tree, although smaller in stature than the Brazil nut, and native to the *terra firma* (dry uplands) and *varzeas* (white water floodplain terraces) of Amazônia and the southeastern transition zones to cerrado. Sapucaia fruit vary enormously in size, from about the size of a Brazil nut to 5 or more times that, although they contain about the same number of seed (10-25) (Mori & Prance 1990a). Although the seeds are generally reputed to have a better flavor than those of the Brazil nut, sapucaia is rarely found at market because the fruit capsule opens while on the tree, providing a feast for bats (which also disperse the seeds) and parrots and monkeys (which are seed predators), but leaving little for humans to collect. On the *varzea* the trees are frequently planted around dwellings and, being relatively isolated from the forest, escape from predators and provide humans with a chance to collect the seed (B. Nelson, INPA, pers. com.). Attempts to graft sapucaia onto Brazil nut and vice versa have failed, but sapucaia on itself takes well and provides a method for the selection of superior types and their propagation.

Description and phenology

The following description is paraphrased from Mori & Prance (1990b) and FAO (1986).

Brazil nuts are large trees, frequently canopy emergents attaining 50 m in height, with straight cylindrical unbranched trunks attaining 1-2.5 m in diameter at breast height, clothed in a rough gray-brown bark with conspicuous longitudinal fissures. The openly branched crown occurs at or above canopy level and may have a diameter of 20-30 m in an emergent. The leaves are simple and alternately arranged on the branches. The leathery leaf blade is oblong, 17-36 cm long by 6-15 cm wide, smooth on both surfaces, with an entire leaf margin, attached to a 2-3.5 cm long petiole. The flowers are born on axillary or terminal spikes, with one or two orders of branching, although it is rare that more than one flower per inflorescence mature into fruit. The flowers are 3-4 cm in diameter when fully opened, with 6 petals, each 3 cm long, of a pale yellow to creamy white color. The creamy white to yellow androecium forms a hood over the ovary, with an internal depression containing a ring of stamens, numbering 80-135. The androecial hood must be forced open by the large bees that pollinate it; these are attracted by nectar. The Brazil nut is an allogamous species, possibly presenting very small levels of autogamy (O'Malley et al. 1988, Buckley et al. 1988). The fruit are large (10-12 cm in both diameters), round capsules, with a hard woody capsule wall, weighing 0.5-2.5 kg, containing 10-25 seed. The seed are about 3.5-5 cm long by 2 cm wide, with a distinctly triangular cross section. Each seed weighs 4-10 g. The Brazil nut is, in fact, a seed rather than a nut, but popular usage continues to prevail.

The Brazil nut flowers during the dry season. In eastern Amazônia flowering starts at the end of the rainy season (September) and extends to February, with the greatest intensity in October-December (Moritz 1984). In Manaus, flowering starts earlier because the dry season starts in June, and extends to August-September. The Brazil nut fruit takes 15 months to develop to maturity (Moritz 1984). Fruit fall, therefore, starts at the beginning of the rainy season. This is January to April in eastern Amazônia and November to March in the Manaus area.

Distribution, abundance and ecology

The Brazil nut may have originated in southeastern Amazônia (S. Mori, NYBG, pers. com.) from a *Lecythis*-like ancestor, similar to *L. lurida* (Miers) Mori (Mori & Prance 1990b). The seed is thought to be dispersed principally by agoutis (*Dasyprocta* sp.), small forest rodents, which are the only animals known to open the Brazil nut fruit and extract the seed. Some of the seed are consumed immediately, others are stored for later consumption or are forgotten and germinate (Mori & Prance 1990b). This seed dispersal mechanism must have severely limited the Brazil nut's original range, because viable seed would have great difficulty in crossing major river tributaries.

The arrival of humans in Amazônia probably changed the Brazil nut's distribution dramatically. Its evident food value, due to oils and protein, and flavor must have made it a preferred extractivist resource very early in the human occupation of Amazônia. Later, seed and perhaps seedlings were planted by Amerindians into suitable locations and into their developing agroecosystems. This practice continues among the Amerindians in southeastern Amazônia today (Posey 1985) and elsewhere in Amazônia among Amerindians, *caboclos* (mixed blood long-term natives) and modern colonists. Muller et al. (1980) suggest that most "natural" stands of the Brazil nut were created through Amerindian intervention. Agouti dispersal may then have completed the species' occupation of a new area.

Today the Brazil nut is found in most of Amazônia, the adjacent Guaiana highlands and forested lowlands, and the upper Orinoco River basin. In Amazônia it is found in Brazil, French Guiana, Suriname, Guyana, southern Venezuela, southeastern Colombia, eastern Peru and northern Bolivia. There are some curious irregularities in its distribution that give support to Muller et al.'s (1980) hypothesis of Amerindian intervention as a means of distribution. The area around Manaus, although well populated at contact, was free of the Brazil nut until it was planted in historic times (Nelson et al. 1985). The Juruá River basin also appears to have had no Amerindian or agouti introduced Brazil nut until recently (B. Nelson, INPA, pers. com.). One can only assume that the Amerindian groups that occupied these areas did not consider the Brazil nut to be as delectable as other groups obviously did.

The Brazil nut occurs as a rare emergent or upper canopy component of the *terra firma* forest throughout much of this region, at an abundance of 1 tree or less per hectare, although occasionally occurring in stands. This suggests that Brazil nuts are gap dependent (Mori & Prance 1990b), which means that they only attain reproductive size when growing in a light gap created in the forest by the fall of a large tree or other disturbance. This type of abundance pattern is also compatible with agouti dispersal.

In numerous areas, however, the Brazil nut is found in *castanhais* (Brazil) or *manchales* (Peru). These are areas of high abundance, frequently attaining 15-20 mature trees/ha. This type of abundance pattern also supports Muller et al.'s (1980) hypothesis of Amerindian intervention in Brazil nut population dynamics and distribution. These *castanhais* frequently cover 5-10 ha or more and are separated from one another by 0.5-1 km or more, suggestive of the pattern of Amerindian exploitation of the forest environment with widely spaced swidden plots. In some areas of SE Pará and SE Acre states the *castanhais* may occupy 50-100 ha areas. One of these large *castanhais* can be seen in Acre in a degrading pasture; unfortunately most of the trees had been killed by the periodic fires used to control weeds and enrich the soil in the pasture. This practice, while technically legal, is severely eroding the genetic resources of the species (Clement & Chavez 1983).

The Brazil nut is found principally on the nutrient-poor, well-structured and well-drained oxisols and ultisols of the *terra firma*. In eastern Amazônia especially, its taproot is known to penetrate 5-10 m into the soil and may penetrate much deeper (C.H. Muller, CPATU, pers. com.). It is not found in areas with poor drainage nor on excessively compacted soils.

Diniz & Bastos (1974) report that the Brazil nut is found in areas with a mean annual rainfall of 1400-2800 mm, a mean annual temperature of 24-27°C and a mean annual relative humidity of 79-86%. These ranges cover the "Ami", "Afi" and "Awi" climate regimes of Köppen, giving it an extremely wide climatic tolerance. In eastern Amazônia, the mean rainfall and relative humidity are at or near the lower limits of the ranges mentioned, and the species is subjected to 2-7 months of water deficit (dry season = less than 100 mm rainfall/month). This climate regime is "Ami" in Köppen's scheme. As a consequence, Muller (1981) suggested that the Brazil nut requires two to five months of low rainfall to develop properly.

Uses and economic potential

Principal use

Brazil nuts are consumed raw, roasted, salted, in ice creams or as prepared confectionery items (Mori & Prance 1990b, Rosengarten 1984). They are an important ingredient in shelled nut mixtures (Rosengarten 1984). Woodroof (1979) presents 50 recipes for the Brazil nut, mostly for confectionery uses. Clark & Nursten (1976) analyzed the seed flavor components.

Table 1 presents the proximal composition of the Brazil nut kernel. Mori & Prance (1990b) cite Zucas et al. (1975) as reporting that Brazil nut protein contains all the essential amino acids, although without reporting which of may fall below FAO/WHO (1973) limits. They do report that Brazil nut protein has a lower nutritional value than casein, suggesting that some of the essential amino acids are limited. Table 2 presents the mineral composition and vitamin content of Brazil nut kernels (USDA 1975, cited by Rosengarten 1984).

Table 1. Proximal composition of the Brazil nut kernel.

Component	Sanchez (1973)	USDA (1975)	Adams (1975)
Water[1]	4.0	4.6	2.0
Protein[2]	17.0	15.0	16.3
Fats[2]	65.0	70.1	68.3
N-Free extract[2]	10.1	8.2	6.6[4]
Fiber[2]	0.9	3.2	^
Ash[2]	3.0	3.5	3.6
Energy[3]	-	654	694

1. % fresh weight; 2. % dry weight; 3. calories/100 g fresh weight; 4. N-free extract and fiber combined.

Table 2. Mineral composition (A) and vitamin content (B) of Brazil nut kernels (USDA 1975, cited by Rosengarten 1984).

A.	Phosphorus[1]	Potassium	Iron	Sodium
	693	715	3.4	1.0
B.	Vitamin A[2]	Thiamine[3]	Riboflavin	Niacin
	trace	0.96	0.12	1.6

1. minerals in mg; 2. Vitamin A in Intern'l Units; 3. other vitamins in mg

The nuts require considerable care in handling, because they are highly susceptible to bruising, molding and insect infestations (Woodroof 1979). Because of this, a relatively high proportion of nuts collected are later rejected by processing plants, which have traditionally been located in the major urban centers, hundreds of kilometers from the collection centers. As a result of molding, they may accumulate aflotoxins, which can cause the rejection of whole batches of nuts exported in-shell (FAO 1986). Because the nuts are very rich in oils, they rancify easily and may absorb foreign flavors, losing their own (Woodroof 1979).

Over the last decade, Brazil nut production has hovered around the 40,000 MT level, but could expanded easily if demand expanded. This additional production could come from the thousands of forest trees that are currently not harvested because of the low prices paid to most collectors. The low prices are due partially to slack international demand and partially to the number of middlemen involved in getting the nuts from the forest to the processing plants. The extractivist reserves now being set up in Acre, Pará and Rondônia are trying to organize local processing and cooperative commercialization so that a greater proportion of the end value of the nuts can be paid to the collectors, hopefully encouraging greater harvests while improving the collector incomes. Cultural Survival's Rainforest Marketing Project is collaborating with the extractivists in Acre on this attempt.

Secondary uses

Brazil nut is considered to be amongst the finest timbers of Amazônia, as it has a straight grain, is easy to work, takes a finish readily, has a pleasing appearance and is very durable (Loureiro et al. 1979). Although the felling of Brazil nut is prohibited by law in Brazil, there is thought to be a considerable black market for its wood (Mori & Prance 1990b). SUDAM (1979) concluded that it has superior silvicultural characteristics, including fast growth (more than 1 m/yr in the first decade), straight trunk, tolerance or resistance to pests and diseases in plantation. G. Hartshorn (WWF-US, pers. com.) has observed that Brazil nut can even be abandoned in second growth and still give excellent growth and trunk shape. This suggests that Brazil nut could be used to help restore degraded sites (100,000 km^2 in Amazônia) as a multipurpose species, yielding nuts after 15-20 years and timber after 50-100.

As with most nuts, the Brazil nut is rich in oils, variously reported at 65-70% of seed dry weight (Pesce 1985, Woodroof 1979). This oil is rich in unsaturated fatty acids (75%) and may be attractive for various culinary uses (Woodroof 1979). Table 3 presents the fatty acid composition of the kernel fat (Woodroof 1979), with the percentage of insaturation, a highly relevant summation in modern dietary theory. Assunção et al. (1984) report on the stability of this oil. Nuts that are rejected for export could be pressed for oil, if a market is found. This would encourage quality control, now rather precarious in some processing plants, and increase the value of the nuts to the collectors.

One of the reasons frequently cited for conserving the Amazonian rainforest is to conserve the genes that make up its enormous specific and intraspecific diversity, since these are the raw materials for the biotechnology revolution now underway in the developed world. Brazil nut is an example of how this idea works.

Table 3. Fatty acid composition (%) of pressure extracted Brazil nut kernel fat (Adams 1975, cited by Woodroof 1979).

C14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	%IS
0.05	13.85	0.45	10.25	30.50	44.90	-	75.85
0.48	13.74	-	5.45	42.79	26.54	-	69.33

C14:0 = myristic; C16:0 = palmitic; C16:1 = palmitoleic; C18:0 = stearic; C18:1 = oleic; C18:2 = linoleic; C18:3 = linolenic; %IS = % insaturation = C16:1 + C18:1 + C18:2 + C18:3.

The Brazil nut is rich in sulfur amino acids (methionine, cysteine), which are deficient in the seed of the common bean (*Phaseolus vulgaris*), for example. Since the common bean is a major source of protein in the Third World, two laboratories (one in California, one in Brasilia) are racing to put Brazil nut amino acids into the bean (Gander 1986). The relevant gene has been isolated, inserted into the bean genome, and found to be expressed in bean callous tissue. Both laboratories are having some trouble regenerating the transgenic plants from callous and must then determine that the amino acid genes are expressed in the seed (E. Gander, CENARGEN, pers. com.). When the transgenic plants are finally grown out, they must then be bred conventionally to obtain cultivars suitable for distribution to farmers. Once this process is completed, the common bean will have nutritional characteristics much superior to those it now has and will become even more important a staple than it currently is. The steps followed in this process to date can be traced in Altenbach et al. (1984), Ampe et al. (1986), Castro et al. (1987), Guerche et al. (1990), Kamiya et al. (1983), Plietz et al. (1988), Sun et al. (1987ab).

Historical production data

Brazil nut entered world commerce in the late 18th century, introduced by Dutch traders during the period that they attempted to colonize eastern Amazônia and Maranhão (Mori & Prance 1990b). A prosperous trade developed soon after Brazil opened its ports to world trade in the late 19th century and Brazil nut has been an important item of trade since that period (ibid.). Before this, it had been an extremely important subsistence product for the Amerindians and later the colonists.

Figure 1 presents historical production data (IBGE, cited by Mori & Prance 1990b, plus more recent data). The historical production mean is close to 40,000 tons but could be much larger if there was sufficient demand (note 1970 production of 104,000 tons).

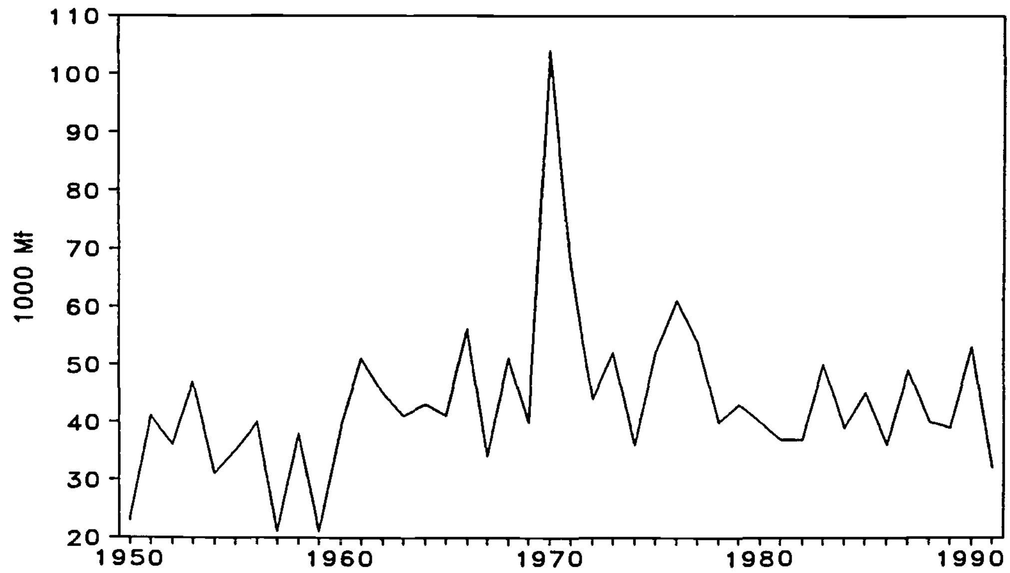

Figure 1. Four decades of Brazil nut production (IBGE 1951-1991).

Figure 2 presents export data for the decade 1975-84 (CACEX 1976-85). Most exports during the period were in-shell (either raw or partially dehydrated), which results in a lower unit value for the product. The FOB value of shelled Brazil nut is generally at least twice that of the in-shell nut. Rosengarten (1984) noted that both in-shell and shelled nuts are now being packaged much more efficiently (see below). In fact, in-shell raw nuts disappeared from the CACEX registry during 1982-84, suggesting that at least that part of the in-shell exports is now being partially processed.

Miscellaneous information

It is frequently commented that Brazil nuts can cause hair loss if consumed in large quantities. This has, in fact, occurred, and is due to high concentrations of selenium. Thorn et al. (1978) report on the presence of selenium in Brazil nuts in England. Chansler et al. (1986) and Palmer et al. (1982) report on experimentally induced selenium toxicity in laboratory animals.

The reason that Brazil nut concentrates selenium is probably that this element is very similar chemically to sulfur, an essential nutrient in seed protein (see section 5.2). Sulfur is frequently deficient in Amazonian soils, especially after decades or centuries of Brazil nut harvesting and export from the *castanhais*. If the soil contains significant amounts of selenium, this is used by the plant instead of sulfur. If selenium is not present, there is no problem, other than reduced yields, as sulfur becomes limiting.

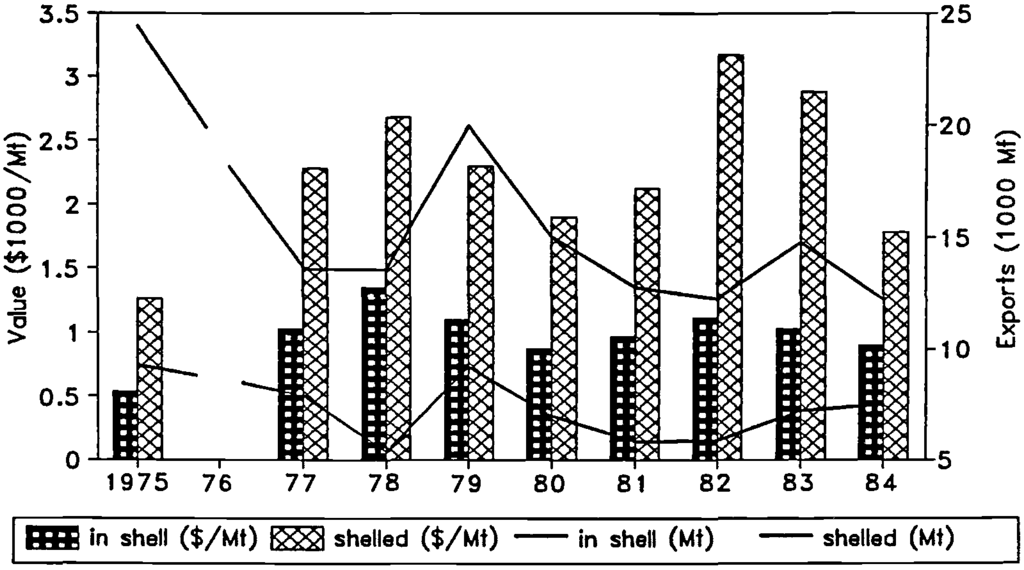

Figure 2. Brazil nut exports of shelled and in-shell nuts (lines) with their respective FOB values (bars).

A simple solution to the selenium problem is to fertilize the affected area with sulfur. This is commonly practiced by the *caboclos* along the Rio Madeira to improve yields (V. Cruz Alves, INPA, pers. com.), although there are no reports of selenium problems there. The *caboclos* use pharmaceutical sulfur, the only form available to them, and apply it in the following manner: they drill a small hole (approximately 1 cm in diameter) in the bark of the tree as far as the cambium layer; they then place 1-2 grams of sulfur into this hole; the hole is then closed with pitch or jatobá (*Hymenaea courbaril*) resin. If the sulfur is applied after the flowering season, the following flowering season will result in significantly improved yields. This *caboclo* practice pointed to a solution to the selenium and low yield problems in older *castanhais* throughout Amazônia, but no experimental work has been done to prove the validity of this theory.

Collection methods and yields

Rosengarten (1984) reports that a mature tree can yield 100-225 kg of unshelled nuts in a good year. The lower figure is probably close to an average yield on good soils, with adequate rainfall and low competition from other trees. No detailed experimental yield results exist. Based on Rosengarten's report and a monoculture plantation density of 100 seedling trees/ha, this yield is equivalent to 10 MT/ha/yr. It is emphasized that this is only a projection to allow comparison with other species. Rosengarten (1984) also points out that a good year is generally followed by a poor one, as the tree uses most of its accumulated reserves and takes more than a year to accumulate more. Alternate bearing is common in undomesticated species and will be one of the first traits modified by selection in the on-going Brazil nut improvement program executed by EMBRAPA's Agricultural Research Center for the Humid Tropics (CPATU).

Mori & Prance (1990b), Moritz & Ludders (1985), Rosengarten (1984) and Woodroof (1979) discuss collection and processing of the Brazil nut and describe the life and hard times of the *castanheiros* (the Brazil nut harvesters), so only a brief outline will be presented here.

The fruits are collected from the ground under wild trees during the rainy season, generally in the morning. Because of competition from agoutis, insects and fungus, the *castanheiros* visit the trees regularly. A good day of collecting will yield 700-800 fruit, containing 700-20,000 seed (the last figure is highly unlikely, however, and was derived from the multiplication of the highest collection figure by the highest seed number figure given previously). Collecting is a dangerous business because the heavy fruit fall from the 40-50 m high canopy at a great velocity and can cause serious injury or even death if they strike a person.

In the afternoon the fruit are opened, either with a machete or with an axe, and the seed removed. These are generally washed immediately, left to dry for a few hours and stored out of the rain. A conscientious *castanheiro* will sun dry his seeds for a few days and store them in a dry environment, although, with a relative humidity of 80% during the rainy season, this is still quite humid. This lack of adequate storage conditions in the *castanhal* is the major reason that seed quality is not very high when the *castanheiro* finally gets his harvest to market.

C.H. Muller (CPATU, pers. com.) has worked on solar sun driers and plastic bagging to store seed in the interior. While he has had moderate results, the realities of *castanheiro* economics have relegated these ideas to the library. The beginning of a cooperative enterprise in Acre and other Brazil nut regions could change this and allow the *castanheiros* to maintain quality and obtain a better price for their harvest.

Most *castanheiros* sell their harvest to intermediaries who cruise the interior during the harvest season. These merchants then sell to others or directly to a processing plant, generally located in a major urban center. Traditionally Manaus and Belém have been the major centers, although Rio Branco (Acre) has become important recently.

At the processing plant, the nuts are sorted, first by floating (as damaged and diseased nuts will generally float, while healthy nuts will sink), then by visual inspection. They may be graded at this stage or after shelling. If the nuts are to be shelled, they will be soaked for 8-24 hours in room temperature water. They are then dried, to shrink the kernel from the shell, and cracked open with a hand press. The shelled nuts are then graded by size and quality (tiny, midget, medium, large, chipped, broken).

Modern packaging involves placing graded, high-quality, shelled nuts into laminated plastic bags, which are vacuum-sealed (Rosengarten 1984). Nitrogen gas is then introduced into the package to further conserve quality. Bag sizes vary from 20 to 50 kg. These can be stored and shipped conveniently, although most product is shipped shortly after packaging and inventories are kept low.

With the advent of a cooperative system in Acre and elsewhere, it is possible to process and package Brazil nut close to the harvest area. This is also a part of Cultural Survival's Rainforest Marketing Project and is the best way to add value for forest-extracted Brazil nuts. The alternative is plantations, which are already being installed in several areas. To support the rainforest peoples and conserve significant areas of tropical forest, however, an extractivist system of forest management appears to be feasible if it is combined with on-site processing and direct marketing. These two factors eliminate most of the middlemen currently involved and allow the *castanheiros* to receive a greater percentage of the final value of the nuts. Without this, the *castanheiro* has little or no incentive to expand, or sometimes even to continue, harvesting. When this happens the fate of the forest is left to the next colonist, which generally means chain saws and fire.

Propagation and cultivation methods

C.H. Muller and his colleagues at CPATU, in Belém, have executed the most complete research project undertaken with Brazil nut to date. They have developed seed germination techniques, grafting practices, field establishment and density recommendations; collected elite germplasm for breeding; and started a selection program. The following discussion is based upon their work, as outlined by Mori & Prance (1990b) and discussions with C.H. Muller.

The seed of the Brazil nut may take 12-36 months to germinate and even then only attain 60% germination. Figueiredo et al. (1980) and Frazão et al. (1984) used physical and chemical methods to scarify the seed and enhance germination. Some of these worked, but not well. Finally they simply removed the shell (after soaking for 24 hours in water), treated the seed with fungicide for 60-90 minutes and sowed the seed in sand or sawdust germination beds. Germination starts within one month and after 6 months attains 80%.

Because the Brazil nut seedling has a vigorous taproot, the seedling must be transplanted early and carefully to a deep plastic nursery bag. Unfortunately, root bound plants are still common because the taproot will bottom-out and start to curve around the bag. An untested method is to transplant the seedling into a screen bottomed or funnel-shaped tube (dibble tubes) raised above ground level. When the taproot reaches the bottom of the tube, it would be "air-pruned" and stop growing. If this air-pruned root is not damaged in any other way, it will start growing again when planted out. This idea is currently expanding rapidly in North American horticultural circles and can be executed with extremely rudimentary materials. With locally available materials it could be used anywhere in Amazônia.

The young seedling should be hardened-off and planted out when about 40-60 cm tall. A planting pit about 40 cm on each side, containing a mix of surface soil, well-rotted manure and 100 g of treble super phosphate, should be prepared at the end of the dry season and the seedling planted out at the beginning of the rainy season.

Because the seedling should be 2 cm thick at 20 cm above ground level to graft, most grafting is done in the field after the seedlings are established. If the air-pruning technique is developed, it may be possible to grow seedlings large enough in the nursery to allow grafting. In either case, patch buds from orthotropic branches should be selected from highly productive trees with desirable characteristics. The Forkert grafting method has given the best results. If grafted plants are to be used, it is also worthwhile to obtain seed for root stock from highly productive trees that appear never to have been fertilized and, if possible, are found growing in less than favorable environments. These kinds of plants are probably very efficient at scavenging nutrients from Amazônia's nutrient-poor ecosystem. A grafted plant may start fruiting after only 8-10 years in the field, versus 15-20 for seedling plants. This differential precocity suggests that future plantings be directed towards grafted plants, although this will require more skills on the part of the farmer, a large number of high quality clones to choose from (6 at a minimum) and more information on the biology and reproduction of clonal plantings.

A seedling monoculture density of 65-100 trees/ha (10 x 15 m or 10 x 10 m) appears to be suitable, although there are no experimental results yet; grafted trees may do well at higher densities (8 x 10 m or even 8 x 8 m). Muller (1981) recommends 10 x 15 m for mixed cropping schemes and 15 x 20 and 20 x 20 m for establishment in pastures. Posey (1985) reports on Kayapó agroforestry plantings but does not give densities. Observed densities in "natural" castanhais, however, suggest that only 15-20 trees/ha are used. More research on planting in mixed cropping, agroforestry and forest-enrichment environments is required. G. Hartshorn's (WWF-US, pers. com.) comments on the Brazil nut with regards to surviving and growing well in abandoned secondary forest, however, suggest that this species may be easy to manage in alternative agricultural systems.

Padoch et al. (1987) report that the Brazil nut is being planted in a market-oriented agroforestry system near Iquitos, Peru. Although Brazil nut is not the major species there, this does show that Amazônian agroforest farmers, without government-sponsored extension support, are following the Amerindian traditions. This is obviously because there is money to be made.

The future of Brazil nut as a crop can be three-fold: as an extractivist product; as an agroforestry/forest management component; and as a modern monoculture plantation crop. As already mentioned, the first option will help conserve tropical forests and the cultures of numerous tropical-forest peoples, both Amerindian and *caboclo*. The second option is the preferred route to enrich already deforested areas with Brazil nut and provide for the long-term capitalization of the Amazonian farmer. The final option is for the already capitalized investor and may become limited by pests and diseases (Andrade & Cardoso 1984, Freire & Ponte 1976) in the future.

Research contacts

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Pendula Nut

Paulo de T. B. Sampaio

Family: Chrysobalanaceae

Species: *Couepia longipendula* Pilger

Common names: Castanha de galinha, castanha pêndula (Loureiro et al. 1979), pendula nut (proposed English name).

Related species

Couepia edulis Prance - The cutia nut is a large tree (20-35 m in height by up to 1 m DBH) found in the *terra firma* (non-flooded upland) forests throughout most of Amazônia; it is occasionally cultivated, more commonly protected when a swidden is opened. The fruit resembles that of the pendula nut (see below) but has a hard woody epicarp, extremely difficult to crack open, containing a slightly larger nut. It fruits from November to May in the middle Solimões River basin. The nut is very popular in the interior of Amazônia, consumed either raw or toasted. The tree is reputed to bear more heavily than the pendula nut (Cavalcante 1988). The nut contains 73% oil.

Couepia bracteosa Benth - The pajurá is a medium tree (10-25 m in height by up to 0.5 m DBH) of the *terra firma* forests of central Amazônia to the Guianas; it was frequently cultivated in the Manaus area, commonly protected when a swidden was opened, but has slowly disappeared from the markets during the last decade or so. Unlike the two nut species, the pajurá fruit is a large drupe (to 15 cm long), with a thick fleshy, granular textured mesocarp, that has an attractive aroma and taste when ripe. Fruiting occurs from January to March in the Manaus region. The fruit falls from the tree before it is ripe for consumption, which occurs two to four days later, at which point it is sweet and its flavor and aroma are at a maximum. It maintains this consumption point for only one day or so, however, after which it quickly loses its edible qualities. Although Cavalcante (1988) claims that the mesocarp is the only edible part, and in fact it is the only part consumed near Manaus, it would be surprising if its nut were inedible.

Description and phenology

The pendula nut is a medium to large tree, attaining 30 m in height and 50 cm in diameter at breast height (DBH), with a thin bark (0.5 cm) that has a blood-red inner layer, supporting an abundantly branched crown. The leaves are simple, alternate, ovoid-oblong, 8-18 cm in length by 4-7 cm in width, semi-leathery in texture, smooth and lustrous on the upper face, with a pointed tip, all on a short petiole. The inflorescence is characteristic, with a long (up to 100 cm) filiform peduncle, supporting several white-petaled, aromatic flowers. The fruit is an egg-shaped drupe, 4-6 cm in length by 4 cm in width, with a thin epicarp and a fibrous, woody mesocarp. Each fruit contains one large nut, with a light green endosperm and a sweet, mild flavor, measuring 3-5 cm in length by 2-3 cm in width (Cavalcante 1988, Loureiro et al. 1979, Rodrigues 1972).

Around Manaus, the pendula nut fruits during the rainy season, from January to March (Cavalcante 1988). Although several trees are planted at INPA, its flowering season has not been published.

Distribution, abundance and ecology

The pendula nut occurs throughout central and western Amazônia and the western Guiana shield. In Brazil it is found in western Pará, all of Amazonas, and the southern part of Roraima. It is found in the Colombian and Peruvian Amazon as far as the foothills of the Andes, and so probably also occurs in Ecuador. It is not mentioned by RADAMBRASIL (1974) in Acre or Rondônia, Brazil.

To the east of Manaus, RADAMBRASIL (1974) reports an abundance of 0.036 trees/ha in the low plateaus south of Santarém, Pará. Along the Trombetas River, near the frontier between Pará and Amazonas states, INPA's Dept. Silvicultura Tropical (1982) reports 3 trees/ha with diameter at breast height (DBH) ≥ 25 cm.

Rodrigues (1972) states that the pendula nut is common in the forests near Manaus. RADAMBRASIL (1974) reports 0.112 trees/ha in dense forest north of, and 0.013 trees/ha in secondary/primary forest transition areas south of, the Negro River near Manaus. At INPA's A. Ducke Forest Reserve, Marvalhas et al. (1965) reported 7 trees/ha with DBH ≥ 15 cm, and 4 trees/ha with DBH ≥ 25 cm, while Alencar (1986) reports an average of 6.8 trees/ha. At INPA's Tropical Silviculture Experiment Station (EEST), in SUFRAMA's Agricultural District, INPA (1981) reports only 0.34 trees/ha with DBH ≥ 25 cm along the ZF-2, while Jardim (1985) found 1.2 trees/ha with DBH ≥ 20 cm nearby. South of the EEST, INPA-DST (1987) reports an abundance of 0.16 trees/ha at km 52 BR-174, while Proflama (1972) reports 1.4 trees/ha in other parts of the SUFRAMA Agricultural District.

West of Manaus, along the *varzeas* (the annually flooded white water river terraces) of the Purus River, Atlantic Veneer da Amazônia (1982) reports 0.06 trees/ha with DBH ≥ 25 cm. Slightly further west, at the Forest Research Center (CPF) of the Federal University of Parana (UFPr), in the Polo Juruá-Solimões, FUPEF (1981) reports 1.44 trees/ha with DBH ≥ 50 cm and 0.94 trees/ha with DBH ≤ 50 cm on the *terra firma*. RADAMBRASIL (1974) reported 0.098 trees/ha in "open" *terra firma* forests east of the Juruá River and 0.132 trees/ha in the same formation between the Juruá and the Javarí Rivers. Along the Japurá River, RADAMBRASIL (1975) reports 0.4 trees/ha, while along the Iça River they report 0.115 trees/ha, again on the *terra firma*.

Rodrigues (1972) states that the pendula nut is common in the forests of the upper Negro River, especially above the mouth of the Curicuriari River, just below São Gabriel da Cachoeira, Amazonas.

It is most common in *terra firma* forests in central western Amazônia, preferring clay oxisols, where the greatest tree sizes are attained, but growing moderately well on sandy ultisols also. Near Manaus, Altman & Souto (1965) report that it can attain the upper canopy when on clay oxisols, even being a dominant species there, but on sandy ultisols it is a component of the understory. It can occasionally be found in *varzea* areas.

Uses and economic potential

Principal use

Throughout its distribution, the pendula nut is a popular product during its fruiting season as a fresh or toasted nut. Although popular, it rarely is found in the market and when found is only found in shell, never prepared. Its mild flavored, slightly sweet nut is very agreeable fresh or toasted, frequently comparing favorably with the Brazil nut (*Bertholletia excelsa*).

Secondary uses

The wood of this species is heavy (0.9-1.0 g/cm^3), with a dark brown, nearly black heartwood and a clear beige outer layer, both having an irregular grain, medium texture, indistinct odor and flavor. The wood is difficult to work; nonetheless, it is used in civil and naval construction (Loureiro et al. 1979).

The seed contains a clear yellow-green oil (70-80% of dry weight), with semi-drying properties, and which is very susceptible to oxidation (rancifying easily) (Loureiro et al. 1979, Rodrigues 1972). It is occasionally extracted and used in human diets. Rodrigues (1972) presents some of the physical-chemical properties of this oil (Table 1).

The seed cake, after oil extraction, has excellent flavor, slightly sweet. It is high in protein (32.5% of dry weight), fiber (10.6%) and ash (8.3%), and is therefore an excellent potential addition to the human diet. Both whole ground nuts or seed cake are used to make regional pastries, especially *paçoca* (mixed with sugar and baked) and *bejú* (mixed with sugar, kneaded and baked as a cake) (Cavalcante 1988, Loureiro et al. 1979, Rodrigues 1972).

Table 1. Physical-chemical characteristics of pendula nut oil (Rodrigues 1972).

Density at 20°C	0.9178	Acidity value	6.9%
Refraction index	1.42	Ester value	185.5
Point of fusion	16.5°C	Sabonification	192.4
Point of solidification	11°C	Iodine value	71.1
		Insabonifables	1.8%

Collection methods and yields

The ripe fruit falls from the tree and is collected from the ground. This should be done frequently during the harvest season, as the nuts are very popular with forest rodents and wild pigs. They also rancify rapidly (Rodrigues 1972). The nuts are easily extracted from the mesocarp with a knife, as the fibrous mesocarp allows relatively easy penetration.

No yield data has been obtained from either forest or plantation trees grown in full sun. The trees start to fruit within 5 years after planting out into full sun and fruit annually with little apparent year-to-year variation at INPA's A. Ducke Forest Reserve.

Propagation and cultivation methods

Fresh seeds from trees at INPA's A. Ducke Forest Reserve have a mean germination of 83.5% [although Rodrigues (1972) reported 90%], initiating germination within 7-15 days after sowing and finishing 15-21 days thereafter (Magalhães et al. 1979). Germination is of the epigeal type (Rodrigues 1972).

Seeds lose viability rapidly (Alencar & Magalhães 1979): 1 month after harvest - 78% germination; 2 months - 10%; 3 months - 0%.

Seedlings of the pendula nut can be obtained by direct sowing of seed into plastic bags or sowing into seed beds with later transplant to plastic bags. Direct sowing into the field is not recommended, however, because seed predators avidly hunt for the seeds. Alencar & Magalhaes (1979) report that seedlings grown in 50% shade attain 60 cm in height and 6 mm in diameter at soil level after 5 months. Grafting has not yet been tried.

Planted in full sun, the pendula nut grows rapidly. At open spacing (6 x 6 m) it forms a very nice horticultural tree, with a low spreading crown, easily harvested. At silvicultural densities (eg 3 x 4 m or tighter) it attains 12 m in height and 20 cm DBH by 8 years on a clay oxisol at INPA's EEST. Its precocity and rapid growth recommend it for agroforestry (S.F. Paitán, Univ. Amazônia Peruana, Iquitos, pers. com.) where experimentation is starting.

Research contacts

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Bacuri

Charles R. Clement

Family: Guttiferae

Species: *Platonia insignis* Martius

Synonym: *P. esculenta* (Arruda de Camara) Rickett & Stafleu

Common names: Bacuri, bacury, bacuryuba, ibacopary, ibacury, pacoury, grande pacuru, ubacury (Brazil); bacury-guazú (Paraguay); pakooru (Guyana); pacouri (French Guiana).

Related species

Bacuri is the only species in its genus. A closely related genus, *Rheedia*, has several interestingly flavored fruits that have the same general fruit structure, although they are always smaller. See FAO (1986) for details.

Description and phenology

The mature bacuri tree may attain 20+ m in height and 50 cm in diameter at breast height and is an element of the mid-to-upper canopy in these transitional forests. The cultivated plant, grown in more open conditions, may attain 15-20 m in height and have a crown of 10-15 m in diameter. In forest individuals there is apparent apical dominance, although this is not always apparent in field-grown plants. Branches arise at an angle of 50-60° from the trunk. The short-petioled, smooth, leathery leaves mature to a dark green, attaining 8-14 cm in length by 4-8 cm in width.

The bisexual, solitary flowers are born terminally on young branches just after leaf fall. They have 5 sepals and 5 pale rose-colored petals; the numerous stamens are fused into 5 bundles; the superior ovary has 5 locules. The fruit are ovoid to subglobose, 7-15 cm long and 5-15 cm in diameter, weighing 200-1000 g. The rind is thick (1-3 cm), pale yellow to brownish-yellow in color, tough and somewhat elastic, and exudes a yellow latex when bruised. The pulp is creamy white, somewhat mucilaginous, fibrous and juicy and envelopes the 1-5, generally 3 seeds. When a seed does not develop, the pulp forms a parthenocarpic segment that is greatly appreciated by consumers.

The large seeds are oblong-ovoid, somewhat angular, 4-6 cm long and 2-3 cm in diameter.

The bacuri starts flowering at the beginning of the dry season (June to September in Belém). Harvest season extends from December to May in Belém, with greatest intensity in February and March.

Distribution, abundance and ecology

The bacuri's natural distribution is along the forest-savanna transition zone south of the Amazon forest, from the Atlantic to Paraguay (Cavalcante 1988), occurring in the Brazilian states of Pará, parts of Maranhão, Piauí, Goiás and Mato Grosso (Cavalcante 1988, FAO 1986); it is reputed to occur throughout the Amazon basin (León 1987, Loureiro et al. 1979), although Huber (1904) doubts that it occurs in western Amazonas state and western Amazônia in general. It also occurs in the Guianas (FAO 1986, Loureiro et al. 1979). The bacuri is probably indigenous to eastern and southeastern Amazônia (FAO 1986).

The bacuri occurs at low frequency (0.5-1.5 trees/ha) throughout the transition zone (FAO 1986) and at an even lower frequency around Manaus, where it is used for its wood rather than its fruit. There are occasional stands of 50-100 trees/ha in eastern and south-eastern Amazônia (FAO 1986). These bacuri stands are probably due to Amerindian or caboclo management.

The bacuri is common on upland soils and appears to do better on poor soils than most other regional fruit species (FAO 1986), although it responds very well on good soils. Cavalcante (1988) states, however, that one area of great abundance is on the poorly drained soils of Marajó Island and other parts of the Amazon River estuary. The species requires full sun for good growth and yield (Calzavara 1970). Throughout its distribution the dry season is moderate to severe (2-8 months) with 1,300-3,100 mm during the rainy season (Diniz et al. 1984, FAO 1986).

Uses and economic potential

The bacuri is one of the most popular fruits on the Belém market. During the last decade several small industries in Belém have started to produce canned parthenocarpic sections, fruit puree, jams and ice creams. Some of these are now being shipped to southern Brazil but there doesn't appear to be an export market yet (Clement & Venturieri 1990).

Principal use

The bacuri pulp has only been studied as *materia prima* for nectar, although it is also used in ice creams, jellies, puree and canned parthenocarpic sections (Clement & Venturieri 1990). Corrêa (1926) states that fresh pulp is difficult to digest, but Cavalcante (1988) states that it is avidly consumed fresh during the season, especially the parthenocarpic sections.

Barbosa et al. (1979) present one fruit component analysis, based on small fruit (213 g average) from the Belém market. They found only 12% pulp, 18% seed and the rest exocarp. Cruz et al. (1984) found similar proportions in fruit from Maranhao, although Calzavara (1970) reports 10%, 26%, 64% respectively. Barbosa et alii's physical-chemical analysis of the pulp is presented in Table 1. Paula (1945) found 5% pectin, however, and suggested that this would be very interesting in the food industry.

Table 1. Physical-chemical analysis of bacuri pulp (Barbosa et al. 1979).

Acidity	1.6	Amino acids (mg % N)	38.8
Brix	16.4	Pulp (%) 3,000 rpm/10 min.	100.0
pH	3.5	Reducing sugars (%)	3.98
Total solids (%)	19.3	Ether extract (%)	0.6
Pectin (%)	0.12	Fixed mineral residue (%)	0.4
Volatils (%)	80.8	Phosphorous (% P_2O_5)	0.13
		Calcium (% CaO)	0.31

Barbosa et al. (1979) prepared a nectar of uncertain composition and pasteurized it at 90°C for 30 seconds, sealed it in 250 ml cans with internal varnish, let it settle for 10 minutes, cooled it under running water and stored it at room temperature. They analyzed brix, pH, acidity, amino acids, vitamin C, pulp (Table 1), odor and flavor after 1 day, 1 week, 1, 2, 3 and 13 months. Brix (from 13.6 to 12.64) and pH (3.25 to 3.2) dropped slightly and amino acids (4.86 to 2.48) dropped significantly during the 13 months. All these modifications were expected by the authors. Odor and flavor remained good throughout the period. Nazaré & Melo (1981) extracted bacuri aroma and used it to flavor yogurt with good results.

Secondary uses

The seed, with its high oil levels and high percentages of palmitic and oleic fatty acids (Table 2), may have some use in industry, especially as a plantation of bacuri can theoretically produce about 3.5 T/ha/yr of seed or 1.6 t of oil per year, which makes it a very interesting alternative for oil production. Corrêa (1926), however, relates that the seed is edible and has a good nutty flavor. He also states that bacuri seed oil has medicinal uses, although he doesn't explain further.

Bentes et al. (1986/87) studied the fatty acid composition of the bacuri seed oil from Belém, which is about 46% of seed fresh weight (about 28% is water), although Cruz et al. (1984) found 71% oil in their sample from Maranhão. Their results are presented in Table 2. Bentes et al. (1986/87) also found about 10% of tripalmitin, a methyl ester of palmitic acid. The two analyses present considerable differences in palmitic (C16:0) and oleic (C18:1) acid proportions, as well as in the other acids. This suggests that fatty acid composition could be easily selected for and maintained through vegetative propagation if the species were to be used as an oil crop.

Table 2. Fatty acid composition (%) and physical-chemical constants of bacuri seed oil (Bentes et al. 1986/87, Cruz et al. 1984).

Fatty acids			Constants	
	Bentes	Cruz		Bentes
C16:0	44.2	65.4	Specific density	0.896
C16:1	13.2	6.2	Refraction index	1.457
C18:0	2.3	-	Acidity index	14.1
C18:1	37.8	26.5	Saponification index	205.1
C18:2	2.5	1.9	Iodine index	47.0
			Index non-sapon. mat.	26.4

The exocarp (rind) is the major by-product in terms of quantity. At the moment it recommended as compost and returned to the plantation to improve soil quality and reduce mineral fertilizer inputs (Cavalcante 1970). There may be an industrial use for the yellow latex, similar to that found in all Gutiferae, and is identified as a resinotonol (Paula 1945). Berg (1982) states that this latex (both from the fruit and the trunk) has medicinal properties, specifically when applied topically for skin ailments, such as eczema and herpes.

Loureiro et al. (1979) describe the wood as heavy (0.8-0.85 g/cm^3), with a rosy beige color in the heart wood and a light beige outer wood, a straight grain, with a rough texture, no smell or distinctive taste. It is easy to work and takes a good finish. It is employed in general carpentry and furniture making, as well as in civil and marine construction.

Collection methods and yields

The fruit fall when ripe, so that harvesting consists of collection from the ground. Because of the thick, durable rind the fruit do not bruise easily and can be transported over great distances and remain in good condition. The pulp remains consumable for 5-10 days within the fruit, counting from fruit fall (FAO 1986).

A vigorous, mature seedling tree (15-20 years old) will produce about 500 fruit per season (Calzavara 1970), although some have been observed to produce 800-1,000 (FAO 1986). At 115 plants/ha, Calzavara's recommended monoculture spacing, the yield of fresh fruit may exceed 20 MT. This is only 2.4 MT/ha of pulp, however, so it will be important to develop utilization for the seed (3.6 MT/ha) and the rind (14 MT/ha).

Propagation and cultivation methods

Propagation by seed, grafting or root cuttings is reputed to be easy, spacing and the rudiments of fertilization are known (Calzavara 1970): cleaned seed from elite trees are sown in a nutrient-rich, light textured seed bed, where germination will start within two to three months (A. Kato, CPATU, reports that the radicle develops first and that shoot development may only occur several months later); when the plantlets are 20 cm tall they are transplanted to a polibag nursery, where they will remain until 60 cm tall, when they will be hardened-off.

Field planting should be done at the beginning of the rainy season, at 10 m triangular spacing (115 trees/ha) in 50 cm planting pits, previously enriched with manure, 500 g dolomitic calcium, and 100 g each of superphosphate and potash. Bacuri can be intercropped with annuals or short lived perennials during the first years. Seedling trees may take 6-10 years to start yielding, while grafted plants may take 3-5 years (FAO 1986). Top cleft grafting has given good results on bacuri root-stock (A. Kato, CPATU, pers. com.), while root cuttings have given variable results, apparently depending upon time of year.

It is probable that phytosanitary problems will develop as cultivation becomes more intensive, but bacuri currently has so few pests, probably because of the latex, that it is impossible to guess which might become limiting.

Given bacuri's adaptation to nutrient poor soils in southern Amazônia, this species could become an important multipurpose (fruit, nut, oil, timber) agroforestry or monoculture species for recuperation of degraded sites. The small research efforts that exist (at CPATU, in Belém, and EMAPA, in Maranhão) are poorly funded but because they have quality staff could provide significant information rapidly with adequate support.

Research contacts

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Camu-camu

Wanders B. Chávez Flores

Family: Myrtaceae

Species: *Myrciaria dubia* (H.B.K.) McVaugh (1963)

Synonyms: *Psidium dubium* Kunth; *Eugenia divaricata* Benth.; *Myrciaria phyllyraeoides* Berg; *M. divaricata* (Benth.) Berg; *M. paraensis* Berg; *M. caurenses* Steyerm.; *M. spruceana* Berg

Common names: caçari, araça d'agua - Brazil (Cavalcante 1988, Ferreira 1986); guayabo - Colombia; camu-camu, camo-camo - Peru (Ferreyra 1959, Gutierrez 1969); guayabito - Venezuela (Romero 1961); camu-plus - E.E.U.U. (Calzada 1980).

Related species

Myrciaria cauliflora Berg or *M. jaboticaba* Berg - The "jabuticaba" is a small tree native to the central south of Brazil, where it grows spontaneously in the sub-tropical climates of Minas Gerais and São Paulo, although it adapts well in warmer areas, like Espirito Santo and Rio de Janeiro or cooler areas like Paraná (Gomes 1977, Andersen & Andersen 1988, Anônimo 1989). It is found on diverse soil types, although it prefers rich, deep, well-drained soils with sufficient moisture (Cañizares 1968, Gomes 1977, Andersen & Andersen 1988).

Barbosa Rodrigues (cited by Gomes 1977) states that there are two species of jaboticaba: *M. jaboticaba*, with small fruit and a dark-colored peduncle; *M. caulifolra*, with large, sessile fruit. He affirms that there are several types within *M. cauliflora*: jabuticaba "Sabará", which is widely planted, very productive, with small flavorful fruits and early maturation; jabuticaba "Paulista", which is very productive, with large fruits and late maturation; jabuticaba "Rajada", with large, flavorful fruits and mid-season maturation; jabuticaba "Branca", a medium-size plant, with large delicious fruit of a green color; jabuticaba "Ponhema", a large-size plant, with large fruit, a leathery rind, that should be consumed very ripe.

The Federal University of Viçosa has obtained numerous species and types of *Myrciaria* from diverse regions of Brazil (Andersen & Andersen 1988), some of which have not been identified botanically and are not listed here:

- ***M. jaboticaba*** Berg: "Sabará", jabuticaba-murta;
- ***M. cauliflora*** Berg: "Paulista", "Punhema", jabuticaba-açu;
- ***M. peruviana*** (Poir) var. ***truncifolia*** Mattos: jabuticaba de cabinho;
- ***M. coronata*** Mattos: jabuticaba-coroada, olho-de-boi;
- ***M. grandifolia*** Mattos: jabuticabatuba, jabuticaba-graúda;
- ***M. phitrantha*** Kiaersk: jabutica-costada;
- ***M. alongata*** Mattos: jabuticaba-azeda.

The tree takes from 4 to 10 years to start producing, which is a major limiting factor and the reason that most producers maintain only home gardens or small plantations (Ferreira et al. 1987, Andersen & Andersen 1988, Anônimo 1989). The fruit is à small round berry, with a reddish-purple to black rind and a whitish sweet pulp with an agreeable flavor, surrounding 1 to 4 seeds (Gomes 1977). Average yields vary from 500 to 800 kg of fresh fruit per tree (Anônimo 1989) or about 100 boxes of 40 liters (Gomes 1977) from mature trees. Flowering occurs between August and September (Andersen & Andersen 1988), although there can be minor flowerings at other times. The trees may produce nearly year round, with a major harvest and up to three minor ones (Calzada 1980, Cañizares 1968). The fruit has not developed a large market because they are so perishable (Anônimo 1989). Their shelf life is measured in days, after which they lose flavor and start to ferment.

A chemical analysis of 100 g of juice from the jabuticaba "Sabará" gave the following results (Andersen & Andersen 1988):

- Soluble solids: 14 g
- Total acids (as citric acid): 1.24 g
- Ratio soluble solids/total acids: 11.3
- Total sugars: 10,87 g
  - reducing sugars: 9.4 g
  - non-reducing sugars: 1.47 g
- Vitamin C: 117.5 mg

The fruit is consumed fresh or prepared as a nectar, preserve, jelly, liquor, wine, brandy or vinegar. It is also used as a home remedy and a food coloring (Cañizares 1968, Calzada 1980, León 1987, Andersen & Andersen 1988, Anônimo 1989).

Description and phenology

The camu-camu is a shrub or small tree, 4-8 m tall, without a detectable trunk, heavily branched from ground level, although each secondary branch has few tertiary branches. The bark on the secondary branches is a brownish-bronze color and that which is found on the tertiary branches is a greenish-brown to greenish-emergent above the canopy, with an unbranched, straight trunk supporting an open leafy crown. When grown in the open, trees are smaller, with abundant branching and a wide crown. The trunk of emergents may attain 2.5 m in diameter at breast height and has a rough, fissured gray-brown bark. The taproot is thick and long, although most roots are superficial. The leaves are trifoliate, with the central, broadly elliptical, apically pointed leaflet 8-22 cm long by 6-12 cm wide, and the 2 laterals slightly smaller, on a relatively long (4-15 cm) petiole.

The large fruit vary in size, from smaller than a baseball to as large as a softball (6-8 cm long by 6-9 cm diameter), and weight (150-750 g; average 300 g); they may contain 4 seeds, although 1 or 2 are most frequent. The thin skin is gray-brown and moderately smooth. The pericarp (an outer, loose mesocarp) is thick (1-2 cm) and fleshy, representing about 65% of fruit weight. The oily mesocarp is moderately thick (0.5-2 cm) and dense, creamy-beige to creamy-yellow, representing about 10% of fruit weight, in which are embedded the endocarp spines. The tough spiny endocarp is composed of short (0.5-1.5) spines arising from a very tough inner layer that surrounds the kernel, representing about 23% of fruit weight. The white, oily kernel is large (2-3 cm long by 1-2 cm diameter) and somewhat soft, although also somewhat crispy, with a pleasant flavor, and represents about 3% of fruit weight. The mesocarp/endocarp forms a hard, oily, kidney-shaped stone, which represents about 35% of fruit weight.

The piquiá flowers during the dry season [July-November in Manaus and Belém (Cavalcante 1988, FAO 1986, Prance & Silva 1973), December-February in Roraima (Prance & Silva 1973)], with fruiting 6-8 months later [March-May in Manaus and Belém (Cavalcante 1988, Prance & Silva 1973)]. Leaves are shed annually at the start of the dry season (FAO 1986).

Distribution, abundance and ecology

The piquiá's modern distribution is limited in the north by the Guiana shield, extending from Cayenne (French Guiana) in the east, through Pará and Roraima, to the middle Negro River in Amazonas (Brazil) in the west, and in the south by the Brazilian shield, extending from São Luiz (Maranhão, Brazil) in the east, through Pará and Amazonas, to northern Rondônia and eastern Acre (Brazil) in the west (Prance & Silva 1973).

Henry Wickham claimed that the piquiá was very abundant near Santarém (Pará, Brazil), at the mouth of the Tapajós River (Lane 1957). Otherwise the species is represented by less than one tree/ha in areas where it is common. Higuchi et al. (1985), for example, found only 0.1 tree/ha north of Manaus, although Rodrigues (1963) found 0.4 trees/ha nearby and FAO (cited by Loureiro et al. 1979) found 0.4-0.6 trees/ha along the Belém-gray. The bark is smooth and, as in other Myrtaceae, peels naturally. The leaves are entire, opposite, petioled; the petiole is 3-6 mm long by 1 mm in diameter; the leaf blade is lanceolate, occasionally oval, glabrous, 3-5 cm long by 1-2 cm wide, with 16-30 primary nerves united by a submarginal nerve.

The inflorescences are axillary, with 1-12 subsessile flowers, arranged in pairs. The calix is globular to sub-globular, with 4 ovoid lobes, glabrous; the corolla has 4 white petals that alternate with the ovoid sepals.

The spherical fruit is 2-3 cm in diameter, reddish-purple to purplish-black when mature, with a 10 mm or shorter peduncle. The pulp is acidic, edible, with an agreeable flavor. It contains 1-4 elliptical, flattened seeds, covered with short white fibers.

In the wild, most plants will flower after attaining 2 cm in stem girth, with flowers appearing throughout the crown (Peters & Vasquez 1986/87). In Peru, flowering starts at the beginning of the flood season, usually in July, extending to September (Picon et al. 1987, Gutierrez 1969, Alvarado 1969, FAO 1986), with fruiting from September to December (Alvarado 1969, Gutierrez 1969). New leaves appear throughout the year.

On the dry uplands in central Amazônia, the phenology is similar: flowering in September to December and fruiting from December to April (Chávez 1988). Falcão et al. (1989) suggested that this is influenced by the rainy season, with flowering at the end of the dry season and fruiting during the rainiest part of the humid season. Ferreira (1986) states that in a good year, with abundant rainfall, camu-camu may flower during most of the year on the uplands. Leafing also occurs year round on the uplands, although Falcão et al. (1989) found more abundant leafing at the beginning of the flowering period.

According to Picon et al. (1987) and Mendoza et al. (1989) there may be two species of camu-camu: ***M. dubia***, a shrubby plant located primarily on the active erosion area and first river or lake flooded terraces; ***Myrciaria*** sp., a small tree located primarily in drier areas along the second flood terrace or the edge of the uplands.

Distribution, abundance and ecology

The camu-camu is a shrubby species native to the floodplains of Amazônia, whose center of origin has not been determined. Some authors affirm that it is native to some tributaries of the Amazon River in Peru (Ferreyra 1959, Calzada 1978, 1980, Picon et al. 1987, Mendoza et al. 1989). The distribution established by McVaugh (1969) extends from the center of Pará state, Brazil, along the mid and upper Amazon River to the eastern part of Peru; in the north it appears in the Casiquiare and the upper and middle Orinoco River. In Brazil it is found in Rondônia along the Maçangana and Urupa Rivers (Ferreira 1986) and in Amazonas, in the municipalities of Manaus and Manacapuru (Cavalcante 1988) and along the Javarí, Madeira and Negro Rivers (Chávez 1988).

Camu-camu is an important element of the riparian vegetation in western Brazil, eastern Colombia and Peru and southern Venezuela (McVaugh 1958, Alvarado 1969, Peters & Vasquez 1986/87). According to Calzada (1980), Picon et al. (1987) and Peters & Vasquez (1986/87) it is common along the margins of rivers and lakes in the Peruvian Amazon, where large natural, nearly mono-specific populations are found; isolated individuals are rarely encountered. In natural populations, C. Peters (NYBG, pers. com.) has found as many as 12,310 plants/ha.

The camu-camu is extremely tolerant of flooding, withstanding 4 to 5 months with the roots and even one-half or two-thirds of the stem submerged in water (Alvarado 1969, Calzada 1980, Ferreira 1986, FAO 1986, Peters & Vasquez 1986/87, Chávez 1988, Falcão et al. 1989).

In the wild state, camu-camu is found only in hot, humid areas, Holdridge et al.'s (1971) "Humid Tropical Forest". It grows mostly on alluvial soils with a clay-silt texture, a pH 5-6.5 (Alvarado 1969, Gutierrez 1969, Calzada 1980, Ferreira 1986, Chávez 1988, Falcão et al. 1989). It adapts reasonably well on the poor, acidic (pH 4-4.5), upland soils in Iquitos and Manaus (McVaugh 1958, Chávez 1988, Falcão et al. 1989). It grows well with mean annual temperatures of 20-30°C, an annual rainfall of 1,500-3,000 mm, and an annual relative humidity of 78-82% (Alvarado 1969, Calzada 1980, Ferreira 1986, FAO 1986, Peters & Vaquez 1986/87, Chávez 1988, Falcão et al. 1989). Picon et al. (1987) and Chávez (1988) affirm that it is a heliophyllous species.

Uses and economic potential

The major potential use of camu-camu is as a source of organic vitamin C, since this may attain 2.99 g/100 g of fresh fruit (Table 1). Mendoza et al. (1989) affirms that this value is 60 times that of the lemon (*Citros limon*) which contains only 44 mg/100 g. The vitamin C is present in both the pulp and the fruit rind, both of which are generally used (Calzada 1980). J. Andrade (INPA, pers. com.) has found that the fruit rind contains up to 5 g/100 g.

Alvarado (1969) explored several different uses for the concentrated juice; it makes an excellent flavoring for ice creams and can be diluted to make juices or mix with other fruits for fruit punch. In Iquitos, Peru, the most common use is as a fresh juice (Alvarado 1969, Gutierrez 1969, FAO 1986, Peters & Vasquez 1986/87). Use in jams, jellies, wines, liquors and pie fillings have been reported (Alvarado 1969, Gutierrez 1969, Calzada 1980, FAO 1986). Alvarado (1969) considers the juice, either concentrated or prepared for immediate consumption, and tablets, made from the fruit pulp and rind for organic vitamin C, to be exportable products. The vitamin C contained in several prepared products is presented in Table 2.

Table 1. Chemical analysis of mature fruit of camu-camu (g/100g of pulp) (Roca 1965).

Component	(g)	Minerals	(mg)	Vitamins	(mg)
Calories	17.0	Calcium	27.0	Carotene	trace
Humidity	94.4	Phosphorus	17.0	Thiamin (Vit.B1)	0.01
Protein	0.5	Iron	0.5	Riboflavin (Vit.B2)	0.04
Oil	-			Niacin (Vit.B5)	0.62
Carbohydrates	4.7			Reduced ascorbic ac.	2,880.00
Fiber	0.6			Total ascorbic acid	2,994.00
Ash	0.2				

Table 2. Reduced and total ascorbic acid in several products elaborated from camu-camu (Roca 1965).

product	reduced	total
Ice cream	102	-
Sweetened juice 1	334	1050
Sweetened juice 2	579	1041
Marmalade 1	250	796
Marmalade 2	214	639
Jelly without pectin	917	1680
Jelly with pectin	290	1041

Alvarado (1969) and Whitman (1974) commented that, in 1967, Nutritional Specialties, Inc. of Puerto Rico, in collaboration with the Banco de Fomento Agropecuário del Perú, imported several tons of camu-camu fruit to the US, with which they prepared several experimental products and marketed "organic" vitamin C tablets, sold under the name "Camu-Plus". The reasons for the failure of this effort are not given by these authors. Perhaps this product was marketed somewhat ahead of its time, since the real boom of organic vitamins came in the mid-1970's, or it was not marketed creatively enough by Nutritional Specialties.

Both in Brazil and in Peru there are large natural populations of camu-camu that are worth evaluating in terms of collecting from the wild and preparing products for the internal and export markets (Peters et al. 1989). These could be exploited during January to April, by establishing a small pre-processing plant in the community to wash and select fruit and to extract seeds, and then export the cleaned product to the major cities (Manaus or Iquitos) for use and export.

Collection methods and yields

The potential yields of camu-camu in the wild in Peru are limited by the natural flood levels of the rivers each year (Peters & Vasquez (1986/87). Alvarado (1969) found that individual plants in wild populations yield an average of 12 kg of fruit/plant and extrapolated this yield to the hectare level, assuming a spacing of 4 x 4 m (625 plants/ha), and estimated a total yield of 7.5 MT. C. Peters (NYBG, pers. com.) and Peters et al. (1989) consider an average wild population to contain about 1,224 fruiting plants/ha, with a yield potential of 9.5-12.6 MT of fresh fruit. On upland soils near Manaus and Iquitos, fruit production starts in the third or fourth year after planting out (Calzada 1980, Ferreira 1986, FAO 1986, Chávez 1988).

Fruit harvest in the wild or in cultivation occurs generally between December and April, with the greatest intensity in January and February (Alvarado 1969, Chávez 1988). A small harvest may be expected in June and July on the upland soils near Manaus (Chávez 1988). Harvesting is labor intensive, as the ripe fruit is picked from the shrub. In natural populations near Iquitos this is done from a canoe in the late afternoon or very early morning, so that they can then be transported to the morning market (Alvarado 1969, Calzada 1980). In cultivation the harvest should be done two or three times per week and the fruit sent to market immediately (FAO 1986, Chávez 1988).

Propagation and cultivation methods

Camu-camu is normally propagated from seed (Gutierrez 1969, Calzada 1980, Ferreira 1986, FAO 1986, Picon et al. 1987). Seed sown in composted sawdust or sandy loam start to germinate within 10 days and finish after another 20 days (Ferreira 1986). FAO (1986) reports that seed sown within two days after removal from the fruit will germinate rapidly and completely (14 to 21 days); after 3 days germination will be incomplete (90%) but rapid; seed sown 30 days after removal from the fruit and maintained in the local environment will not germinate. Alvarado (1969), Gutierrez (1969), Calzada (1980), Ferreira (1986) and Picon et al. (1987) state that camu-camu can be propagated vegetatively but do not report that results and experiments at INPA have been unsatisfactory. The only experiment with stem cuttings gave poor results (Pineda 1979).

The camu-camu is a species in the process of being domesticated. Studies on phenology, floral and plant biology, agronomy and ecology in the wild and in cultivation are being pursued in Brazil and Peru (Falcão et al. 1989).

This species may have a future as a monoculture crop, both within and outside of Amazônia. This is because it naturally occurs in monospecific stands in the floodplains. Hence, it appears to be tolerant or resistant to pests and diseases. In the floodplain, especially during peak flood period, no pests and diseases can attack it when most of the plant is under water. Additionally, at least in white water areas, it is always in a good nutritional state since all required nutrients are supplied by the river. This further enhances its resistance and tolerance. On the dry uplands near Manaus, a small monoculture of camu-camu at INPA has remained relatively pest and disease free for 10 years.

Ideal monoculture densities are still subject to discussion: Calzada (1980) and Ferreira (1986) recommend 625 plants/ha; FAO (1986) and Chávez (1988) recommend 1,111 plants/ha (3 x 3 m).

Camu-camu's utilization in agroforestry systems does not appear promising because of its growth habit and requirement for full sun (Picon et al. 1987).

Management of the large monospecific stands of camu-camu in western Amazônia appears promising (Peters et al. 1989). Even intensively harvested, the stands recruit enough juveniles to maintain themselves indefinitely. Population and horticultural management techniques require research. For example, ideal densities could further increase reported yields of 9-12 MT/ha/yr and pruning might also enhance yields.

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Cupuassu

Giorgini A. Venturieri

Family: Sterculiaceae

Species: *Theobroma grandiflorum* (Willdenow ex Sprengel) Schumann

Synonyms: none current, as Cuatrecasas' (1964) revision is definitive; previously *Bubroma grandiflorum*, *Guazuma grandiflora* and *T. macrantha*.

Common names: cupuaçu, cupuassu, cupú-assú, copuassú, cupai-açú, cupu, cupu do matto, pupu, pupuaçu, cacau cupuaçu (Brazil); bacau (Colombia); cupuazur (Peru).

Related species

The genus *Theobroma* has numerous useful species, the most important being cocoa (*T. cacao*), the basis for the chocolate industry, which was domesticated in Central America although indigenous to Amazônia (Purseglove 1968, Cope 1976). *T. bicolor* appears to have been at least semi-domesticated in Peru and adjacent Ecuador and Colombia where its roasted seeds are considered a delicacy (FAO 1986). All *Theobroma* have edible pulp around the seeds and at least five serve to prepare chocolate from the seed.

Description and phenology

The following description is condensed from Cavalcante (1988) and Cuatrecasas (1964).

The mature cupuassu tree may attain 20 m in height and 45 cm diameter at breast height. The cultivated plant, grown in more open conditions, generally attains only 6 to 8 m in height, but may have a crown 7 m or more in diameter. The trunk is orthotropic and its pseudo-apical growth occurs in spurts of 0.5 to 1.5 m, at which point it produces a spiral of three plagiotropic branches, giving it a typically pagoda-like architecture. The short-petioled leathery leaves are reddish when young, maturing to dark green, attaining 25-35 cm in length by 10-15 cm in width.

The axillar or extra-axillar inflorescences have 1 to 5 flowers and are only produced on the plagiotropic branches. The flowers are the largest in the genus, with 5 triangular sepals and 5 reddish petals forming the corolla. The 5 stamens each have 6 anthers and are covered by the recurved petal-hoods; the obovoid ovary has 5 locules. The fruit are also the largest in the genus, varying from 200 to 5,000 g and averaging 1,200 g. They have a short, thick peduncle that abscises at maturity and is covered with a brown tomentum. The smooth, hard, woody epicarp is about 2-4 mm thick, the "mesoendocarp" (Cuatrecasas' term) is thick (5-7 mm), soft and fleshy at maturity. There are 30-50 seeds, each surrounded by a creamy whitish to yellowish, juicy, fibrous aril. Each seed is ovoid to ellipsoid-ovoid, 2-3 cm long by 2-2.5 cm wide and 1-1.5 cm thick.

Falcão & Lleras (1983) studied 7-year-old plants near Manaus, Amazonas and found that they produced an average of 3,500 flowers per year, most of which are produced during the dry season (July-October in Manaus). Less than one percent of these produce mature fruit, unless heavily fertilized (C.H. Muller, CPATU, pers. com.), in which case about two percent may mature. Yields are therefore low. The main harvest is from January to May in Manaus.

Distribution, abundance and ecology

Cupuassu's natural distribution is restricted to high and low forest on the south side of the Amazon River, east of the Tapajós River (a major southern tributary), including the south and south-east of Pará state and the "pre-Amazonian" region of Maranhão state, Brazil (Ducke 1953), which is its probable center of origin (Cuatrecasas 1964). Today it is found throughout the Amazon basin, generally as a garden tree or escape (Cavalcante 1988), as well as at numerous research centers in other parts of Brazil and Latin America and occasionally in home gardens in humid tropic climates in Brazil and other areas. Because of the prevalence of witch's broom disease (*Crinipellis perniciosa*) (see below) it has generally not been taken to other cacao-producing regions of the world.

Cupuassu is locally abundant in its natural distribution (Venturieri et al. 1984), although Cuatrecasas (1964) reports it as being scarce throughout this region. It is possible that local abundance is due to human influences, as Clement (1988) has defined it as a cultivated species, probably since pre-Colombian times. Ducke (1946) explains that wild and cultivated cupuassu are indistinguishable except for growth habit, which is probably an ecophysiological response to respective ecosystems.

In its natural distribution, the cupuassu is restricted to upland clay soils of varying texture (oxisols and ultisols), although it has adapted well to the high flood-plain soils (humic gleys). In its natural habitat it is a lower to middle canopy species, occasionally reaching the upper canopy. Consequently it develops well in shady environments and is considered to be shade tolerant. Diniz et al. (1980) describe the climatic conditions that prevail in its natural and cultivated distribution: average yearly temperature from 24 to 28°C; average yearly rainfall from 1,900 to 3,100 mm, generally with a 2-6 month dry season; average humidity from 64-93%.

Uses and economic potential

The cupuassu is one of Amazônia's most popular fruit species, commanding excellent prices during its harvest season. It is starting to develop a market outside of Amazônia, which is supplied by frozen pulp obtained in Belém or Manaus. Calzavara et al. (1984) mention the growing industrial importance of cupuassu in the Belém market and give a decade's worth of data, unfortunately prior to the recent enthusiasm for the species. A few industries are actively preparing several cupuassú products and commercializing them in Amazônia and exporting them to southern Brazil, Europe and the US. This is a new activity, with less than a decade of active processing and commercialization. Both the pulp and the seed are potentially important for developing industrial products. Calzavara et al. (1984) present 61 recipes for using cupuassu in drinks, pastries, sweets, desserts, and even in pizza!

Chemical-nutritive and industrial analysis

Fruit components vary considerably with size, provenance, harvest period and separation methods. Table 1 presents several data sets. Manually extracted pulp (which generally means a housewife with a pair of scissors) is preferred by most consumers because this leaves chunks of pulp that give texture to dishes made from cupuassu. Mechanical separators have been adapted for use with cupuassu and are generally more efficient than the manual method (Table 1). Gelar S.A., of Belém, obtains 23% pulp and 19.4% seed from their machinery (Calzavara et al. 1984).

Barbosa et al. (1979), Chaar (1980), Oliveira (1981) and IBGE (1981) analyzed the pulp for a variety of factors of interest in food technology (Table 2). Nutritional value is low; even the vitamin C is not at nutritionally interesting levels, although the pulp does supply energy (68 cal/100 g) (FAO 1986).

Chaar (1980) analyzed the centesimal composition of the cupuassu seed; Chaar (1980), Silva (1988) and Vasconcelos et al. (1975) analyzed the fatty acid composition of the seed oil; and Silva (1988) and Vasconcelos et al. (1975) analyzed its physical and chemical constants. In Table 3 these data are contrasted with those from the cocoa. Silva (1988) found traces or small amounts of myristic, palmitoleic, heptadecanoic, linolenic, galadoleic and beenic acids in his sample, probably because of better equipment and a more complete standard set.

Table 1. Variation in cupuassu fresh fruit size and components from several sources. [pulp extracted manually (*) or mechanically (**)]

Component	Santos & Conduru* (1972)	Barbosa et al.** (1979)	Chaar ** (1980)	Oliveira ** (1981)	Calzavara et al. * (1984)	Miranda ** (1989)	Venturieri * (1990)	Average
Fruit diameter (cm)	-	10.3	12.5	10.5	11.3	-	11.7	11.25
Fruit length (cm)	-	20.0	17.5	17.0	18.0	-	23.7	19.3
Seed number	-	47.5	35.0	41.5	35.3	-	44.8	40.8
Fruit weight (kg)	1.53	1.2	1.25	1.3	1.33	0.75	1.57	1.275
Pulp %	36.8	40.0	45.5	38.4	35.1	38.5	33.8	38.5
Seed %	16.7	18.0	15.0	17.2	18.9	19.5	14.9	17.2
Exocarp & Waste %	46.5	42.0	37.5	44.4	46.0	38.4	49.0	43.4
Placenta %	-	-	-	-	-	3.6	2.3	2.9

Table 2. Physical-chemical analysis of cupuassu pulp.

Determination	Barbosa et al. (1979)	Chaar (1980)	Oliveira (1981)	IBGE (1981)
Humidity (%)	89.0	86.8	87.8	81.3
Protein (% d.wt.)	-	1.92	1.55	1.7
Amino acids (mg % N)	21.9	-	-	-
Ether extract (%)	0.53	0.48	0.65	1.6
Starch (%)	-	0.96	-	-
Reducing sugars (%)	3.03	3.0	2.8	-
Non-reducing sugars (%)	-	5.81	4.0	-
Fiber (% d.wt.)	-	1.79	1.89	0.5
Fixed mineral residue (%)	0.67	0.73	0.81	0.7
Brix	10.8	10.51	10.8	-
Acidity (% citric acid)	2.15	2.35	2.0	-
pH	3.3	3.6	3.2	-
Vitamin C (mg %)	23.12	28.32	18.5	33.0
Pectin (mg/100g)	390.0	703.0	850.0	-

The small number of analyses available limits our understanding of the genetic variability from which to select plants that best meet industrial requirements. The cupuassu, however, is currently receiving considerable research attention and it is expected that this will rapidly provide a variety of new data, including data for the plant breeder to use in selecting new clones or mass-selected populations.

Table 3. (A) Centesimal composition of the cupuassu and cocoa seed
(B) fatty acid composition
(C) physical-chemical constants of their oil.

A.	Humidity --% f.wt.--	Protein	Fats	Carboh	Fiber	Ash
		----------------% d.wt.----------------				
cupuassu *	56.6	19.9	50.7	15.8	9.6	4.0
cocoa **	not given	12.0	46.3	34.7	8.6	3.4

B.	C16:0	C18:0	C18:1	C18:2	C20:0
cupuassu *	6.7	35.5	45.0	3.3	9.1
***	7.2	30.8	43.9	4.6	11.0
****	5.8	38.3	42.8	8.3	4.8
cocoa ****	32.8	35.5	29.6	1.0	1.1

C.	pH	fusion point	specific density	index refract	index acid	index iodine	index saponif
cupuassu ***	-	29-30	-	1.4583	3.3	34.5	191.0
****	5.7	32-34	0.9074	1.4583	4.2	45.9	174.6
cocoa ****	6.3	30-35	0.973	1.456-7	1-4	32-42	192-198

* Chaar 1980 *** Silva 1988
** Leung & Flores 1961 **** Vasconcelos et al. 1975.

Principal use

The pulp is the most important use at this time. In Amazônia it is used to make juices (actually a thick nectar), ice creams and preserves. It has only been studied as ***materia prima*** for nectar, however. There is currently international interest in making ice creams, sorbets, kefir, and fruit-filled chocolates. A review of the nectar and pulp storage research follows.

Barbosa et al. (1979) prepared a nectar of uncertain composition and pasteurized it at 90°C for 30 seconds, sealed it in 250 ml cans with internal varnish, let it settle for 10 minutes, cooled it under running water and stored it at room temperature. They analyzed brix, pH, acidity, amino acids, vitamin C, pulp (see Table 2 for initial data), odor and flavor after 1 day, 1 week, 1, 2, 3 and 15 months. Brix rose slightly (from 12.64 to 12.88); and pH (3.4 to 3.25), amino acids (4.9 to 4.04) and vitamin C (3.4 to 2.5) dropped slightly during the 15 months. All these minor modifications were expected by the authors. Odor and flavor remained good throughout the period.

Chaar (1980) has made the most complete study of nectar published to date. He prepared a nectar with 37% (by weight) cupuassu pulp, 17% refined sugar and 46% water; used a control, and four chemical (1 - 750 ppm sodium benzoate/250 ppm potassium sorbate; 2 - 500/500; 3 - 250/750; 4 - 750/0) and two pasteurization (75°C for 15 min.; 85°C for 5 min.) treatments. He analyzed brix, pH, acidity and vitamin C, as well as microbial contamination (at 4-day intervals for 28 days) and used a taste-testing panel (at 8-day intervals for 28 days). The 75°C for 15 min. pasteurization treatment was statistically superior to the others, both in terms of "consumer" preference and of all the quality-control analyses made. The first chemical treatment also gave good results.

Oliveira et al. (1984) prepared three nectars (1 kg pulp : 4 liters water : 0.9 kg sugar) and varied the amount of citric acid (1, 1.5 and 2 g/l) used to lower pH. These were heated for 3 min. at 70°C; sealed in 350 ml cans; autoclaved for 15 min. at 100°C; cooled; and stored at 25°C. They measured brix, pH, acidity, reducing and non-reducing sugars, and vitamin C at monthly intervals for 6 months. All the quality-control analyses showed only slight variation during the 6 month period.

Barbosa et al. (1979) and Chaar (1980) concluded that cupuassu's low pH did not require further adjustment to maintain quality during the test periods, whereas Oliveira et al. (1984) adjusted pH as the first step in their study. It is probable that Chaar (1980) is correct in stating that cupuassu is acidic enough not to need adjustment of pH. He also states that the pectin levels (see Table 2) are ideal for making jams and jellies.

Alves & Jennings (1979) identified eleven volatile compounds thought to be those responsible for cupuassu's very pleasing aroma. Several are aldehydes, whose esters are responsible for the agreeable part of the aroma. No one component had an aroma similar to that of the fresh pulp, so that this aroma is a complex of many compounds.

To store fresh pulp, Oliveira (1981) tested three methods: A. preheating at 70°C/3 min., canning in clean 350 ml cans, heating at 100°C/15 min., cooling in running water to 35°C, storage at room temperature (28°C); B. as in A. but without heating at 100°C/15 min., storage at -18°C; C. as in B. with addition of 800 ppm sodium benzoate and 200 ppm sodium metabisulfate, storage at room temperature. She measured brix, pH, acidity, reducing and non-reducing sugars, and vitamin C at monthly intervals for 6 months and presented the stored pulp to a taste panel at the end of the period. Treatment B presented the least chemical modification, while A and C presented some discoloring, due to caramelization of the sugars, and considerable loss of vitamin C. Treatment A was the "consumers' choice".

Miranda (1989) stored fresh pulp at 8, -2 and -12°C for four months and controlled quality by analyzing pH, acidity, reducing and non-reducing sugars, vitamin C and microbial contamination. Storage at -12°C gave best results, probably because of more complete inhibition of microbial activity and chemical reactions. Fresh pulp is generally quite contaminated with micro-organisms because of the unsanitary conditions in which it is processed, so that this becomes the primary factor in fresh pulp storage.

Pulp that is frozen in a domestic freezer releases a large quantity of juice upon thawing. This is certainly due to cell rupture by large ice crystals formed at temperatures near 0°C. If the pulp is quick frozen in "freezing tunnels" at very low temperatures, the ice crystals are smaller and tend not to rupture the cell membranes. Upon thawing, the pulp looks like unfrozen pulp (P. Petry, INPA, pers. com.). This rapid, deep-freeze technique should avoid loss of vitamin C and control microbial activity as well. The technology is common in other parts of Brazil and is being introduced into Manaus and Belém.

In 1991, one kilogram of frozen pulp (requiring 5 one-kilo fresh fruit to prepare) ready for export was worth US$4.00 to US$4.50 in Manaus. Upon reaching New York harbor, the same kilo was worth US$5.04 (J.W. Clay, Cultural Survival, pers. com. 1992). At least 13 MT were shipped from Manaus to New York; while there were reports of other shipments, their destination was unknown.

Secondary uses

The cupuassu seed is very rich in fats (±57% dry weight) which are 91% digestible by humans (Corrêa 1926/1969). In general, these fats are very similar to those of cocoa in their physical-chemical constants, although they have a different fatty acid profile (see Table 3). Silva (1988) states that cupuassu's saturated to unsaturated fatty acid ratio is 1.04, whereas cocoa's is 1.71; according to modern dietary theory, the lower ratio is preferable for human diets. Calzavara (1970) states that Nestle's has expressed an interest in using cupuassu for making white chocolate, but apparently nothing has come onto the market to date, probably because of uneven quality and supply of the *materia prima*.

Silva (1988) examined cupuassu fat for use in chocolate. Although cupuassu's fatty acid ratio is nutritionally better than cocoa's, its melting point is much lower and therefore it does not melt in the mouth the same way chocolate does. At 10°C, cocoa has about 90% solid fats, while cupuassu has only about 50%; at 27°C (body temperature), cocoa still has about 50%, while cupuassu has only about 30%; at 30°C, cocoa has gone to zero, while cupuassu still has a few percent (it goes to zero at 35°C). All this means that cupuassu can not substitute cocoa directly for use in chocolate bars. Silva (1988) found that up to 10% of cupuassu fat does not significantly change chocolate melting points.

Venturieri & Aguiar (1988) studied centesimal composition of home-made *cupulate* (chocolate made from cupuassu seed) and commercially available chocolate. This product has not been studied technologically but is well-accepted locally.

Aragão (1990) studied the seed fermentation process for use in making chocolate. The de-pulped seeds were fermented for 7 days in a 40 x 40 x 60 cm wooden box with a perforated base; each day they were stirred and a sample was removed for analysis. They were then shade-dried at room temperature to 12% humidity, then sun-dried to 8%, after which they were toasted at 180°C for 30 minutes, skinned, ground and analyzed. The cotyledon's pH rose from 5.25 to 6.8; phenolic compounds rose from 1.12 to 1.34 mg/100 g; fats remained unchanged at 63.5% dry weight; and color changed from a beige cream with rosy tints to a dark reddish caramel. The flavor and aroma of the fermented seed were indistinguishable from that of fermented cocoa seed.

A probable caffeine precursor, 1,3,7,9-tetrametiluric acid, has been found in cupuassu seeds (Baumann & Walker 1980, Vasconcelos et al. 1975). No caffeine, nor "theobromine" (Freise 1935), has been found. More detailed studies are indicated, however, especially if the seed is to be extensively industrialized.

Recently a skin cream made from cupuassu seed fats has been commercialized on the Manaus market, although there are no studies to back up its claimed effectiveness as a skin rejuvenator.

The fruit rind (43% fruit fresh weight) makes a reasonably good compost for manuring, as it contains 1.5% potassium, although it contains only moderate amounts of nitrogen (0.7%) and phosphorus (0.04%) (Silva & Silva 1986). Although Calzavara et al. (1984) recommend its use as animal feed also, this appears to be of doubtful value because of very high fiber levels (48%) and low protein levels (5%) (Silva & Silva 1986).

Collection methods and yields

The fruit falls from the tree when ripe, so that collection involves nothing more than picking the fruit from the ground. Because the fruit peduncle scar offers an easy entry for fungus, bacteria and Escolitidae fruit borers, the plantation should be harvested several times a week and the fruit processed as soon as possible. If unripe fruit are removed from the tree they will not ripen normally and either do not develop full flavor and aroma or rot within a few days.

Calzavara et al. (1984) consider average yields, without fertilization, to be 12-20 fruits/plant at five years from seed, each weighing about 1 kg. At 234 plants/ha (7 x 7 m triangular spacing) this is 2.8-4.7 MT/ha/yr (1-1.8 MT of pulp; 0.45-0.8 MT of seed). Venturieri et al. (1985) suggest that better management and adequate fertilization can raize yields to a level of 20-30 fruits/plant (4.7-7 MT/ha/yr of fruit; 1.8-2.6 MT of pulp; 0.8-1.2 MT of seed) at five years, increasing to 60-70 (14-15.4 MT/ha/yr of fruit; 5.3-5.6 MT of pulp; 2.4-2.6 MT of seed) at 7 years. Although this is much lower than many fruit crops, current market prices make it extremely lucrative. In 1991, a 1 kg fruit on the Manaus market during harvest sold for US$0.50 to US$1.00, making it one of the most expensive local fruits. At least one local farmer profits more from his one hectare of cupuassu than from 20 ha of cocoa, using the recommended cocoa management practices on both species.

A seedless mutant has been found near Cametá, Pará (Calzavara et al. 1984, Venturieri & Mendonça 1985). The mutation suppresses the formation of the embryo and endosperm, but not the testa, which results in the pulp being almost ready for use. The empty testa, however, is more difficult to remove from the pulp than a normal seed; if it is left in the pulp it imparts a reddish tinge and minute fragments to the processed product. Additionally this cultivar has low yields and is exceptionally susceptible to witch's broom disease, the major disease of both cocoa and cupuassu in Amazônia.

Propagation and cultivation methods

Fruit yield is the result of the interaction of two main factors under human control: the genotype of the plants used and the care that the farmer gives the plants. Since the cupuassu has not yet been improved genetically, it is extremely important to obtain seed or grafting material from elite germplasm. At a farm near Manaus, Amazonas, mass selection was used to identify

16 elite plants from a plantation of 800. These 16 plants yielded more than twice as much as the plantation average, which gives a clear idea of the variation available and the advances that can be made through selection. An elite plant should yield well above the average in its area, have fruit with high pulp/waste and high seed/waste ratios, have pulp with excellent flavor and aroma, have seed with adequate fatty acid composition for the desired end use and be free from locally important pests and diseases, especially witch's broom.

The selected seed should be cleaned of pulp, treated lightly with a fungicide and sown directly in 2 kg black plastic nursery bags or other adequate container in a shaded (±50%) nursery. Germination is rapid, rarely needing more than 4 weeks to attain 90+%. If two seeds are sown per bag, the weaker or later seedling can be removed shortly after germination and thus guarantee a more uniform stand. When the plants are 40-60 cm tall they should be partially hardened-off for transplanting to the field, by gradually removing the shade until there is only about 25% remaining.

Grafting is relatively easy. The modified Forkert patch budding technique or the side veneer graft both give good results (Venturieri et al. 1986/87). Muller et al. (1981) recommend deep shade for the grafted plants until take has been confirmed and new growth has been achieved.

Similar to the practice in cocoa, the cupuassu should be transplanted into a provisional shade [annatto (***Bixa orellana***), banana (***Musa*** spp), cassava (***Manihot esculenta***), pigeon pea (***Cajanas*** spp), castor (***Ricinus vulgaris***), papaya (***Carica papaya***), passionfruit (***Passiflora*** spp.) or other short-term crop], which will be removed after its harvest or when the cupuassu needs more space. It can also be transplanted into second growth, of which Amazônia now has more than 100,000 km².

The square planting pit should be 40 cm in each dimension, filled with topsoil, several kg of manure and 100 g treble superphosphate (Calzavara et al. 1984). Spacing will depend upon plans for pruning seedling trees or use of grafted plants, as well as what permanent shade will be used. Grafted or heavily pruned plants can be planted at 6 x 6 m, interplanted with a relatively open shade [coconut (***Cocos nucifera***), pupunha (***Bactris gasipaes***), hog-plum (***Spondius lutea***), or pruned legumes like inga (***Inga edulis*** or ***I. cinnamomea***) or leucena (***Leucaena*** spp.)]. Lightly pruned or unpruned seedlings should be planted at 7 x 7 m or wider, with similar shade species. In second growth, especially on degraded land, spacing should be wider, even for grafted plants, so that these have more space to exploit for nutrients.

Cocoa fertilization schemes (see Purseglove 1968 or similar texts) should improve cupuassu yields significantly, although there are no experimental results to date. Potassium deficiency symptoms (cracked fruits) have been observed; the fruit export potassium, phosphorous, calcium and magnesium in significant quantities (Silva & Silva 1986).

As an Amazonian native, cupuassu has numerous co-evolved pests and diseases which are not a problem at its usual low abundance. In plantation situations, even mixed with other species, phytosanitary pressures quickly build up. There are several boring insects, both of the fruit and the trunk, that can become a problem in some areas; control should be done as needed and is rarely cumbersome. Near Manaus a fruit borer (*Conotraquelus* sp., Escolitidae) is becoming serious. It destroys seeds and excavates epicarp galleries (B. Ronch Teles, pers. com.). There is no efficient control method for this pest.

Diseases are much more of a problem, especially witch's broom disease, which can cause die-back or a heavy growth of side-shoots on the branches and pod rot of the fruit. Control is labor intensive, i.e. pruning of the infected branches (to 10 cm below the evident symptoms in the cambrium), followed by burial or burning. Other diseases, like anthracnose (*Colletotrichum gloesporioides*), burning string (*Pellicularia koleroga*), and diseases spread by infected pruning implements (*Botriodiploidia* spp) are less important and relatively easy to control.

Currently there is significant planting of cupuassu in both the Manaus and the Belém areas, both in monoculture and at high density in agroforestry environments (i.e. cupuassu with shade trees, as mentioned above). As long as demand remains strong and provides sufficient capital to maintain these plantations, biological pressures are controllable. More research on both types of agroecosystem is urgent, however, as little is known about cupuassu behavior in either.

Cupuassu appears to be suitable for a forest management environment also, as it is tolerant of shade and has not yet been so modified by selection to change its tropical-forest adaptations. Yields will be significantly lower, however, unless special germplasm can be found or developed for this environment. Nonetheless, this area also requires research, as none has even started yet.

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Copaíba

Paulo de T.B. Sampaio

Family: Leguminosae-Caesalpinoideae

Species: *Copaifera multijuga* Hayne

Common names: copaíba, copaíba angelim, copaíba mari-mari, copaíba roxa (Brazil).

Related species

Copaifera has about 60 described species (Dwyer 1951): 32 occur in Africa and 28 in South America. Numerous oil-resin producing species occur in Amazônia, among which are: ***C. bijuga*** Hayne; ***C. cuneata*** Tul.; ***C. guianensis*** Desf.; ***C. glycycarpa*** Ducke; ***C. longicuspis*** Ducke; ***C. longifolia*** Huber; ***C. marginata*** Benth; ***C. martii*** Hayne var. ***C. rigida*** (Benth) Ducke; ***C. officinalis*** L.; ***C. pubiflora***; and ***C. spruceana*** Benth (Ducke 1930, Fróes 1959, LeCointe 1947, Pio Corrêa 1932). Dwyer (1951) can be consulted for a botanical description of each, its geographic distribution and production of oil resin.

Description and phenology

C. multijuga is a large tree, that can attain 36 m in height, with a DBH of up to 80 cm. The bark is smooth, persistent, about 1 cm thick. The alternate, compound leaves have two leaflets, oblong lanceolate, pointed at the tip and rounded at the base, with fine hairs along the principal vein. The white flowers are sessile, with 4-5 mm long petals that have a rusty red color. The unilocular fruits measure about 3 cm in diameter and are a red color when mature. The seeds are oval or spherical, with an intense yellow-colored aril (Alencar 1981, Loureiro et al. 1979). It is distinguished from other species in the genus by the special shape of its leaflets, the agreeable smell of its wood (a strong coumarin perfume is always present) and by the larger size of its flowers. The tree and its wood are otherwise very similar to ***C. reticulata***, but the oil resin produced is clearer and more liquid, with a more agreeable smell than in most of the other species.

C. multijuga flowers between January and April (the local rainy season) and fruits between March and August. It is an evergreen, although occasionally semi-deciduous at the end of fruiting (Alencar et al. 1979). Vastano (1984) found that the species is allogamous (out-breeding), as expected for a perennial tree species in Amazônia.

Distribution, abundance and ecology

C. multijuga has an ample geographic distribution. It is found from the mid-Tapajós River in the east to Amazonas and Rondônia states in the west (Ducke 1949) on the south side of the Amazonas River; it is also found from the Trombetas River west into Amazonas on the north side.

In a 26.5 ha forest inventory done along the Trombetas River (eastern Pará), an average abundance of 1 tree/ha of *C. multijuga* was found, for the 20 cm or greater diameter at breast height (DBH) class (INPA 1982). Alencar et al. (1972) found this species in the forests of the Cuieiras and Urubu Rivers (Manaus, Amazonas), with an abundance of 1 to 2 trees/ha for the 25 cm or greater DBH class. According to Loureiro et al. (1979), the wood volume (with bark) in the terra firma forest of SUFRAMA's Agricultural District (Manaus) is about 0.12 m^3/ha, with an abundance of 2 trees/ha. In the Bacia 3 experimental area, at the Tropical Silviculture Experiment Station, INPA, in SUFRAMA's Agricultural District, Jardim (1985) found 0.125 trees/ha and a volume of 0.23 m^3/ha, for the 40 cm or greater DBH class. In the area of the Projeto Esperança (Novo Aripuanã, southern Amazonas), Jardim & Fernandes (1983) found 0.14 trees/ha, for the 35 cm or greater DBH class. In a systematic sampling of a 10,000 ha area along the Arinos River (northern Mato Grosso), an average of 1.5 trees/ha were found, for the 20 cm or greater DBH class (Higuchi & Barbosa 1983).

C. multijuga occurs in numerous habitats, from the terra firma forests, to the flooded and/or sandy margins of lakes and streams, to the cerrado forests of central Brazil. It occurs on both sandy and clayey soils, and generally occupies the upper canopy or may occasionally be an emergent (Alencar et al. 1979).

Uses and economic potential

Major use: timber

C. multijuga's wood is heavy (0.75 to 0.85 g/cm^3), with a brownish-red heartwood and a lighter, well defined, outer layer. The wood has a regular grain and medium texture, quite similar to cedar (*Cedrella odorata* Meliaceae). It emits a strong odor of coumarin when cut and has an indistinctive flavor. Its luster is silky and alive. *C. multijuga* is widely used for sawn lumber, construction and carpentry, and makes a good charcoal (Loureiro et al. 1979).

Potential major use: oil resin

An oil resin is extracted from the leaves, trunk and stem. It has a strong demand on the Brazilian and international markets, as a component of high temperature resistent varnishes, cosmetics (as a perfume fixative), and in the pharmaceutical industry (Prance 1987). It is used to improve the clarity of the image in low-contrast areas in photographic film development. It is also used as a substitute for linseed oil in paints, because of its drying properties. It is reputed to be used in the paper industry as a fixative (Prance 1987, Nascimento 1980).

This oil resin is composed of various sesquiterpenes, among which are cubebene, cadinene and tocoferol (Alencar 1982). According to Langenheim (1973), the African species produce a viscous oil resin rich in terpenoides that solidify into a type of amber or "copal". *C. multijuga*, however, produces a liquid oil resin, that is nearly transparent, slightly viscous, with a strong smell of coumarin, and a bitter taste.

The physical properties of the stem oil resin, separated into its major fractions, are presented in Table 1. The fatty acid composition of the seed oil is presented in Table 2. According to Gottlieb & Iachan (1945), the physical-chemical properties of the oil resin vary with procedence and soil type.

Table 1. Physical properties of the *C. multijuga* oil resin complex, based on oil resin obtained from the trunk (Gottlieb & Iachan 1945).

	Oil	Resin
Density at 24°C	0.89	1.035
Acidity index	0.5	106.3
Saponification index	0.9	133.2
Acetylene index	10.6	107.2
Pollensk index		0.5
Reichert-Meissel Index		1.5
Iodine index	147.2	75.7
Saponifiable fraction (%)	-	76.7
Insaponifiable fraction (%)	64.8	22.9

Alencar (1982) mentions that clean copaíba oil, direct from the trunk, can substitute for diesel oil directly. An engine will run normally; the only detectable difference is that the exhaust smoke is bluish. This observation excited some planners during the 1973 oil crisis, but only a small amount of money for research resulted because of disappointing yields (see below).

Table 2. Fatty acid composition (in % of oil) of the seed oil of *C. multijuga* (Maia et al. 1978).

Palmitic	Oleic	Linoleic	Arachidic	Bunic	Coumaric
24.9	35.3	35.7	1.1	3.0	0.15

Secondary use: medicinal

The oil resin of *C. multijuga* is popularly used in Amazônia to treat throat infections, bronchitis and other respiratory problems; as an antiseptic for wounds and scratches; and as a cure for diarrhea and problems in the urinary tract. In weak doses it is a stimulant for the appetite, with direct action on the stomach (Pio Corrêa 1932). It is currently being commercialized in Manaus in the form of capsules to treat infections, reputedly as an anti-inflammatory.

Historical market data

In 1939, the US imported 100 MT of *C. multijuga* oil resin from Brazil. Alencar (1982) estimates that the total oil production in Amazônia may be on the order of 200 MT, including oils that are not registered for export but are used locally, mostly as medicinals. This oil resin is a significant item in the list of extractivist products exported from Amazonas state: between 1974 and 1979 the state exported an average of 89 MT/yr, with an average value of US$215,000/yr (or US$2,415/MT) (IBGE 1980). In 1984 total Amazonian exports (Amazonas, Pará, Rondônia, etc) reached 120 MT, with a value of US$207,000 (or US$1,725/MT) (CACEX 1986). The lower value in recent years suggests that the market for traditional industrial uses is saturated or that this market is turning to synthetic substitutes. The major markets were the US (58 MT), France (22 MT) and West Germany (17 MT) (CACEX 1986).

Collection methods and yields

In the genus *Copaifera* the oil resin is secreted in small pockets in the leaves and the primary xylem (Langenhein 1978).

In the secondary xylem of the trunk and branches the oil resin is stored in vertical tube cells organized in concentric rings, interconnected in such a way that the oil resin drains from all the tube cells when one of them is perforated (Prance 1987). Extraction of the oil resin is thus simply a matter of perforating the trunk with a drill, preferably into the center of the heartwood, at 60-70 cm above the soil. If the oil resin does not drain easily, a fire may be made around the base of the tree to heat the oil resin and aid drainage (Alencar 1982).

According to Alencar (1982), the yield of oil resin of *C. multijuga* varies with soil type and procedence. In a 200 ha research area at the A. Ducke Forest Reserve (INPA, Manaus), 82 trees with DBH ≥ 30 cm were studied. In each tree, two holes were drilled in the trunk from opposite sides in order to collect the oil resin. At 6- to 14-month intervals and at different times of the year, a total of 5 collections were made from each tree. In the first collection 45% of the trees on clay soils and 75% of those on sandy soils did not yield any oil. Only 9 trees yielded more than 500 ml at the first collection and 3 trees yielded more than 2 liters. Yields and number of trees yielding varied from collection to collection and from season to season, but declined continually during the period to an average of 34 ml/tree in the fifth collection (Alencar 1982).

These rather disappointing yields suggest that the energetic potential of *C. multijuga* is rather limited, even if rationally exploited in commercial plantations (Alencar 1982). A rather protracted improvement program would be necessary to make it even marginally attractive with the germplasm that was studied in Manaus. Nonetheless, it is possible that more productive populations and specific edapho-climatic conditions exist where this potential may be much higher. The species is certainly worth looking at more intensively. Pio Corrêa (1932) mentions that *C. reticulata* may also be worth further study, due to the good quality of its oil.

Propagation and cultivation methods

Seed of *C. multijuga* sown in Jacobsen germinators at a temperature of 30°C, presented 91% germination when sown immediately after being collected and 56% germination after storage for 30 days at room temperature (Façanha & Verela 1987). According to Alencar (1981), this species presents an average germination of 87.5%, starting within 14 days after sowing and taking about 35 days to finish the germination period.

Seedling growth of *C. reticulata* in clay substrate in full sun was poor, presenting heights of only 10-30 cm after 200 days (Ledoux 1982), strongly suggesting that the species requires shade in the juvenile stage. *C. multijuga* is expected to behave similarly.

According to Alencar & Araujo (1980), *C. multijuga* planted in full sun at 5 x 2.5 m on heavy-textured yellow latosols at the A. Ducke Forest Reserve (INPA), presented average heights of 8.2 m and DBH of 9.2 cm at 16 years of age; this is only about 50 cm/year, however, which does not promise much for plantation management as the tree would probably have to be at least 20 cm in diameter in order to be tapped. Under the partial shade of the primary forest, this species presented an average height of 1.5 m and DBH of 1.4 cm, with the same edapho-climatic conditions during the same period. This suggests that, like other upper canopy and emergent species, *C. multijuga* requires shade during the seedling stage but requires sun in order to attain height and girth.

From the above discussion it is evident that more research on the agronomic and silvicultural requirements of copaíba is urgently necessary. Identification of the correct soil and climatic conditions for most rapid growth, together with collection of the most promising germplasm, will allow a more adequate evaluation of its potential in agroecosystems, either monoculture or agroforestry. In forest management areas, silvicultural research to enhance growth and yields is required. Enrichment with promising germplasm will also be necessary.

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Jatobá

Carlos A. Cid Ferreira & Paulo de T. B. Sampaio

Family: Caesalpiniaceae

Species: *Hymenaea courbaril* L.

Common names: jatobá, jutaí, jutaí-açu, jutaí-roxo, jutaí-bravo, jataí, jataípeba, jataiuba, jatiuba, (Brazil); courbaril (Peru, Ecuador, Martinique); guapinol (Colombia, Mexico, Central America); corabore (Venezuela); copal, abati, avati (Paraguay); simiri, locust (Guyana); locust-tree (English).

Related species

Hymenaea L. includes 15 American species, 13 of which occur in Brazil. Most of them have some to considerable economic value: they furnish good- to high-quality timber, valuable resins, edible fruits, tannin-rich bark and numerous uses in popular medicine. Two examples are:

H. stilbocarpa Hayne is native to the dry forests of Brazil's southern-central highlands, in São Paulo, Minas Gerais, Goiás and the Federal District. It is also found in the Brazilian Northeast, where it is known by the names of yellow jutaí, jataíba and jataí. This species attains 18 m in height and 1 m in DBH. The leathery leaves are obtusely pointed. Its fruits measure only 8-12 mm x 3-4 mm and have properties similar to those of *H. courbaril*, although with less resin. The wood and its uses are also similar (see below). Yellow jutaí flowers in January-February and fruits in October-November. One kilogram of fruit yields about 270 seed, which germinate within 25-28 days (Rizzini 1971).

H. altissima Ducke is found in Brazil's Atlantic forest, in Minas Gerais, Rio de Janeiro and São Paulo. Its wood is also used commercially. Its small leaflets are thin and taper to a long point; its fruit are smaller than those of *H. courbaril*. It flowers in November-December and fruits in March (Rizzini 1971).

Description and phenology

Hymenaea courbaril L. is generally a large tree, attaining 40 m in height and 2 m in DBH; the thick bark, up to 3 cm, has a reddish-brown color internally and contains a gummy resin. In some individuals the bark cracks longitudinally; this does not appear to have any relationship with resin production, however. There are two leathery, smooth leaflets on each leaf, both having an oblong-lanceolate shape, with a pointed apex more attenuated than in other species and a heart-shaped base; there are no reticules and the glands are translucent. The flowers are presented on terminal corymbs; there are 5 greenish-brown concave sepals and 5 white petals, 10 stamens and an ovary with a unilocular carpel with 6-19 ovules. The fruit is an indehiscent oblong, subcylindrical pod 8-15 cm long; the thick, rigid, dark reddish-brown exocarp contains small pockets of resin near the surface. The seeds are enveloped in a powdery, sweet, agreeably though distinctively flavored mesocarp.

The jatobá's phenology varies from region to region, as expected in such a widely dispersed species. Near Belém, Pará, it flowers from August to October and fruits in February (Cavalcante 1988). In Central Amazônia it flowers from August to November and fruits from February to September (INPA Herbarium).

Distribution, abundance and ecology

The jatobá is common from Mexico to Paraguay; in Brazil it occurs in most regions, with a uniform distribution in Amazônia. In this region it is generally found in the forests on the *terra firma* clay soils, occasionally in the high *varzea* (the, levies along the major sediment-rich rivers). It is occasionally cultivated and frequently managed, i.e. protected when a swidden clearing is opened.

Heinsdijk & Bastos (1963) estimated a frequency of 0.1-0.2 trees/ha and a volume of 0.1-1.8 m^3/ha for Amazônia as a whole. Near the city of Manaus, jatobá is not abundant; at the A. Ducke Forest Reserve (INPA, km 26 AM-010) it was found at a frequency of 0.2 trees/ha and 0.4 m^3/ha, in an inventory of trees with 25 cm diameter at breast height (DBH) or greater (Rodrigues 1963). At INPA's Tropical Silviculture Experiment Station (km 45 BR-174), Jardim & Hosokawe (1987) found an average of 0.657 trees/ha, while in the forest just to the west of this station, in an area called Bacia 3, 2 trees/ha were found, with a volume of 1.806 m^3/ha, for plants with 40 cm DBH and above (DST 1982). In the municipality of President Figueiredo (300 km north of Manaus), an inventory in 8,000 hectares of terra firma forest found 0.143 trees/ha, with a volume of 0.027 m^3/ha, for trees between 10 and 20 cm DBH (Poyry 1984). In an inventory on the Trombetas River, Pará, Higuchi et al. (1982) mentioned the presence of the species but not its abundance, suggesting an extremely low occurrence.

Uses and economic potential

Principal uses

The wood of jatobá is well-accepted on the local market. The color of the heartwood varies from rosy-brown to dark reddish-brown; its cut surface is smooth but lusterless; it is very heavy and durable, and difficult to work. The relatively thick outer wood is yellowish-white. It is used in heavy construction, such as hydraulic work, truck bodies, railroad ties, etc. (Loureiro et al. 1979).

Jutaica or American Copal is the common name of the resin that exudes from the trunk, the branches and the fruit pericarp. Sometimes it solidifies on the tree, otherwise it falls to the soil near the trunk in chunks of varying sizes. If it gets covered with soil it can become fossilized, taking on a form very similar to that of amber, produced by various species of ***Pinus***. Langenheim et al. (1973, 1974) concluded that the trunk and fruit resins contain mostly diterpenoides with some sesquiterpenes.

Analysis of fresh resin found 8 to 16% copalic acid. With resin extracted from the bark of young individuals, the quantity of copalic acid varied from 50 to 55%, while in older bark this varied from 55 to 58%. The point of fusion also varies with age of the resin: fresh resins solidify at 180-192°C, while in older resins, especially in fossilized resin, this temperature may reach 265°C or more.

In studies done in Central America, Amazônia and elsewhere in South America, the foliar resin composition of ***H. courbaril*** varied more between populations than within, although within populations variation was greater in Amazônia and South America than in Central America. This may be due to local environmental effects, although it is more likely a genetic effect, probably reflecting the narrow genetic base of the Central American populations due to a founder effect. In Amazônia the composition of the resin is generally more variable than in other areas in South America; the greatest morphological variation is also found in this region (Langenheim et al. 1977).

The resin is used industrially in the fabrication of varnishes. In some areas of the interior of Amazonas, Brazil, it is used in the fabrication of ceramics, mostly kitchen utensils, as a sealant to reduce or eliminate water penetration.

The foliar resin has toxic and repellent effects on at least one important crop pest, the caterpillar of *Spodoptera exigua*, and may have similar effects on other leaf-eating insects (Stubblebine et al. 1977).

Secondary uses

In popular medicine the jatobá is used in several ways. The bark is boiled and the tea is used to treat cystitis, as well as being an excellent vermifuge, pectoral astringent and general stomach cleaner. The sap, when mixed with bee's honey, is used to treat bronchitis and various heart ailments.

In some areas the pulp is used in substitution of cassava flour or out of hand as an agreeably flavored fruit. The pulp is a dry powder, with the consistency of flour when taken from the fruit; it is greatly appreciated by children in the interior of Amazônia and has served as famine food when other foods are absent. While no nutritional or quality information is known to us, jatobá fruit flour might have potential as a specialty flour for confectioneries. In order to penetrate this market, however, chemical-nutritive and safety data will be essential.

Hubbell et al. (1983) observed that the leaf-cutter ants (*Atta cephalotes*) do not attack the jatobá in Costa Rica and discovered that the leaves contain a terpenoid "caryophyllene epoxide" that inhibits the growth of the fungus that the leaf-cutter ants cultivate. Additional tests determined that this terpenoid has a wide spectrum fungicidal effect. This terpenoid and other leaf chemical compounds are worth further study (Robinson 1988).

Collection methods and yields

No specific collection technique has been defined for jatobá resin since it is generally collected only when found in the forest. In some areas of Amazônia attempts at collection have been made by cutting longitudinal slashes along the trunk, unfortunately without any positive results (O.P. Monteiro, pers. com.); the same happened with the trees at the INPA Tropical Fruit Experiment Station (C. Clement, pers. com.). Nonetheless, at the Maracá Ecological Station (Roraima, Brazil), there are trees that naturally produce up to 15 kg of resin. This same productivity has been observed in trees found in Santarém (Pará) (D.F. Coêlho, pers. com.). If the resin of this species is to find a larger market, research needs to be done to develop adequate harvest methodology and determine the environmental conditions and plant genotype most appropriate for harvesting this material.

The jatobá fruits prolifically, although yield estimates could not be found. Very roughly, it is estimated that a mature (10-year-old) tree grown in the open may yield 1,000-2,000 fruit, each weighing about 50 g; hence one tree yields 50-100 kg of fresh fruit each year (@100 trees/ha = 5-10 MT). Most of the fruit is composed of the pod (probably 50-70%), and seed (25-

40%), so there is very little floury mesocarp (5-10%). Thus, one tree may yield 2.5-10 kg of flour (250 kg to 1 MT/ha/yr). On most of the poor soils of Amazônia, the lower estimates are more likely or may even be high.

Propagation and cultivation methods

The jatobá is generally propagated from seed. Its natural regeneration is limited, probably because of seed predation. Seed germination varies from 30 to 100%, taking approximately 17 to 20 days to start. Germination can be accelerated by submerging the seeds in boiling water, followed by adding sulfuric acid (Loureiro et al. 1979). Seeds are sown in beds or directly in plastic nursery bags; there are about 480 seeds/kg (SUDAM 1979a). When juvenile the seedling exhibits a robust taproot and large, persistent cotyledons. Seed should be stored at 26°C and 12% humidity (Loureiro et al. 1979).

Almeida (1943) observed the following growth data from 34 trees of about 16 years of age in wild environments in Gávea (Rio de Janeiro): maximum height - 18.5 m, minimum - 3.0 m; maximum diameter - 40 cm, minimum - 5 cm. In full sun at Curuá-Una (Santarém, Pará), on an acidic (pH 4-4.5) yellow oxisol, jatobá had a good survival index (80-90%) with 75% crown, a total height of 7.6 m and a DBH of 7 cm, at 15 years (SUDAM 1979b). For a legume (and apparently a facultative heliophyte), this is relatively slow growth. On a similar soil at the Tropical Fruit Experiment Station (INPA, km 41 BR-174), three trees planted in 1979 had dimensions of ± 10 m in height, ± 8 m in crown diameter and DBH of ± 50 cm in 1990 (C. Clement, pers. com.).

Given jatoba's apparent resistance to some pests and diseases conferred by its secondary metabolites, it is likely that this species could be planted in monocultures, as well as in agroforestry systems and in forest management areas. Only a few silvicultural experiments have been done (cited above), so that research and development of this species needs to start at a very preliminary stage. If methods for tapping the trees can be developed, it is worth pursuing this research; if not, it may not be worthwhile.

Research contacts

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Andiroba

Paulo de T.B. Sampaio

Family: Meliaceae

Species: *Carapa guianensis* Aubl.

Synonyms: *Carapa procera* (separated from *C. guianensis* by Pennington et al. 1981)

Common names: Andiroba, A. Branca, A. do Igapó, A. Saruda, A. Vermelha, Andirova, Angirova, Comacari, Mandiroba, Yandiroba, Carape, Carepenha, Gendiroba, Jandiroba, Penaiba, Purga de Santo Inacio, Aboridan (Brazil); Caraba, Crabwood, Damerara, Brasilian Mahogany, Lowland Crabwood, Highland Crabwood, White Caraba, Karaba, Karapa, British Guiana Mahogany (Guyana); Bois Caille, Cachipou, Carape, C. Blanc, C. Rouge, C. Pune, Crapo, Andiroba Carapa (French Guiana); Kareppa (Suriname); Andiroba (Peru); Andiroba (Paraguay); Bateo, Cedro Bateo, Cedro Macho (Panama); other names found commercially: Bois Rouge Carapat, Crabbaum, Nandirova, Parama Mahogany, Mazabalo, Tangare, Guino (chico).

Related species

Carapa procera is more widely distributed than *C. guianensis*, being found both in South America and Africa. In the New World its distribution is restricted to northern South America, in ecological habitats similar to those favored by *C. guianensis* (see below). Its distribution in Africa is more ample, being found in both Central and Western Africa, with the same ecological preferences noted above (Pennington et al. 1981).

The botanical differentiation of *C. procera* from *C. guianensis* was done recently by Pennington et al. (1981). The morphological characters used to discriminate the two species are presented in the following key:

1. Flowers sessile, subsessile or, very rarely, short and thick pedicled, predominantly 4 meras with 8 anthers, 1 ovary, 4 locular and (2-)3-4(-6) ovules per locule; leaflets more elliptical, with a sharply pointed apex: *C. guianensis*;

2. Flowers always tenuously pedicled, predominantly 5 meras with 10 anthers (rarely with 6 petals and 12 anthers), 1 ovary,

5(-6)-locular and (2-)3-6(-8) ovules per locule; leaflets generally oblong with rounded apex: *C. procera*.

Description and phenology

The andiroba is a large tree, reaching 30 m in height, with a straight cylindrical stem, above frequently buttressed roots. It has a thick, bitter-flavored bark, which flakes off in large plates. The medium-sized crown is abundantly branched. The alternate leaves are compound, with long petioles; its length is 30-60 cm and it is up to 50 cm wide; the leaflets are opposite (up to 19 pairs), ovoid-oblong, with a short apical point, generally leathery in texture, dark green in color, smooth and flat, with an entire margin. The panicle inflorescence is axillary, generally near the branch tips, about 30 cm long. The flowers are subsessile, smooth petaled, cream colored (Loureiro et al. 1979, Rizzini & Mors 1976).

The fruit is a round to nearly round capsule, dehiscent along four sutures that separate upon impact with the ground, which liberates the seeds (Aublet 1977, Loureiro et al. 1979). The 4-16 seeds have angular sides, due to mutual compression within the fruit. Each seed averages 21 g, although there is great variability due to seed number (Carruyo 1972, McHargue & Hartshorn 1983, Pinto 1963).

Andiroba flowers in the early rainy season (February to March) and fruits in the late rainy season (March to May) at the Curua-Una Experiment Station, south of Santarem, Pará (SUDAM 1979). At the A. Ducke Forest Reserve, Manaus, Amazonas, it also flowers in the early rainy season (December to March) and fruits in the mid to late rainy season (March to April) (Alencar et al. 1979).

Distribution, abundance and ecology

Andiroba is widely distributed in the Neotropics and Tropical Africa. In the Neotropics it is found from Central America south through Colombia, Venezuela, Suriname, Guyana, French Guiana, Brazil, Peru and Paraguay, as well as on several of the Caribbean Islands. In Brazil, it is found in the entire Amazon basin, preferentially in the *varzeas* (seasonally flooded white water terraces) and in the *igapó* (perennially flooded margins of black or clear water rivers and streams), frequently in association with ucuúba (***Virola surinamensis***) and Pará rubber (***Hevea brasiliensis***) (Cavalcante et al. 1986). It is occasionally cultivated on the *terra firma* (dry uplands), generally on well drained clay soils, where it grows well (Le Cointe 1947, Bena 1960, Carruyo 1972, Loureiro et al. 1979, Pennington et al. 1981).

Forest inventories in various parts of Amazônia, done by FAO in 1956-1961 (SUDAM 1975), found 0.24-4.91 trees/ha. RADAMBRASIL (1974/78) also found the species in diverse areas.

Glerum & Smith (1965) found an average of 1.2 trees/ha near Curua-Una, Pará, with diameter at breast height (DBH) above 45 cm. On the Ilha de Marajó and in Pará's Zona da Mata), IDESP (1975) found 1.87 trees/ha in *terra firma* primary forest, 4 trees/ha in transitional forest between *terra firma* and *varzea* and 1.6 trees/ha in primary *varzea* forest, in all cases for trees with DBH ≥ 25 cm.

In SUFRAMA's Agricultural District, Manaus, Amazonas, an average of 3 trees/ha were found in *igapó* forest and 7 trees/ha in *terra firma* forest, all with DBH ≥ 25 cm (PROFLAMA 1972). At INPA's Tropical Silviculture Experiment Station, in the same Agricultural District, Jardim (1985) found only 0.125 trees/ha with DBH ≥ 20 cm. Three hundred kilometers further north, in Presidente Figueiredo, Amazonas, Poyry (1984) found only 0.4 trees/ha (DBH of 30-60 cm) in *terra firma* forest and 0.6 trees/ha in *igapó* forest in a 8000 ha sample. In the same area, at the Balbina Hydroelectric Project, Rio Uatumã, Amazonas, INPA's Tropical Silviculture Dept. found only 1 tree/ha with DBH ≥ 10 cm (INPA 1983).

In the Projeto Esperança area, Novo Aripuanã, southern Amazonas, Jardim & Fernandes (1983) found 0.3 trees/ha with DBH ≥ 25 cm. Further west, in the Polo Juruá-Solimões, Amazonas, Hosokawa (1981) found 1.2 trees/ha with DBH ≤ 50 cm and 1.1 with DBH ≥ 50 cm.

Uses and economic potential

The wood of andiroba is its principal use, being considered one of Amazônia's noble timbers, and the seed oil is used in popular medicine as a home remedy. The oil has other potential uses, however, which will be explained.

Principal use

The wood is moderately heavy (0.70-0.75 g/cm^3); the heartwood is dark red to reddish-brown immediately after cutting; the outer wood is pale brown; the grain is quite regular, the texture is a little thick, the smell and flavor are indistinct. The wood works very well, accepting a finish exceptionally well, and is very popular on the local market for furniture and cabinetry; when prepared as charcoal it has high calorific potential (SUDAM 1979).

A combination of air and oven drying is recommended to avoid warping. It is not resistent to soil rot (Loureiro et al. 1979). Preservation tests have classified andiroba as difficult to impregnate, due to a very low absorption rate and only superficial penetration (SUDAM 1979).

Secondary uses

Andiroba seeds contain approximately 74% kernel and 26% shell (Pinto 1963). The kernel contains 56% liquid oil, which is a transparent yellow color, that will solidify to a consistency of petroleum jelly at temperatures below 25°C. The fresh oil contains about 9% glycerine, principally olein and palmitin, as well as other glycerines in lower proportions (Loureiro et al. 1979).

Kernel analysis gave the following results: humidity - 40%; proteins (N x 6.25) - 6.2%; fats - 33.9%; glycerines (by difference) - 6.1%; fiber - 12.1%; minerals - 1.8%. Its physical-chemical constants and fatty acid composition are given in Table 1.

Table 1. Physical-chemical constants and fatty acid composition of andiroba oil.

	Pinto (1963)	Amorim (1939)	Loureiro et al. (1979)
Density at 15°C	0.923-0.934	-	0.923
at 25°C	0.930-0.941	-	-
Fusion point (°C)			
(initial)	22.0	30.0	22.0
(complete)	43.0	-	28.0
Solidification point (°C)			
(initial)	19.0	-	19.0
(complete)	5.0	-	5.0
Index of			
Saponification	195-205	197.0	205.0
Iodine	58-76	66.0	33.0
Reichert-Meissl	0.2-3.5	2.6	2.5
Polenske	0.3-3.0	0.4	0.3
Acidity	10-20	18.0	81.9
Refraction at 40°C	1.452-1.459	1.461	1.4648
Insaponifiables (%)	0.6-2.6	1.0	1.0
Volatile acids (%)	0.8	0.7	-
Myristic acid (%)	17.9-18.1	17.9	-
Palmitic acid (%)	9.3-12.4	12.4	-
Oleic acid (%)	56.4-59.0	58.4	-
Linoleic acid (%)	4.9-9.2	4.9	-

Andiroba oil is extremely bitter, both when pressed cold or hot. When obtained by hot press, it becomes cloudy when left standing, condensing out a solid white fat composed principally of palmitin. This solid fraction is used for making sodium soaps in northern Brazil.

Small quantities of oil are used to sooth muscular distentions, skin tumors and other superficial skin ailments. The Amerindians use it as an insect repellent (Pinto 1963).

The modern export market

Table 2 contains some export information extracted from the IBGE Annual Statistical Summaries (IBGE 1976, 1979, 1982, 1985). The external market for these kernels is clearly quite small. The use to which they are put outside of Brazil is not explained in the literature cited here.

Table 2. Exports of andiroba kernels (MT) from 1974-1985 (IBGE 1976/79/82/85).

year	1974	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
tons	325	252	302	233	276	277	305	342	334	345	356	363

Collection methods and yields

A mature andiroba tree may produce 180-200 kg of kernels/ year (Rizzini & Mors 1976). In a monoculture, at moderate density (6 x 8 m) [an area of 3 x 4 m is used in some silvicultural research (see below)], a yield of 25-50 kg/tree might be possible. This extrapolates to a yield of 5-10 MT/ha/yr, which contains 50% oil. The seeds are collected from the ground around the tree, preferably within a couple of days after falling to avoid predation by mammals and insects (SUDAM 1975).

In Amazônia, andiroba oil is extracted in small processing plants by the following process: the seeds are ground into small sections; these are dried in an oven at 60-70°C until humidity reaches ≈8%; the mass is then pressed at 90°C, in hydraulic presses of the "Cage Press" or "Expeller" type. Double pressing rarely yields more than 30% oil from seeds at 8% humidity, a rather disappointing yield (Pinto 1963).

Propagation and cultivation methods

Andiroba seed germinates well (85-95%) if sown soon after falling from the tree (Viana 1982), starting within 6 to 10 days after being sown in sand covered by sawdust. Germination is complete within 2-3 months (Viana 1982) and the seedlings can be transferred to plastic nursery bags; alternatively, they can be sown directly into the nursery bags (Loureiro et al. 1979, Alencar & Magalhães 1979). Direct sowing is easy and more efficient because of the size of the seed (≈60 seed/kg) and its rapid germination. This practice is recommended when the plantation area is near the seed production area, since the seed only remain viable for 2-3 months. Direct sowing, however, may be difficult because of rodent attack; the rodents are attracted by the large nutrient reserves of the seed (SUDAM 1975). Nursery or field grown seedlings are susceptible to shoot borer (*Hipsiphylla grandella*) attack (SUDAM 1979).

Vianna (1982) concluded that the best conditions for storing andiroba seed is in a humid storage area (14°C and 80% R.H.) or in dry storage (12°C and 30% R.H.), with the seed placed in plastic bags. In either condition, they remain viable for up to 7 months.

Fernandes (1985) analyzed the A. Ducke Forest Reserve (Manaus, Amazonas) experiments and suggested that andiroba could be harvested on a 18-23 year cycle, based upon height, diameter and volume data in plots on yellow latosools, planted at 3 x 4 m. He found yields of 152.5-189.5 m^3/ha. At the Curua-Una Experiment Station, Pará, in full sun, planted at 2.5 x 2.5 m, the andiroba showed 80% survival, and average annual increments of 1.8 m in height, 1.1 cm in diameter and 11.4 m^3 in volume; the trees started to fruit at 10 years (SUDAM 1979).

Andiroba has been recommended for second growth enrichment near Belém, Pará, because, after 48 months in the field, it presented an annual growth increment of 1.65 m in height and 1.9 cm in diameter (Yared & Carpanezzi 1981). While these data are of short duration, others (see below) show similar results and suggest that andiroba may have great potential as a forest enrichment and/or agroforestry species. Its seed oil could supply annual income to the agroforester or forest manager after the tenth year until the trees are large enough to cut for timber, at which time the pros and cons of timber versus oil could be weighed. The species also has great potential to help recuperate the large degraded areas in the more humid parts of Amazônia.

Volpato et al. (1972) mention its great potential for planting in full sun, both to obtain oil and wood, and its potential for enrichment planting for wood. Alencar & Araujo (1980) concluded that growth in full sun gave superior diameter increments but inferior height increments when compared to trees planted in primary forest enrichment. They explained that the lower height increments are due to intense attack by *H. grandella* or excessive insolation. The former reason appears to be more likely, because the *H. grandella* attack destroys apical dominance and causes excessive branching.

Very little work has been done with andiroba in agroforestry systems or in multipurpose forest management. Its potential as a multipurpose (oil-wood) crop seems great.

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Babassu

Michael J. Balick & Claudio U. B. Pinheiro

Family: Palmae

Species: *Orbignya phalerata* Martius

Synonyms: *O. martiana* Barbosa Rodrigues, *O. barbosiana* Burret, *O. speciosa* (Martius) Barbosa Rodrigues.

Common names: babaçu or babassu (from the Tupi-Guarani: *ba* = fruit; *açu* = large) in Brazil; cusi in Bolivia (Anderson et al. 1991).

Related species:

Orbignya oleifera Burret is found in the Brazilian states of Minas Gerais and Bahia, where it is basically a subsistence oil crop. It is vegetatively similar to babassu (see below), although with fewer leaves. *O. oleifera* has a higher sex ratio (more female inflorescences), resulting in greater fruit yields (≈ 5 MT/ha/yr vs ≈ 1.5 MT/ha/yr for *O. phalerata*), and a higher kernel to fruit ratio (10-22% vs 7%), resulting in significantly higher estimated oil yields (0.5-1.1 MT/ha/yr vs 0.1 MT/ha/yr).

Orbignya cohune (Martius) Dahlgren is found in Mexico and Central America, where it is called *corozo*. It is widely used as a subsistence oil crop and is occasionally processed for local markets. It is vegetatively similar to babassu (see below), but has a much smaller fruit with a thinner endocarp and generally only two seeds, which are much easier to extract.

Both species have potential for hybridization with *O. phalerata* to introduce such useful traits as high sex ratio (*O. oleifera*), high kernel to fruit ratio (both), and thin endocarp (*O. cohune*). A natural hybrid between *Attalea compta* and *Orbignya oleifera* has been identified in Santa Fé, Minas Gerais. This has been described as *Attabignya minarum* Balick, Anderson, and Medeiros-Costa (1987).

Description and phenology

The babassu is a solitary stemmed palm, with stem diameter varying from 20 to 50 cm and attaining up to 30+ m in height. The crown contains 10-25 erectly arching pinnate leaves. The leaf sheath varies from 40 to 120 cm in length, the petiole from 10 to 40 cm, and the leaf rachis from 550 to 850 cm. There are 300-400 leaflets along the rachis, each 20 to 185 cm long by 1 to 6 cm wide depending upon position and tree health and age.

The inflorescences are androdioecious [either exclusively staminate (male) or androgynous (staminate and pistillate (female) together], one arising from the axil of each leaf, although occasional abortions occur. Before anthesis, the inflorescence is covered by a woody bract that splits open along the lower side to release the inflorescence. The peduncle and the main bunch rachis are 50-180 cm long. In staminate inflorescences, there are 270-400 rachillae, each bearing 15-100 staminate flowers. In androgynous inflorescences, there are 320-470 rachillae, each bearing 1-2 (rarely 3) pistillate flowers and one to several staminate flowers that are frequently aborted.

The fruits are broadly elliptic to oblong, 6-13 cm long, 4-10 cm wide and weighing 40-440 g (dry weight). The epicarp is fibrous and 1-4 mm thick. The mesocarp is mealy, dry, and 2-12 mm thick. The endocarp is woody, 35-75 mm in diameter, and contains 3-6 ovate to elliptic seeds (rarely only one or two, or more than six, up to eleven), each 3-6 cm long, with an oily white endosperm.

Babassu has a consistent phenology over a wide range. Leaf emergence and flowering occurs during the local rainy season, followed approximately nine months later by fruit ripening and leaf senescence and loss (Anderson et al. 1991).

Distribution, abundance and ecology

The babassu is widely distributed along the southern edges of Amazônia from the Atlantic Ocean to Bolivia, as well as throughout eastern and central Amazônia and northward to the Guianas.

The babassu zones of southeastern Amazônia, especially Maranhão and Piauí, are areas of extremely high abundance of this palm. Anderson et al. (1991) report abundances of 10,000 palms per hectare, although the vast majority of these are seedlings and stemless juveniles. Fruiting palms can number 100-200/ha. These authors emphasize that the *babassu zones* are directly related to human activities in the area, as the babassu is an especially vigorous colonizer of disturbed sites. The *babassu zones* currently occupy 100-150,000 km^2 along the southeastern fringes of Amazônia, especially Maranhão, Piauí, Goiás and Tocantins states in Brazil, and are probably expanding in most areas as human activity degrades previously forested land (Table 1).

Table 1. Babassu coverage and estimated productivity and fruit production in the states of Maranhão (MA), Piauí (PI), Goiás (GO)* and Mato Grosso (MT) (MIC/STI 1982).

State	Occurrence (ha)	Effective Area (ha)	Mean Yields (kg/ha)	Annual Production (MT)
MA	10,303,503	4,722,812	1,689	7,796,000
PI	1,977,600	502,842	1,245	626,000
GO	2,970,900	1,137,655	2,921	3,324,000
MT	3,184,156	612,386	1,135	695,000

* The state of Goiás is now divided into two states: Goiás and Tocantins.

In primary forest in southeastern Amazônia, there may be as many seedlings and stemless juveniles, but the mature, fruiting palms are rarer ($\approx$ 50/ha) because they require the occasional forest gap to attain sufficient stature to receive enough light to fruit. In other parts of Amazônia, however, the babassu is less abundant, possibly because soils are generally poorer than in Maranhão or because local ecotypes are less vigorous.

The babassu has extremely wide ecological tolerances, although the *babassu zones* tend to be found in areas with favorable soils and climate. In the cerrados (semi-forested savannas), the babassu grows with an average rainfall of 1200+ mm and six months or more of drought. While it occurs on well to excessively well-drained upland soils, it is more abundant (forming *babassu zones*) in the gallery forests along water courses, where it can easily obtain sufficient moisture. In the forested parts of its distribution, the babassu grows with 1500-2500 mm mean rainfall and six months or less of drought. It grows on both upland and valley soils, forming *babassu zones* where soil characteristics and human activities are favorable. Although it occurs in ecosystems characterized by severe flooding, eg. the wetlands or *baixada* of Maranhão, it is limited to non-flooded elevations in these areas.

Uses and economic potential

During this century, the babassu has become an important subsistence resource in southeastern Amazônia, especially in Maranhão and Piauí, Brazil. A minimum of 300,000 families harvest babassu in Maranhão, and are often dependent upon this activity for their economic survival. All parts of the plant are used in the rural household subsistence economy (Table 2). Although it is extremely important in rural areas, it is difficult to quantify its economic value because most of the uses cited are subsistence-based. May (1986) offered a conservative estimate of an annual combined economic and subsistence value in Maranhão of US$85 million.

Principal use and market value

The kernel contains 60-70% of a vegetable oil rich in lauric acid, similar in composition to that of coconut (*Cocos nucifera* L.) or African oil palm kernel (*Elaeis guineensis* Jacq) (Pesce 1985). Unfortunately, only 6-10% (mean 7%) of fresh fruit weight is kernel, so oil yields are low (90-150 kg/ha/yr). Nonetheless, at least 85,000 MT of babassu kernel oil were obtained yearly during the 1970's in Maranhão.

Pesce (1985) states that babassu kernel oil first became an important commodity during World War I, when other sources of vegetable oil became scarce in Europe. At that time it was used principally as an edible oil, both for making margarine and as a cooking oil. Anderson et al. (1991) showed that babassu kernel exports peaked during World War II, at 40,000 MT (≈ 26,000 MT oil), and fell to zero by the mid-1960's. Occasional exports are still processed if international prices are attractive. In the mid-1980's, for example, there was a shortage of coconut oil and some babassu oil was exported at ≈ US$1,000 to US$1,200 per MT. When coconut oil markets returned to normal, babassu ceased to be exported again. As can be seen in Figure 1, production and exports of babassu oil are extremely variable, due to linkage with the world market for coconut oil.

After 1965, the Brazilian soap and cosmetic industries absorbed all babassu oil production (peak production of ≈ 150,000 MT in 1985). Currently babassu oil remains Brazil's most important source of lauric acid oils, although the industries in southern Brazil have successfully lobbied the government to liberate the importation of coconut and African oil palm kernel oils because sources of babassu oil are more expensive than alternative oils, less reliably obtained and starting to become scarcer as the *babassu zones* are privatized and/or eliminated in Maranhão and elsewhere.

Table 2. Subsistence uses of the babassu palm (adapted from May et al. 1985).

Tree

Shade for human dwellings and livestock
Food from palm heart extracted from crown meristem
Mulch used in gardens from decayed stems and leaves

Leaves

Fibers for baskets, mats, fans, sieves, twine, torches, whisks, bird cages, hunting blinds, animal traps
Whole for thatching roofs and walls, burned for nutrients recycling and pest control
Petioles for laths for window frames and support of clay-packed walls, rails for fencing, crop support, raised planters
Medicine is obtained by pressing a juice from the rachis, which is used as antiseptic and styptic

Stems

Construction - entire stems used to make bridges, foundations, benches
Food - sap collected from stumps of felled palms is used to attract beetle larvae that are eaten or used as fish bait

Fruits

Whole fruit - burned to smoke rubber; used to attract game, principally large rodents
Kernels - consumed raw as snack nuts; made into "milk" to use as a beverage or for stewing meat and fish; pressed to extract oil used for cooking, lighting, soap; residues used as animal feed, fish and shrimp bait and as substitute or filler for coffee; beetle larvae extracted from kernels used as human food or to grease bows so as to increase resiliency
Mesocarp - flour used as substitute for manioc or to make chocolate-like beverage
Medicine - liquid endosperm used to treat wounds and bleeding; tar from burning husks rubbed on gums to alleviate toothaches; mesocarp flour as a "panacea" used to treat gastric ulcers, colitis, varicose veins, cellulitis, rheumatism, hernias, allergies, asthma, obesity, alcoholism and leukemia
Husks (endocarp) - used to make charcoal, which is a principal source of fuel for cooking, smoke also acts as insect repellent; for handicrafts

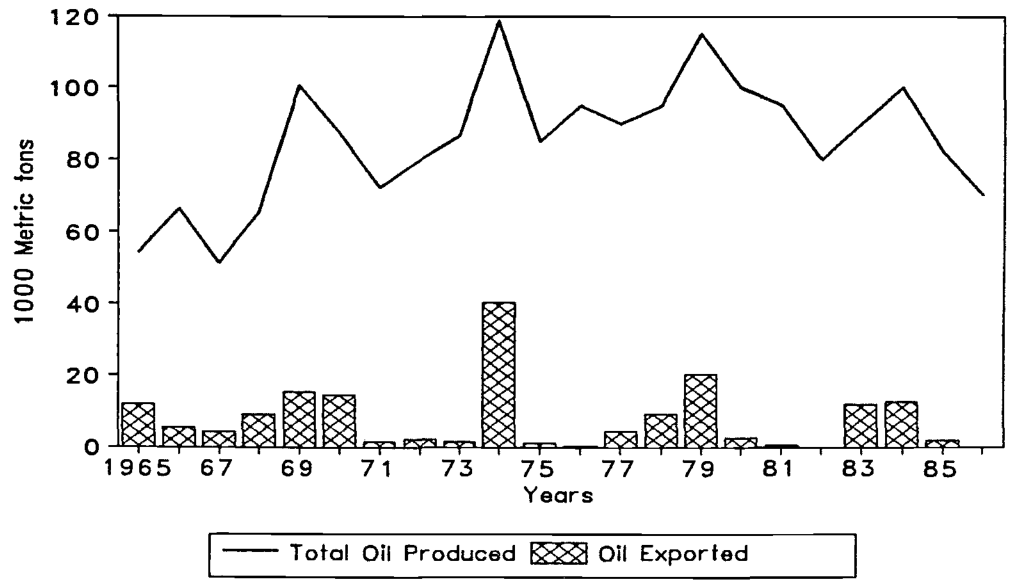

Figure 1. Babassu kernel oil production and exports during the period 1965-85. Note that exports only occur when coconut oil is scarce or its price is higher than babassu oil.

Secondary uses and market potential

The most important "secondary use" of babassu today is for the preparation of charcoal from the fruit endocarp. This charcoal is of exceptionally high quality, being a suitable substitute for high-quality metallurgical coking coal (Table 3).

This high-quality charcoal is an important fuel in the babassu zone. An average family uses 500 kg/yr, obtained from 1.7 ha of *babassu zone*. If babassu is unavailable, the same family would need 3.2 m^3 of fuelwood, which, ideally, would come from a sustained-yield timber plot devoted to this purpose. Unfortunately, this type of timber plot does not exist to day in most places in Amazônia or the Brazilian northeast, so that primary or secondary forests will be degraded in order to supply this wood.

This charcoal has potential for the pig-iron foundries now established along the Carajás-São Luis railroad. The loss of primary and secondary forest around these foundries is already serious and growing rapidly. If babassu were sown to provide this charcoal in the future, it would both enhance employment opportunities in the region and provide a sustainable yield of charcoal. Whether the babassu can yield enough to make this idea attractive to Vale de Rio Doce and the private foundries remains to be seen.

Table 3. Comparison of babassu charcoal and two sources of high quality metallurgical coal (Anderson et al. 1991, Pesce 1985).

	Anderson et al.		Pesce	
	Babassu Charcoal	Cardiff Coal	Babassu Charcoal	Arley Coal
	-- % wt --			
Fixed carbon	81-91	59	75	79
Volatile matter	4-15	34	16	12
Ash	4-6	6	4.2	3.5
Sulfur	0.05	0.9	-	-
	- kcal/kg -			
Caloric pot.	7250	7000	8000	7900

Babassu charcoal has at least one disadvantage, however, it is fine-grained. Thus it requires pressing and gluing into briquettes for shipping and use. If the charcoal is prepared in steel kilns, however, numerous by-products are obtained, such as tar, methanol and acetates. The tar can be used to bind the charcoal grains into briquettes. The other by-products have potential markets, both in Brazil and internationally (Anderson et al. 1991; IPT 1979).

Pesce (1985) considered babassu mesocarp to have great potential as a starch source, as 60+% of the dry mesocarp is starch. Anderson et al. (1991), however, mention babassu starch only as a minor product, useful in animal feeds or as a raw material for fermentation to alcohol. An additional use, as medicine for a variety of ailments (Table 2), is also possible. Pharmacological studies recently undertaken by Maia and Rao (1989) demonstrated that in rats the mesocarp powder possesses anti-inflammatory properties.

José Mário F. Frazão, of EMAPA, in São Luis, Maranhão has recently developed a simple tool for extracting the palm heart from stemless juvenile plants, of which thousands exist in a *babassu zone*. The palm heart of babassu is bone white and has a slightly sweet, very agreeable flavor, which suggests that this product has potential in a managed babassu zone.

Chemical analyses

As can be seen from Table 4, babassu oil is remarkably similar in its chemical and physical properties to coconut oil. This similarity allows for the use of babassu oils in cosmetics, confections, etc. where coconut oil has been traditionally used.

Table 4. Chemical Composition and Properties of Coconut and Babassu Oils (Source: Eckey, 1954).

Fatty Acids (%)	Coconut Oil	Babassu Oil
<u>Saturated</u>		
Caproic	0.0-0.8	0.0-0.2
Caprylic	5.5-9.5	4.0-6.5
Capric	4.5-9.5	2.7-7.6
Lauric	44.0-52.0	44.0-46.0
Myristic	13.0-19.0	15.0-20.0
Palmitic	7.5-10.5	6.0-9.0
Stearic	1.3	3.0-6.0
Arachidic	0.0-0.4	0.2-0.7
<u>Unsaturated</u>		
Oleic	5.0-8.0	12.0-18.0
<u>Fat Characteristics</u>		
Iodine Value	7.0-10.0	10.0-18.0
Saponification Value	251.0-264.0	245.0-255.0
Acid Value	1.0-10	1.8-8.5
R-M Value	6.0-8.0	5.8-6.2
Polenske Value	12.0-18.0	10.0-12.0
Unsaponifiable	0.15-0.6	0.2-0.8
Melting Point (°C)	23.0-26.0	22.0-26.0
Titer (°C)	20.0-24.0	22.0-24.0
Refractive Index nD40°C	1.448-1.450	1.449-1.451

Yields, harvesting and processing methods

Babassu is a low yielder in most ecosystems, averaging only 1.5 MT/ha/yr in Maranhão. There are indications, however, that adequate management of natural stands can double this. Nonetheless, even 3 MT/ha/yr is a low yield. As mentioned above, however, ***Orbignya oleifera*** yields an average of 5 MT, so there is potential for increasing the yield of the genus if it is to be commercially exploited.

The babassu fruit is generally harvested after it has fallen from the bunch. People gather the fallen fruit and either split it immediately to remove the kernel or take it home for later kernel separation. The fruit can be stored for subsequent kernel extraction, but a beetle can destroy one or more kernels.

Kernel extraction has traditionally been carried out by women and children, who take a whole fruit and split it lengthwise by pounding it with a mallet against an up-turned axe blade. Two or three splits are necessary to extract all the kernels. This labor intensive process generally yields per day 5-8 kg of whole kernels per person, with many damaged ones resulting.

The numerous industrial efforts for babassu in Maranhão and elsewhere have attempted to develop mechanical methods for extracting the kernels. Unfortunately, babassu is not a cooperative fruit with which to work, as fruit vary widely in size and in number of kernels contained in each. Consequently, machine extraction yields mostly damaged kernels that must be processed immediately to avoid rancidity.

As the babassu industry moves from an oil-extraction process to integrated use of the fruit (see Anderson et al. 1991), machines to separate the husk from the mesocarp and the kernel from the endocarp are being developed. Village or farm level machinery is also being developed. Current work is extremely promising at the village level, as this allows the rural inhabitants to obtain a greater percentage of final price for the material that they sell. Although Anderson et al. (1991) do not provide much detail, because of the incipient nature of this project, this is the most likely route that could be followed to reinvigorate the babassu industry and to permit babassu to return to prominence as a valued renewable resource of Maranhão and elsewhere.

In 1989-1990, the first village-level babassu processing plant was set up near Bacabal, Maranhão, in the area of an agricultural cooperative. The Agricultural Research Enterprise of Maranhão (EMAPA) and the Financiadora de Estudos e Projetos (FINEP) collaborated on the development of a village scale splitting and processing technology. Simple, but durable machines were developed to separate the husk and mesocarp from the endocarp, and to crack the endocarp to extract the seeds. A village-level oil press, designed to handle small amounts of kernel at each pressing, could then be used to immediately extract oil and avoid rancidity. Small kilns were designed to make charcoal and extract tars.

The model proposed by EMAPA for that area included the introduction of mechanization and integral processing of fruits at the village level, and the organization of fruit collection and transportation to the processing area. In this system, fruits are gathered by cutting off the mature infrutescences (just after the fruits start falling), and by using the traditional system of collecting the fruits which have already fallen to the ground. By using this system, a person can collect, on average, 25 infrutescences/day, equivalent to ≈ 625 kg of fruits. Animals carry the fruits to the roads, and the fruits are transported to the processing area by trucks. Using small-scale equipment with capacity of processing ≈ 15 MT/day, the working area for fruit collection must have approximately 3 km of radius which corresponds to ≈ 2,850 ha of continuous area. The area must also have an effective palm coverage of approximately 50-60% and a mean productivity of 1,800 kg of fruit per hectare in order to satisfy the processing capacity of the equipment. The machinery consists of a dehusking machine which separates epicarp and mesocarp (capacity of 2 MT/hr), a breaking machine (1.5 T/hr), and as the final step a machine to separate the small pieces of broken endocarp from the kernels.

If the processing plant works as planned, and the cooperative can market the kernel oil, kernel press cake, starch, charcoal and tar, the members of this cooperative stand to receive five times what they would have received for fresh kernels from the same amount of fruit. This economic incentive could help reestablish babassu's prominence in the local community.

Additionally, members of the cooperative were organized to manage their babassu zones as agroforestry systems. At densities of up to 80 palms/ha, subsistence crops can be planted and yield well under the palms. Rice, maize and manioc are the traditional crops of this area. Anderson et al. (1991) point out that a shifting cultivation cycle of only 4-5 years can be established under babassu because the palm produces such a large foliar biomass. Every 5 years the leaves are cut and burned to provide nutrient-rich ash for planting crops. After the harvest, the palms recuperate and continue to yield fruits that help sustain the farm family until the next cropping cycle.

The combination of village-level processing and an adequate agroforestry management of the babassu stands with annual crops appears to be sustainable both ecologically and economically in this part of Maranhão. This could contribute to raising the extremely low standard of living in rural Maranhão to levels that could create a permanent rural economy based on babassu. These same technologies are planned for use in the first extractive reserve for babassu being organized in Maranhão.

Propagation and cultivation methods

The embryo in the babassu seed is straight and basal, measuring, an average 1.0 cm long by 1.5 mm wide (Pinheiro & A. Neto, 1985). The babassu seed has a type of germination known as "remote tubular," according to classification of Gatin (1906), and it germinates hypogeally, since the cotyledon does not emerge from the seed. A cotyledonary axis (comprising petiole and sheath) elongates 20-60 cm downward from the kernel into the soil, carrying the undeveloped plantlet (plumule and radicle) below the surface. The haustorium (Tomlinson, 1960) enlarges within the seed and occupies the space formerly filled by the endosperm. The radicle (that precedes the plumule) persists for a limited period, reaching 20-40 cm in length, and is replaced by adventitious roots. The first leaf grows out through an opening in the sheath.

Fire and shade stimulate germination, both conditions being common in the forest-cerrado transition zone where babassu is most common. The palm forms an extensive root system that can extend to several meters in depth and a dozen meters or more from the stem. The apical meristem remains buried in the soil as it expands in diameter, usually requiring several to many years to produce enough leaves to provide sufficient diameter to start stem growth. This period encompasses the seedling and stemless juvenile phases of babassu growth and the plant is difficult, if not impossible, to kill at this stage because the meristem is buried in the soil. As one might imagine, it is also extremely difficult to manage this type of growth in a nursery.

One of the great difficulties when working with palms in nursery production is obtaining reliable germination levels. Considerable work on germination of the babassu seed has been carried out at EMAPA, Maranhão, Brazil (Frazao & Pinheiro 1985; Pinheiro 1986; Pinheiro & Araujo Neto 1987ab).

Most work with babassu has focused on managing natural stands, rather than creating new plantations (although this is also being attempted). As mentioned in the above discussion, babassu is an excellent candidate for agroforestry systems; it is also an excellent silvo-pastoral component.

In either case, the large number of seedlings and stemless juveniles need to be controlled. Because these plants are immune to fire and slashing, they must either be harvested for palm heart or sprayed with systemic herbicides. A mix of juveniles and young fruiting plants can then be identified for further management; the older fruiting plants and purely staminate plants can be eliminated as they contribute little or nothing to stand productivity. A stand density of 80 plants will permit adequate light to reach the soil for either annual crops or pasture to grow under them. Meat yields from cattle are reputed to be higher in pasture under babassu stands, probably because of a combination of nutrient cycling from the palms, shade for the cattle and the generally better management practiced in the area to control the palms.

No information has been published on babassu response to fertilizer application, although trials are underway in Bacabal to determine the result of fertilization. Since the palm does better where soils are naturally richer, it is expected that it will respond well to any fertilizer applied. In both agroforestry and silvo-pastoral systems, some fertilizer will need to be applied to restore nutrients lost by export from the area. This might only be necessary at relatively advanced ages, however, because of babassu's deep and extensive root system that is reputed to be an efficient deep soil to surface nutrient pump. Additional research is necessary on this topic.

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Ucuúba

Paulo de T.B. Sampaio

Family: Myristicaceae

Species: *Virola surinamensis* (Rolander) Warb.

Synonyms: *Myristica surinamensis* Rolander, *M. fatua* Wartz, *M. angustifolia* Lamark, *M. sebifera* Aublet var. *langifolia* Lam., *Virola mycetis* Pulle.

Common names: Ucuúba, ucuúba da várzea, ucuúba branca, bicuiba (Amazônia brasileira), andiroba (Ceará, Brazil); virola, guingumadou, guingamadou de montagne, yayamadou, yayamadou de marecage, jea, flamadou, moulamba, moussigot, bali, dalli, arbre a suif (French Guiana); bamboen, bamboentrie, baboenhoedos, baboenhout, baboum, houdou, moonba, dallie, waroesie, moschetboon (Suriname); dalli, dalliba, white dalli (Guyana); camaticaro, cuajo (Venezuela), cajuca, wild nutmeg (Trinidad); muscadier fou (Guadalupe); camaticaro (Colombia); banax (Honduras); cumala (Peru); muscade de Pará, cove longo (Spain).

Related species

Virola divergens Ducke - This species produces an oil that contains "trimyristine", with applications in perfumes, shaving soaps and pastries (Pinto 1951). The wood is moderately heavy (0.55-0.65 g/cm^3) and widely used for plywood (Loureiro et al. 1979).

In the forest the tree can attain 25 m in height and 1 m in diameter at breast height (DBH). The young branches and leaf petioles are covered with tomentum, the leaves are oblong (18-45 cm in length by 15-60 mm in width) and leathery. The male inflorescence is abundantly branched, to 25 cm long; the female inflorescence is less branched, 6-18 cm long. Four to eight fruit are produced per bunch, each covered with a velvety coat (Loureiro et al. 1979). The species is a heliophyte, occurring generally at the forest edge on the *terra firma* (the dry uplands of Amazônia). Flowering is from April to July (Pinto 1951) and fruiting from July to January in Manaus, Brazil (Loureiro et al. 1979). Manaus is its probable center of origin; it is distributed from Pará, through Amazonas, to Acre and Peru (Rodrigues 1972).

Virola multinervia Ducke - This species produces small quantities of the alcaloide N, N-dimetil-triptamine in the root, although less than in other species of the genus (Silva et al. 1977). The wood is moderately heavy (0.55-0.68 g/cm^3) and used for plywood (Loureiro et al. 1979).

In the forest the tree can attain 35 m in height and 45 cm in DBH. The male and female inflorescences are 15-20 cm long, abundantly branched; the bunch contains 3-15 oblong fruits with reddish arils (Silva et al. 1977). It is distributed in central and western Amazônia (Amazonas and Acre in Brazil and in Peru) as a component of the *terra firma* forest.

Description and phenology

Ucuúba is a large tree, attaining 30 m in height and 1 m in DBH, generally with a straight, cylindrical trunk, above the buttress roots. The smooth bark is yellowish-brown, with occasional gray or white areas. The crown is small, with few, horizontally oriented, densely leaved branches. The alternately spaced leaves have short petioles, a leathery textured leaf blade with a thin oblong shape, 10-20 cm in length by 2-5 cm in width, with a rounded to subcordate base and long thin apex. The inflorescence is abundantly branched, with 5-20 terminally grouped flowers, each 1.6-2.4 mm in length (Rodrigues 1972). The fruit are smooth, greenish, spherical, bi-lobed capsules, that dehisce at maturity, liberating the seeds. These have thin, loose, papery rinds, brown at maturity, blackening with time, 12-14 mm in diameter, weighing about 1.4 g each, with a 9-12 mm diameter, firm, oily endosperm (Pinto 1951).

In French Guiana the ucuúba flowers twice a year, in March and September, with fruiting in May-June and November-December (Bena 1961). Near Manaus flowering extends from August to November and fruiting from January to July (Rodrigues 1972).

Distribution, abundance and ecology

Virola surinamensis is widely distributed from the Lesser Antilles throughout northern South America down to Bolivia in the west and around the Brazilian Northeast coast to Recife, Pernambuco, in the east. In Brazil it occurs in all of Amazônia (Rodrigues 1972).

Glerum (1962) gives a detailed report of ucuúba abundance in the lower Amazon River basin (Table 1). In this region it occurs in association with the *buriti* (***Mauritia flexuosa***), *assai* (***Euterpe oleracea***) and *ubuçu* (***Manicaria saccifera***) palms. The presence of buriti is a good indicator of the presence of ucuúba (Glerum 1962).

Near Manaus, Loureiro et al. (1979) reported abundances of 3-30 ind./ha in the *varzea* and associated streams. Poyry (1984) reported an abundance of 1 ind./ha on *terra firma* and 2 ind./ha in black water stream swamps in Presidente Figueiredo, 300 km north of Manaus.

Table 1. Abundance of ucuúba in the lower Amazon region (lower Tocantins River, Amazon River estuary and lower Amapá River) in 1960 (adapted from Glerum 1962).

	Diameter Class (cm)				
Area	1 (5-14)	2 (15-24)	3 (25-34)	4 (35-44)	5 (45-)
Tucurui - Baiao	1.7	0.9	0.4	0.2	0.3
Estuary Islands	12.9	12.4	12.7	9.6	7.2
Amapá River	5.0	4.3	3.1	1.7	0.6

Ucuúba prefers swampy, fertile habitats, occurring in the *varzea* of the Amazon River and its muddy tributaries. The *varzea* habitat extends from the river's edge through a series of low-lying dikes, swamps and lakes, up to the edge of the *terra firma* and is seasonally flooded by the river. It generally does not occur in black or clear water rivers, except for the Negro River because of human intervention; in these habitats it is substituted by the vicariants *V. carinata* and *V. pavonis*. In these habitats it occurs in the open, i.e. it is heliophyllous. Rodrigues (1972) reports that growth is slow until the tree attains 25-35 cm DBH, after which it speeds up considerably; at this DBH the crown is probably finding its place in the sun.

Uses and economic potential

Principal use

Ucuúba wood is clear beige, soft and light (0.45-0.55 g/cm^3), with rosy to nut-brown tinged heartwood, which takes on a silky sheen in the right light. It has a regular grain, medium texture, no distinct flavor or smell. The wood is easy to work and is widely used in light carpentry, for shipping boxes, match sticks, plywood and pulp for paper (Loureiro et al. 1979). Bertin (1920) states that the wood is not durable, however, rotting quickly (within 3 years) when exposed to the environment, principally because of fungal and insect attack. Therefore, a preservative treatment on the wood is necessary immediately after cutting.

Secondary uses

Ucuúba fat was extremely important in Amazônia before World War II but has gradually lost its importance because the wood is being heavily exploited for plywood and because other sources of fats have become more easily available. Near Manaus, commercial timber size trees are extremely rare today and other areas of the middle and lower Amazon basin are in a similar state. Nonetheless, this species has great potential as a multipurpose species, with harvesting of its oily seed before the plantation is mature for logging.

Pinto (1951) reports that the small seeds have 81-88% endosperm, which contains 60-73% (Tables 2 & 3) oil with a clear yellow color, locally called "sebo de ucuúba", composed principally of the glyceride "trimyristine". Baruffaldi et al. (1975) detail the triglyceride structure of this fat (Table 4). Unless the oil is extracted from fresh or carefully stored seed, it will have a dull brown color (Pesce 1941). Just after World War II, this oil had an important world market for perfumery and cosmetics (Pinto 1951).

Table 2. Centesimal composition of ucuúba seed (Pinto 1951).

	Fresh weight	Dry Weight
Humidity	9.3%	-
Fats	60.8%	67.0%
Proteins	10.5%	11.6%
N-free extract & fiber	17.4%	19.3%
Minerals	2.0%	2.1%

Sebo de ucuúba is popularly used to treat rheumatism, arthritis, stomach aches due to gases, and dyspepsia (Rodriguez 1975). Lucent (1947) reports that cooked bark is used to sterilize wounds and aid healing. Its sap, mixed with *camupu* (**Physalis** sp) extract, is used to treat hemorrhoids (Rodriguez 1975).

Prance (1970) and Schultes (1971) report that the ground bark of several species of ***Virola***, including ucuúba, is smoked for its hallucinogenic effects by many Amazonian tribes, who call it "parica". Schultes (1971) reports that the hallucinogenic agents are 5-etoxi-N, N-dimetilpritmamine and other triptamines, all powerful hallucinogens.

Table 3. Physical-chemical constants of ucuúba fat.

Constant	Lucent 1924	Pinto 1951	Rodriguez 1975	Loureiro et al.1979
Saponification value	219-221	217.2	220.3	219-227
Iodine value (Hames)	9-14	16.9	14.8	12.75
Reichert-Meissl	-	1.1	-	1.4
Insaponifiables (%)	3.2	2.5	3.16	3.2
Free Acids (Oleic) (%)	17.2	10.7	12.0	17.5
Resins (%)	-	4.4	-	-
Glycerine (calc.) (%)	-	11.8	-	-
Total fatty acids (%)	-	88.0	-	-

Table 4. A. Fatty acid composition of ucuúba fats.
B. Principal triglycerides (%) of ucuúba fats.
(From Baruffaldi et al. 1975.)

A.

acid	C8:0	C12:0	C14:0	C14:1	C16:0	C16:1	C18:0	C18:1	C18:2
%	0.7	19.7	68.1	1.7	4.2	0.2	0.2	3.5	0.7

B.

No. carbon atoms	36	38	40	42	44	46	48
	LLL	LLM	LLP+ MLM	LLO+ MLP	PLP	POL+ MOM	MOP+ OOL
	0.1	0.5	3.6	4.2	0.8	0.6	0.8
		LML	MML	MMM+ LMP	MMP	PMP	
		3.6	25.0	29.7	5.7	2.3	
			LPL	LPM	LPP+ MPM	PPM	
			2.4	2.8	0.5	0.2	
				LOL	LOM		
				4.2	0.8		
Total 87.8% =	0.1	+ 4.1	+31.0	+40.9	+ 7.8	+ 3.1	+ 0.8

Recent export data

While Pinto (1951) mentions the importance of ucuúba fats just after World War II, IBGE (1987 and earlier) shows that there is still a small export market for this fat (Table 5).

Table 5. IBGE export data for "sebo de ucuúba".

	1975	1976	1977	1978	1979	1980	////	1986
Tons	110	109	106	85	84	118		12

Collection methods and yields

Pinto (1951) states that the seeds are generally collected at the water's edge, from fruit that have fallen into rivers and streams, so that they are generally cleaner than other oil seeds collected from the wild. Because they are collected from the water, they generally arrive at the processing center with more than 25% humidity; consequently they are generally left to dry in the sun for a few days (Pesce 1941, Pinto 1951). The seeds are then finely ground and pressed to extract the oil, which may be done either hot or cold (Pinto 1951).

An ucuúba tree starts fruiting relatively precociously when grown in adequate ecological conditions and may produce 60-90 kg of seed/year when mature, of which 65-75% is oil (Baruffaldi et al. 1975). At Lucent's (1947) recommended density of 150 trees/ha for oil production, extrapolated yields are quite high: 9-13.5 MT of seed, with 5.8-10.1 MT of oil. The harvesting of these relatively small seed in the *varzea*, however, would be much more expensive than from alternative oil crops on the *terra firma*, eg. African oil palm (*Elaeis guineensis*).

Propagation and cultivation methods

Ucuúba seedlings can be obtained either by germinating fresh seed in germination beds with subsequent transplanting to black plastic nursery bags or by direct sowing into the nursery bags. Sixty to seventy percent of the seeds will germinate within 112 days. The nursery substrate used is 3 parts A horizon forest oxisol or ultisol with 1 part well-rotted manure (SUDAM 1979).

Lucent (1947) suggested monoculture plantations of ucuúba at 144 to 150 trees/ha if the emphasis is on oil yields. At Curua-

Una, Pará, small experimental plots in full sun on yellow latosols (oxisol) at high density (1600 trees/ha) had the following growth characteristics at 18 years: 0.65 m^2/ha/year basal area increment; 0.25 m maximum DBH; 0.07 m minimum DBH; 13.9 m average height; 6.3 m average bole height; 4.93 m^3/ha/year volume increment; and 54.35% crown coverage (SUDAM 1979). At INPA's Tropical Silviculture Exp. Station, 45 km north of Manaus, Amazonas, small experimental plots in full sun on sandy, acid (pH 4.5) podzols (ultisols) presented 96% mortality after 6 years. Pires & Koury (1959) report that ucuúba will sprout from the cut trunk about 25% of the time.

Dubois (1967) suggested two silvicultural methods that may prove promising: 1. the progressive elimination of low commercial value species from natural *varzea* populations of ucuúba, which would stimulate plant growth and natural regeneration; 2. agroforestry, starting from intercropping of ucuúba with annual or perennial crops. Neither of these methods has received research attention, however.

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Cumaru

Paulo de T.B. Sampaio

Family: Papilionoideae (Leguminosae)

Species: *Coumarouna odorata* (Aubl.) Willd.

Synonyms: *Baryosma tongo* Gaertner, *Dipteryx odorata* Willd.

Common names: Cumaru, cumaru amarelo, cumaru roxo, cumaru do Amazonas, kumbaru, paru, muirapaye (Brazil); cumara, cuamara (Guyana); sarrapia (Colombia); guayae, faux, fevetonka, faux gaiac (French Guiana); angustura, serrapia, yape (Venezuela); ebo (Costa Rica, Panama, Honduras); tonka bean (English).

Related species

Dipteryx punctata (Blake) Amshoff. - Cumaru amarelo, or yellow cumaru, is a medium-sized tree (to 20 m), common in humid areas within the forest or along the edges of rivers. The bark and outer, white wood emit a strong odor of coumarin. The fruit is morphologically identical to those of *C. odorata*, although generally a little smaller. The oily seeds have a strong aroma and are used to cure pneumonia and to prepare snuff (Silva et al. 1977). It occurs in Amazonas and Pará states, Brazil, and is rarely found in Suriname, Venezuela and the Antilles (Ducke 1948, Silva et al. 1977).

Coumarouna rosea (Spruce ex Benth) Taub. - This is a small tree, common along river edges and in flooded areas. It occurs in Brazil, Colombia and Venezuela. The fruit and seeds are difficult to obtain, because they generally fall in the river when ripe. The seeds are strongly perfumed and are used to extract coumarin (Ducke 1948).

Coumarouna charapilha (MacBride) Ducke - This is a large tree (to 30-40 m), with aromatic flowers. The fruits are similar to those of *C. odorata*, except for the longer fibers covering the endocarp. The seeds are strongly perfumed. It occurs in western Amazônia (Ducke 1948).

Coumarouna tifoliolata Ducke - This is also a large tree (to 30-40 m) The fruits have a relatively thick pericarp, which is very oily, sweet and edible. The seeds are rich in coumarin, considered to be of very fine quality (Ducke 1948). It occurs in Roraima (Brazil) and Venezuela (Ducke 1939).

Description and phenology

Cumaru is a large tree of the primary forest, attaining up to 30 m, althoug h smaller in secondary forests or when cultivated. The trunk is cylindrical, a light brownish-yellow color, with smooth bark and short buttresses (to 1 m). The leaves are compound, alternately pinnate, with elliptical-oblong leaflets which are frequently asymmetric, the whole attaining 20 cm in length by 8 cm in width. The panicle inflorescences are terminal, rusty colored, with hermaphrodite, zygomorphic, aromatic flowers. The fruit is a oblong-oval indehiscent drupe, 5-7 cm long by 3 cm in diameter, yellow-green when mature. The pericarp (pulp) is fleshy, sour, not edible, enveloping woody endocarp. The seed is smooth, hard, 2.5-3 cm in length, dark purple-red in color, furnishing a clear yellow, aromatic (coumarin) oil (Ducke 1948, Loureiro et al. 1979, Prance & Silva 1975).

The cumaru flowers during the late dry season (September to October in Manaus, October to November in Belém), with variations that depend upon rainfall. The fruits mature approximately 9 months later, falling from May to July (Manaus) and June to August (Belém) (Alencar et al. 1979).

Distribution, abundance and ecology

The cumaru is widely distributed in the Neotropics, extending from the humid forests of Honduras through Central America, to northern South America. It is found in all of the Amazonian countries and along the Caribbean and Atlantic coasts of the Guianas. In Brazilian Amazônia it is found in all states and as far south as Corumba, Mato Grosso (Loureiro et al. 1979, Prance & Silva 1975).

In forest inventories done by the FAO mission, during 1956-1961 (SUDAM 1975), 2.3 trees/ha were found in the forests of Amapá and 0.8 trees/ha along the Curua-Una River. Volumes of 4.3 and 3.5 m^3/ha were found in the region of Cametá, along the lower Tocantins River, in Pará.

Along the Manaus-Itacoatiara highway (AM-010), an average of 0.03 trees/ha, with diameters at breast height (DBH) greater than or equal to 45 cm, and 0.85 m^3/ha were found. Trees with smaller diameters (DBH ≥ 25 cm) are more frequent (0.3 trees/ha) but have smaller volumes (0.65 m^3/ha) (Loureiro et al. 1979). At INPA's Tropical Silviculture Experiment Station, located in SUFRAMA's Agricultural District, Jardim (1985) found 0.125 trees/ha, with

0.83 m^3/ha, for the DBH class ≥ 20 cm. In an 8,000 ha sample of *terra firma* forest in Presidente Figueiredo, Amazonas (300 km north of Manaus), Poyry (1984) found 0.02 trees/ha with a volume of 0.21 m^3/ha, for the DBH class 60-70 cm.

In the region of Senador Guiomard and Plácido de Castro, Acre, the cumaru is extremely rare (FUNTAC 1989). In Novo Aripuanã, southern Amazonas, Jardim & Fernandes (1983) found 0.57 trees/ha, with 2.4 m^3/ha, for the DBH class ≥ 45 cm.

Uses and economic potential

Principal use

Cumaru's commercial value is currently due to its timber, which is very heavy (0.95-1.0 g/cm^3). Its heartwood is a dark yellow-brown color, somewhat fibrous in appearance, its thin outer wood is a light beige color, its grain is irregular, its texture medium. It is somewhat difficult to work but it takes a good finish (Loureiro et al. 1979).

It is used in naval construction, especially in exposed positions, for truck and train wagons, and for high-quality cabinetry (Prance & Silva 1975). The wood is resistent to rot, withstanding 10-20 years in well drained soils. It is therefore considered an excellent wood for railway ties, not only because of its durability but because it does not split easily when exposed to the sun and elements (SUDAM 1979).

Secondary uses

Historically, the extraction of coumarin (orthocoumaric anhydride) from cumaru seed was nearly as important as its principal use. Coumarin was used in the perfume and cosmetic industry and as a flavoring for tobacco (Pesce 1941/85). The best quality cumaru seed, in terms of size and coumarin quality were obtained from Venezuela, with second-quality from the Guianas and lowest quality from Amazônia (ibid). Exports of cumaru kernels to various northern hemisphere markets have varied widely during this century, ranging from lows of 10-15 MT before 1910 (ibid) to highs of 450 MT in 1987 (IBGE 1988). During the first half of this period, the exports were mostly for the perfume and tobacco industries; during the latter period, its uses in the northern hemisphere are not registered in the bibliography available in Manaus. With recent trends to return to natural products, cumaru could again become an important aromatic product.

Thirty to forty percent (dry weight) of cumaru seeds is a clear yellow, perfumed oil, that oxidizes quickly upon contact with the air (Le Cointe 1934). This oil is similar in quality to other *Leguminoseae* oils, like peanut for example, except that it contains linolenic acid and traces of high molecular weight oils, such as beenic and lignoceric acid (Bentes et al. 1980).

The physical-chemical characteristics of cumaru oil are given in Table 1 (LeCointe 1934, Pesce 1941) and the fatty acid composition is given in Table 2 (Bentes et al. 1980).

Table 1. Extraction yield and physical-chemical constants of cumaru kernel oil, after LeCointe (1934) and Pesce (1941).

Constants	LeCointe	Pesce
Extraction percentage	39.2	43.6
Refraction index at 40°C	1.4608	1.4726
Density a 40°C	0.920	-
Acidity value	0.22	-
Saponification value	212.3	189.0
Iodine value	67.0	66.2
Insaponifiable material value	4.9	-

Table 2. Fatty acid composition (% of oil) determined by gas-liquid chromatography (Bentes et al. 1980).

Acid	16:0	18:0	18:1	18:2	18:3	20:0	22:0	24:0
%	6.60	4.50	47.35	21.56	5.50	6.23	4.33	3.93

16:0 - palmitic; 18:0 - estearic; 18:1 - oleic; 18:2 - linoleic; 18:3 - linolenic; 20:0 - arachidic; 22:0 - beenic; 24:0 - lignoceric.

A water extract of cumaru bark is popularly used as an antispasmodic and general tonic, acting as an efficient moderator of cardiac action and respiration (Loureiro et al. 1979, Prance & Silva 1975).

The seeds are occasionally used to make ornamental necklaces and other handicrafts (Ducke 1948).

Recent export data

Table 3 shows some recent cumaru kernel export data (IBGE 1988). Demand rose dramatically in the late 1980's, although IBGE does not explain why. It is worth mentioning that all of the exported kernels are collected from wild trees in the forest.

Table 3. Recent (1975-1987) exports of cumaru kernels (IBGE 1988).

year	1975	'76	'77	'78	'79	'80	//	'86	'87
MT	13	15	34	42	41	70	//	434	457

Collection methods and yields

Cumaru seeds are collected from the ground under the tree during the fruiting season. Each fruit contains one seed, which is separated manually from the mesocarp and endocarp. There are an average of 137 seed/kg (Ducke 1948, SUDAM 1979, Loureiro et al. 1979).

The dried seeds are treated with alcohol, and covered to dry slowly for several days, after which they are covered with crystallized coumarin (Pesce 1941/85), with an extraction yield estimated at about 3% by dry fruit weight (Rizzini & Mors 1976). More modern technology could surely raise this extraction yield and probably result in better quality coumarin.

For oil extraction, the dried seeds are ground and the oil is extracted with solvents (Bentes et al. 1980).

Seedling cumaru trees start to fruit at 4 years of age on sandy soils at INPA's Tropical Silviculture Experiment Station, 60 km north of Manaus. Early yields are on the order of 500 fruit/tree (Silva et al. 1977), which is equivalent to 3.6 kg of fresh kernel. At 400 trees/ha (a rather open silvicultural planting density, but one suitable for fruit monocultures for later thinning) this is equivalent to 1.4 MT/ha/yr during the early years. Yields at more open densities and with older trees have not been reported.

Propagation and cultivation methods

Both direct seeding and nursery germination and seedling preparation techniques have been used in silvicultural experimentation (Magalhães et al. 1986). Seeds are treated with fungicides and take 20-30 days to germinate 90% (SUDAM 1979, Magalhaes et al. 1986). During the first 60 days after germination, the seedlings are shaded. When they attain 25 cm in height, they can be hardened-off and taken to the field (Magalhaes et al. 1986).

In full sun experimental plots at Curua-una, Pará, 80% of the field planted seedlings survived, versus 50% survival of natural regeneration during field clearance (SUDAM 1979). Annual growth increments were 1.4 m in height, 1.4 cm in diameter and 16.1 m^3/ha in volume (SUDAM 1979). At INPA's A. Ducke Forest Reserve, near Manaus, shaded plots at 400 trees/ha presented 75% survival at 11 years of age, with trees averaging 7.3 m in height and 4.5 cm in DBH. In full sun at the same density at 13 years, survival was 92%, average height was 9.2 m and average DBH was 13.2 cm (Loureiro et al. 1979).

From this silvicultural data, it appears that cumaru is suitable for planting both in full sun and in partial shade, making it both a good option for reforestation and for agroforestry systems. If couramin or oil uses find new markets, this fast-growing leguminous tree could make an interesting multipurpose component in regional agroforestry schemes.

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Rosewood

Paulo de T. B. Sampaio

Family: Lauraceae

Species: *Aniba rosaeodora* Ducke (Ducke 1938)

Synonym: *Aniba duckei* Kostermans (Ducke 1938)

Common names: pau-rosa, pau-rosa itauba (Brazil); enclit rosenhout (Suriname); cara-cara (Guyana); bois de rose, bois de rose femelle (French Guiana); rosewood (English).

Related species

Aniba fragans Ducke - Commonly known as "macacaporanga", this species is similar to *A. rosaeodora*, but has a strong and persistent aroma. It is found near Santarém, Pará, in the forest on the edge of the "Serra de Santarém" plateau, and is occasionally cultivated. The macacaporanga is one of the most important ingredients in the homemade perfumes of Santarém, which are made from infusions or powders of local *Lauraceae*. The young branches and the dried leaves of this species are used.

Aniba parviflora (Meisen) Mez - A small tree with light green wood and a strong aroma, principally from the bark. The oil obtained from its wood is also a component of Santarém's popular perfumes. Among the *Lauraceae* it is the most frequent and is found in the lower and middle Amazon river, from Santarém to Manaus, and in the lower reaches of their affluents (Tapajós, Trombetas, Madeira). It is found in non-flooded forest, on swampy ground or very humid soils (preferentially sandy loams), on the banks of black or clear water streams, but never white water (which is rich in sediments).

Description and phenology

Rosewood are tall trees, reaching 30 m in height and 2 m in diameter, with a straight cylindrical trunk, and a yellow-brown bark which falls in large flakes; all parts are aromatic. The generally well-shaped crown occupies the upper or mid-forest canopy.

The leaves are distributed along the smaller branches; they are leathery, smooth, generally 4-5 cm wide, with smooth margins and an acuminate apex; the secondary nerves diverge from the primary nerve at an angle of 45-60°. The inflorescence is a multiflowered panicle. The rusty-brown flowers are small, about 1 mm in length, having a short pedicel and short fillets. The fruit is a conically shaped drupe, green in color, measuring 2-3 cm in length by 1.5 cm in diameter (Ducke 1938, Alencar & Fernandes 1978, Loureiro et al. 1979). Each fruit contains one seed; there are 160-200 seeds/kg.

Flowering occurs from October to February and fruiting from November to March at the National Research Institute for Amazônia (INPA) A. Ducke Forest Reserve (Manaus, Amazonas) (Magalhães & Alencar 1978). According to these authors this species is prenifolia, changing its leaves during fruiting.

Distribution, abundance and ecology

A. rosaeodora is widely distributed in the rainforest from the interior of French Guiana, along the Guiana shield through Suriname, Venezuela and Colombia to the Peruvian Amazon (Ducke 1938). In Brazil, it occurs from Amapa westward along both sides of the Amazon River (SUDAM 1972). The areas of highest concentration run from Curuá-Una (near Santarém) to the Peruvian frontier in the south, and from the Trombetas River to Colombia in the north. It is also found around Belém and on Marajó Island (SUDAM 1972).

In the forests of the SUFRAMA Agricultural District, near Manaus, 2 trees/ha, with 0.05 m^3/ha, are found (Loureiro et al. 1979). At the A. Ducke Forest Reserve, the species has an abundance of 3-4 trees/25 ha (diameter at breast height equal to or greater than 20 cm) on medium and sandy textured latosols (Alencar & Fernandes 1978). They occur in groups of 5-8 trees, with a spacing of 50-100 m among trees and 300-400 m among groups; they also occur as isolated trees (Alencar & Fernandes 1978).

Rosewood grows on yellow and red latosols, both in clay and sandy clay, essentially on the terra firma; it prefers the headwaters of streams. The natural regeneration of this species occurs in clearings; consequently it is considered to be a heliophyte (SUDAM 1979).

Uses and economic potential

Principal use

Rosewood oil is largely linalool, a product with great demand on the national and international market because of its use as a fixative in perfumes. SUDAM (1972) explains that the physical-chemical constituents of the oil vary from population to population in Amazônia, noting that differences exist between the oils of trees from Brazilian Amazônia and from French Guiana. Unfortunately they don't identify those areas with superior oil characteristics. The physical-chemical characteristics of rosewood oil are presented in Table 1.

Table 1. Physical-chemical analysis of rosewood oil (*Aniba rosaeodora* Ducke).

	Leitão (1939)	SUDAM (1972a)	SUDAM (1972b)	Raoul (1953)	Naves (1952)
Density	0.883	0.881	0.889	0.870	0.876
Refraction index at 20°C	1.465	1.458	1.462	1.466	1.463
Acidity value	0.923	-	-	0.26	-
Saponification value	7.67	1.67	2.8	-	-
Ester index	6.7	6.5	4.5	-	-
Solubility in alcohol at 70% (1:2)	-	-	-	complete	-
Total alcohol[1] (%)	-	-	-	95.99	91.0
Combined alcohol[1] (%)	-	-	-	0.96	-
Free alcohols[1] (%)	-	-	-	93.03	-
Esters[2]	-	-	-	1.23	-

1. calculated as linalool, 2. calculated as acetate of linalila.

Secondary use

The wood is heavy (0.80-0.90 gr/cm^3). The light brownish-yellow heartwood has pink reflections, while the outer wood is yellowed; both have regular (occasionally irregular) grain, medium texture, are smooth to the touch and take a polish well. The strong aromatic smell is more intense when recently cut. The wood has a hot, astringent taste. It is easy to work, accepting a fine finish, but its utilization in cabinetry is rare because its principal economic importance is the production of the aromatic essential oil (Loureiro et al. 1979, SUDAM 1979).

Economic data

Rosewood essential oil is produced principally by the Brazilian states of Amazonas and Pará. Exports of the product have decreased considerably during the last decades (Table 2) because of intensive and selective over-exploitation of this species, without the replanting required by law. Brazil exported 92.3 MT of essential oil in 1985, with a value of US$938,000 (FOB), or about US$10,160/MT or US$101/kg. On the Manaus market one liter of rosewood extract sells for US$80.00 (J.W. Clay, Cultural Survival, pers. com. 1990). The major importers of Amazonas' rosewood oil are listed in Table 3.

Table 2. Rosewood essential oil exports from Amazonas, Brazil (SUDAM 1972, AEZFM 1986).

year	1966	1967	1968	1969	//	1985
MT	137.7	222.7	302.6	209.2	//	42.6

Table 3. Countries importing Amazonas' rosewood essential oil in 1985 (AEZFM 1986).

Country	MT	value (US$ FOB)
United States	35.1	358,038
West Germany	1.6	22,023
France	3.2	31,547
Spain	1.1	13,095
Holland	1.1	12,857
United Kingdom	0.5	6,547
Total	42.6	444,107

Collection methods and yields

The whole tree is cut to obtain the essential oil. The wood is reduced to strips, 2-3 cm wide by 5 cm thick, by a shredding machine. The strips are put in a kettle to distill the oil. The duration of distillation depends on the wood, but generally takes about 3 hours (SUDAM 1972). The efficiency in oil extraction depends upon the time elapsed between cutting the tree and the beginning of distillation, as well as the origin of the tree. One ton of wood produces about 9-12 liters of essential oil (Alencar & Fernandes 1978, Prance 1987). After distillation, the oil is strained to separate the impurities and is packed in 180 kg capacity metal barrels for shipping (SUDAM 1972).

The separation of the linalool from the essential oil is done in a two-step process at temperatures between 194 and 200°C (Leitão 1939). This author obtained 75% linalool and 25% polymerized residue.

Araújo et al. (1971) affirm that there is a higher essential oil extraction yield from the leaves and green juvenile branches (2.4%) than from the wood (1.1%). The age of the leaves affects the quality of oil: the older they are, the greater the proportion of terpenes and oxides of linalool; the younger, the richer they are in linalool. This suggests that rosewood could be cultivated like tea, with periodic harvests of green leaves and green branch tips, rather than the current destructive harvesting process that destroys the very resource that maintains the rosewood industry.

Propagation and cultivation methods

Rosewood is propagated from seeds, but the seed production is severely reduced by predators, principally birds of the families *Psitacidee* and *Ranfastidee* (Toucans) that attack the fruit before its maturation (Alencar & Fernandes 1978). In the A. Ducke Forest Reserve an adult tree can produce more than 400 fruits (Alencar & Fernandes 1978), but few are collected because of predation.

Araújo (1967) noted that seeds collected at km 134 and 104 of the AM-010 highway (Manaus-Itacoatiara), presented 75.3% and 61.0% germination, respectively. As they were sown 3 to 5 days after collection, the time elapsed between sowing and the beginning of germination was 43 and 28 days, respectively. Alencar & Fernandes (1987) obtained 37-91% germination in a period of 60-120 days, with seeds collected at the A. Ducke Forest Reserve.

Vegetative propagation of rosewood, by cuttings from young branches without hormonal or other treatment, was studied by

Sampaio (1987), who obtained 70% rooting. This technique allows propagation of elite material for experimental plantations.

SUDAM (1979) noted that this species presents a good survival index (80%), with average annual increments in height of 0.83 m, in diameter of 0.79 cm and volume of 9.1 m^3/ha/year. In the partial shade of the primary forest (30% light) on a yellow clay oxisol at a spacing of 10 x 5 m, this species presented an average annual height increment of 0.75 m in the seventh year after planting (Alencar & Fernandes 1978).

Since rosewood grows well in both full sun and partial shade, it would seem to be an ideal species for inclusion in agroforestry or forest management systems. Monocultures managed like tea might be feasible, although no information has been published about pests and diseases of rosewood that might limit low capital systems. All of these areas require research and development.

Twenty years after Araújo et al.'s (1971) original report on the essential oil content of the leaves, rosewood is becoming locally extinct in many areas of Amazônia due to destructive harvesting of the wood. This valuable natural resource deserves more intensive management, rather than extinction.

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Sacaca

Giorgini A. Venturieiri & Maria Nilse de S. Ribeiro

Family: Euphorbiaceae

Species: *Croton cajucara* Benth

Common names: Muirá-sacaca, cajuçara or caá-jussara (O'bidos) casca-sacaca, sacaca (Manaus), marassacaca (Berg 1982, Le Cointe 1934). The name sacaca originated from the Tupi *saka' ka* which means "witchcraft" or "spellcasting". The name cajuçara originated from the Tupi *ka'á* (leaf) and *yu'sara* (desire or longing) (Le Cointe 1934).

Related species

Croton tiglium L. - This *Croton* is native to East Asia, and is cultivated in India and Sri Lanka. A purgative oil (croton oil) is extracted from its seeds and is considered to be one of the strongest purgatives in the world (Purseglove 1968).

Description

The sacaca is a small tree, 6-10 meters tall. Its elliptical or oblong-elliptical leaves are 7-16 cm long by 3.5-5 cm wide, generally with a pointed tip. They are smooth on the upper surface and pubescent of the lower surface. The raceme inflorescence has small bracts that envelope each female flower; there are 1-3 male flowers on each inflorescence. The calix of the female flower is conical, while that of the male is rounded. The androceum has 15 stamens with globous anthers, while the gineceum is bipartite at the tip. The fruit are three sectioned capsules (Berg 1982). The wood is soft and light, with a yellow color.

Distribution and ecology

Sacaca is found only in eastern and central Amazon. In Pará state it is found in the estuary of the Amazonas River, along the margins of the Trombetas River, around the city of O'bidos (Müeller 1874). It is also found in the east of Amapá state (E. van den Berg, pers. com.). In Amazonas state it is only found cultivated.

Sacaca is generally found as a second growth weed, appearing soon after small plots are abandoned or natural clearings are formed in low lying forest areas. Although it is found in the *varzea* (white water river floodplain terraces), it appears to be restricted to the *varzea alta*, the upper terraces. Sacaca is extremely rustic and grows easily in degraded and abandoned fields. It seems to be undemanding of soils, growing well on yellow clay oxisols of low fertility near Manaus.

Uses and economic potential

Principal use

The sacaca is the most fashionable plant in Belém among those who prefer to treat themselves with medicinal plants. A tea is made from the bark of the trunk and/or from the leaves. It is used as an anti-diarrhetic; in the treatment of diabetes; for liver, vesicular and kidney infections; and to lower the cholesterol level in the blood (Berg 1982). Among the people who treat themselves to lower their cholesterol level, sacaca has a reputation for working quickly, within a few days. Recently the dry leaves have been put into gelatin capsules that are sold in the "natural product" shops of both Manaus and Belém for cholesterol control. If its effectiveness were proven in clinical tests, this use could expand rapidly in the northern hemisphere and among the middle and upper classes of the rest of the world where cholesterol worries are fashionable.

Secondary uses

The sacaca has been suggested as a substitute for rosewood (*Aniba roseodora*) oil, especially for the extraction of linalool (Araújo et al. 1974), principally because rosewood is becoming extinct in Amazônia due to predatory exploitation techniques. Linalool is a terpenic alcohol that is important as a basis for the transformation of other terpenes, such as terpeniol, geraniol and others. It is also used in the preparation of citronelol, tonona, vitamin A, farnesol and sesquiterpenes (Bedoukian 1967). All of these compounds are used in the perfume, flavoring and detergent/soap industries, both in their free forms and in their multiple derived forms, especially acetates.

Dried sacaca leaves contain 0.8% essential oil, which contains terpenes (1.6%), 1,8-cineol (2.4%), linalool (66.4%) and sesquiterpenes (25%). In comparison, the leaves of rosewood contain 2-2.5% of the essential oil, which contains 27-85.6% linalool (Araújo et al. 1971).

In the perfume industry, linalool and its esters represent a source of fragrance that no other material can equal. Its soft character and fresh odor are extremely valuable because they confer a natural character to perfumes based on synthetic aromas. The esters of linalool, with a fresh citrus odor, are excellent fixatives and bases for fragrances, especially colognes, with possibilities for use with both floral and non-floral fragrances (Erickson 1976).

The bark of the trunk is very aromatic and is widely used in perfumed herb bags to scent stored clothes and closets (Le Cointe 1934). These bags are especially popular in the handicraft and household shops of Belém and other Amazonian cities.

Recent commercial data

Amazônia exported a total of 6.5 MT of rosewood essential oil to the US, Germany, the United Kingdom, Spain, France and Japan in 1984 (AEZFM 1985). In the same year, Brazil imported approximately 17.5 MT of linalool and its derivatives from Germany, the United Kingdom, the US, Japan, Switzerland and France (CACEX 1985).

These data show that Brazil imports refined products from the same countries to which it exports the natural essence of rosewood (CACEX 1985). In other words, Brazil is paying a lot for not processing its own natural products. Nonetheless, a majority of the imports are beauty products that are sold more by name than by their chemical content, so that it does not seem very likely that Brazil will be able to substitute these imports easily. Rather, sacaca essential oil and sacaca-derived linalool could be sold as an option to saving rosewood from extinction.

Collection methods and yields

The harvest of the leaves should be done periodically, perhaps at 3-month intervals, as the plant does not react favorably to complete defoliation. Local farmers prefer to collect old green or even yellowed leaves, that are at least 20-25 cm from the terminal bud, because they believe that these have greater medicinal activity. It will be important to determine if these more mature and senescing leaves contain as much oil as younger leaves [younger leaves contain more oil in rosewood (Araújo et al. 1971].

A 4-year old plant may produce 10 kg of dry leaves per year. If sacaca is planted in monoculture, 10 kg/plant is equivalent to 6.25 MT of dry leaves per hectare. If industrial processing efficiency is equivalent to laboratory efficiency (0.8%), 50 kg of essential oil could be obtained per hectare, of which 33 kg would be linalool. Although this estimated yield seems low, it can probably be raised easily and rapidly with appropriate agronomic practices and a selection of germplasm with higher percentages of essential oil in the leaf. An additional advantage is that sacaca can be grown on degraded sites, thus helping to recuperate some of the very extensive areas of degraded lands in Amazônia.

Although rosewood yields considerably more essential oil than sacaca, rosewood has several disadvantages vis-a-vis sacaca: it is harvested destructively; it is a very difficult species to propagate; it is very susceptible to pests and diseases; and it grows slowly (Araújo 1967). Consequently, it is becoming continually rarer in the forest. Its increased rarity is what may allow sacaca to become a rosewood substitute in the market for natural linalool.

Propagation and cultivation methods

No experimental agronomic work has been done with sacaca to date. It is known, however, that sacaca shows very vigorous vegetative growth, similar to that of many second-growth invaders, suggesting that it is a pioneer plant. Exploitation of this vigorous growth offers the promise of developing the sacaca as a new crop.

Propagation is accomplished principally from stolons that arise spontaneously from the root. Apparently sacaca does not produce fertile seed (Moacir Tadeu Biondo, LBA, pers. com.), which suggests that it may be an Amerindian domesticate in eastern Amazônia. Because the wood is so soft and light, cuttings dehydrate easily, which make them less useful than the stolons for propagation.

Observations on a small planting at the Legião Brasileira de Assistência, Manaus, Amazonas, suggests that a spacing of 4 x 4 m (625 plants/ha) is adequate for sacaca (Moacir Tadeu Biondo, LBA, pers. com.).

Because sacaca is a pioneer species, it seems possible to include it in several types of agroecosystems: monoculture, although more information on pests and diseases is urgently needed; agroforestry, where it could be used along edges to catch the sun; reforestation, where it could be a successional species used to help recuperate degraded sites that would otherwise require high capital inputs until climax species come into bearing.

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AMAZON ERVAS; Av. Joaquim Nabuco, 1.248 - Centro or Blvrd Alvaro Maia, 558 - Centro; 69000 Manaus, Amazonas, Brazil; telephones (092) 236-6549 or 234-4141. (Amazon Ervas produces products similar to ProNatus).

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Tagua

Rodrigo G. Bernal & Gloria Galeano

Family: Palmae (Arecaceae)

Species: *Phytelephas aequatorialis* Spruce

Synonyms: *Palandra aequatorialis* (Spruce) O.F. Cook

Common names: Tagua, corozo, coroso (past trade name); marfil vegetal, vegetable ivory (English); avorio vegetale (Italian); Elfenbeinnuss, vegetablische Elfenbein (German); ivoire végetal (French); tagua, corozo (Colombia, Ecuador); jarina (Peru, Brazil).

Related species

The genus *Phytelephas* belongs to the palm subfamily Phytelephantoideae, containing the three genera *Ammandra*, *Aphandra*, and *Phytelephas* (Barfod 1991b), all of which produce vegetable ivory. All the species that were commercially exploited in the past, and also the best known in the group, belong to the genus *Phytelephas*, which includes 4 species: *Phytelephas aequatorialis* Spruce, *P. macrocarpa* R. & P., with three subspecies - ssp. *macrocarpa*, ssp. *tenuicaulis* Barfod, and ssp. *schottii* H. Wendl.; *P. tumacana* O.F. Cook; and *P. seemannii* O.F. Cook. Most vegetable ivory came from *P. aequatorialis* (Ecuador), *P. tumacana* and *P. macrocarpa* ssp. *schottii* (Colombia), and *P. seemannii* (Colombia and Panama).

The genus *Ammandra* contains two species: *Ammandra decasperma* O.F. Cook, from the Pacific lowlands of Colombia, and *Ammandra dasyneura* (Burret) Barfod from northwestern Amazônia, Colombia. The genus *Aphandra* includes one species, *Aphandra natalia* (Balslev & Henderson) Barfod, from Amazonian Ecuador. None of these species played a significant role in the vegetable ivory trade.

Description and phenology

Phytelephas aequatorialis is a solitary, unarmed, erect palm, up to 12 m tall. The stem is 25-30 cm in diameter, and is conspicuously marked by prominent leaf scars spirally arranged. The stem is crowned by up to 30 large, pinnate (feather-like) leaves, to 8 m long, the dead leaves hanging for some time under the crown; each leaf has 100-140 narrow leaflets on each side, the largest ones up to 90 x 6.5 cm, regularly arranged on one plane, or middle leaflets inserted in groups of 2-7, and then arranged on several planes.

All species in the subfamily Phytelephantoideae are dioecious, with male and female inflorescences produced by different trees. Inflorescences are produced among the leaves, and are enclosed in bud in two sheaths (bracts): a basal, outer, coriaceous, flattened profil, and an inner, coriaceous peduncular bract that encloses the flowers until flowering time. Male and female inflorescences are very different in shape and structure. In *Phytelephas* male inflorescences are long, cylindrical, fleshy, and spike-like, up to 150 cm long, with 300-500 cream-colored flower clusters spirally arranged and densely crowded; each cluster has two pairs of male flowers inserted on a short branch; individual flowers measure ≈ 1 cm long, and have reduced petals and 500-700 stamens. Female inflorescences have a 40-50 cm long, club-shaped stalk, with 20-30 stalkless female flowers crowded at the apex; each female flower has 6-8 tepals up to 15-20 cm long, a pistil with a long style and 5 stigmas up to 9 cm long.

The infructescence is almost spherical and head-like, ≈ 30 cm in diameter, usually with 15-20 densely crowded fruits. Individual fruits are conical, often five to six-edged by mutual pressure, 10-15 cm in diameter. The epicarp is thick and woody with numerous spiny projections; the mesocarp is thin, fleshy, oleaginous and yellow to orange. Each fruit has 5-6 seeds, 5 x 3 cm on average, often wedge-shaped, but very variable in size and shape; the endosperm is homogenous, fluid when young, later gelatinous and finally very hard and white, ivory-like at maturity, with a small central cavity (which is often lacking). Seedling leaves are feather-like.

Other species in the genus are quite similar in general appearance. *Phytelephas seemannii* is very distinctive in having a prostrate, creeping stem; *P. macrocarpa* ssp. *macrocarpa* has a prostrate or erect stem; ssp. *schottii* has a subterranean or creeping stem; and ssp. *tenuicaulis* is very distinctive in having slender, clustered stems. Besides *P. aequatorialis*, all other species have leaflets regularly arranged in one plane. The size of the central cavity is variable in the different species, but seems to be smaller in *P. aequatorialis*.

Flowering and fruiting of *P. aequatorialis* are reported as continuous year round (Acosta Solís 1948), although Barfod (1991b) has suggested that flowering of *Phytelephas* species is synchronized with the dry season in areas with a seasonal climate. Actually, in areas where tagua nuts are gathered, production is continuous, although a peak in fruit production does exist in the dry season.

Distribution, abundance and ecology

Species of *Phytelephas* are distributed along the Pacific lowlands of Panama, Colombia, and Ecuador, the valley of the Magdalena River, in Colombia, and northwestern Amazônia in Colombia, Ecuador, Peru, and Brazil. *P. aequatorialis* is distributed in western Ecuador, from the border with Colombia south to the Province of Azuay. *P. tumacana* is restricted to the Tumaco area, in southwestern Colombia, where it is now endangered (Bernal 1989). *P. seemannii* grows along the lowlands of western Colombia (Chocó), and eastern and Central Panama. *P. macrocarpa* is distributed in northwestern Amazônia in Colombia, Ecuador, Peru and Brazil, and one subspecies, ssp. *schottii*, is endemic to the Magdalena River basin in Colombia and adjacent areas of the Catatumbo River basin (Barfod 1991b).

Phytelephas species grow mostly on alluvial soils under 500 meters, with soil temperatures usually over 18°C but *P. aequatorialis* and *P. macrocarpa* ssp. *schottii* often reach 1,000-1,200 m. All species are better adapted to humid and shady areas, mostly with over 2,500 mm of year rainfall, but *P. macrocarpa* ssp. *schottii* is often found on steep slopes in rather dry areas in northeastern Colombia.

On alluvial, often seasonally flooded soils in the Pacific lowlands and northwestern Amazônia, species of *Phytelephas* often form large, rather homogeneous stands, called *taguales* in Colombia and Ecuador. These *taguales* range in area from less than one hectare to 25 hectares or more, with up to 240-500 palms per hectare. Estimates of the areas covered with *taguales* in Colombia and Ecuador have not been made. Although the extension of *taguales* was probably favored by man during the early boom of tagua, flooding rivers are perhaps the major dispersers of the heavy seeds along the floodplains. During an overnight flooding of a small river in western Colombia, about thirty seeds were deposited in a 0.1 ha plot of *taguale* (R. Bernal, pers. obs.).

Rodents, like pacas (*Agouti paca*) and agoutis (*Dasyprocta*), carry the seeds away from the *taguale*, and then eat the fleshy mesocarp, or bury the seeds for later retrieval. This behavior of rodents probably accounts for dispersal of tagua beyond the floodplains.

In some areas palms are left in pastures after the forest is cleared, and they become the woody component of simple silvo-pastoral systems (Borgtoft-Pedersen & Balslev 1990). Under these conditions they continue to set fruit, but they do not regenerate. With the exception of some areas in the Santiago River basin, in NW Ecuador (Acosta Solís 1944a), and on the Mira River, in SW Colombia (Mora Mora 1990), *Phytelephas* species have never been extensively cultivated. In western Colombia, large areas of wild *taguales* were burnt in the last forty years to establish rice fields.

Uses and economic potential

Principal use

The principal use of the tagua palm lies in the endosperm of its seeds. This material is hard and heavy, and has a cream color; when polished, it is quite similar to true ivory (hence the name vegetable ivory), although the materials differ in their properties. Tagua softens when hydrated, recovering its hardness with drying, and dissolves when soaked in water for long periods (Acosta Solís 1944a); ivory remains hard in water. Tagua nuts are easy to polish and dye, and are suitable for carving figurines, chess pieces, scrimshaws, handles, and other items. The most important use in the past, however, was for button production (Acosta Solís 1944ab, 1971; Barfod 1989, 1991a).

The first statistics of tagua production come from Colombia for the period 1840-1841, when tagua "made up a minor percentage of Colombian exports" (Ocampo 1984). After the 1860's tagua became one of the 5 major export products of Colombia (Tovar Zambrano 1989) and one of the 5 major forest products of Ecuador (Acosta Solís 1944a). In the period 1875-1878, tagua made up 3.1 percent of Colombian exports (Tovar Zambrano 1989). For Ecuador, tagua became even more important. The first statistics for this country appear in 1865 (Acosta Solís 1944a). In 1929, during one of its peaks, tagua exports from Ecuador amounted to 25,791 MT, worth US$1.2 million (Acosta Solís 1944a). In today's figures, this would mean about US$15 million. Exports of tagua from Colombia declined in the 1920's and disappeared about 1935. Ecuador continued to produce tagua, but exports declined after 1941, and tagua disappeared from trade almost completely by about 1945 (Barfod 1989).

Tagua button manufacturing was a major industry during the late 19th century and early 20th century. In the 1920's, 20% of all buttons produced in the United States were made of tagua (Acosta Solís 1944a). By the 1930's, plastics began to replace tagua for button manufacture, until tagua industry almost completely disappeared (Barfod 1989). Button production never died off completely, however, and a small button industry survived in Ecuador. This continued to produce the tagua disks from which tagua buttons were manufactured in Japan, West Germany, and Italy (Barfod et al. 1990).

In 1990 Conservation International, based in Washington, D.C., launched the *Tagua Initiative*, a program aimed toward linking the tagua producers in priority rainforest areas, with the international markets. Two clothing companies in the United

States initially joined the program by buying a first lot of one million buttons. Other companies have joined the program since. Revenues from the Tagua Initiative are reverted through the local partner NGOs into conservation and sustainable development programs in the areas where tagua is produced. This program is being developed now in two areas: the Santiago River basin, in NW Ecuador, by CIDESA; and the Pacific coast of NW Colombia, by Fundación Inguedé. Community management of tagua exploitation, as promoted by the Tagua Initiative, offers an attractive economic alternative requiring forest conservation by local inhabitants.

Souvenir manufacturing

Even after tagua disappeared almost completely from the button industry, it continued to be used by small-scale souvenir industries in Colombia and Ecuador. The Ecuadoran souvenir industry is based in the Andean town of Riobamba, where many different figurines are produced. These are sold in town, and in souvenir shops in other cities. In Colombia, the tagua souvenir industry is based in the Andean city of Chiquinquirá, where many different designs are produced. These souvenirs, however, are not sold outside Chiquinquirá (Bernal, in press). It is noteworthy that both in Colombia and Ecuador the tagua handicraft industry is best developed in areas where tagua palms do not grow, raw material being brought from other areas. The Ecuadoran industry has a tradition of hand carving not developed in Colombia, where most products are made in lathes. Several talented artisans are currently exploring tagua again, both in Colombia and Ecuador, and high-quality handicrafts are beginning to be produced.

Tagua as a substitute for ivory

The "rediscovery" of a sustainable source of vegetable ivory in the times of the international ban on elephant ivory has aroused a growing worldwide interest in this exotic material. Fashioned into jewelry, tagua is gaining reputation, and watches, earrings, bracelets, and necklaces featuring tagua are now obtainable in some luxury shops. Also for small sculptures, tagua seems ideal as a substitute, at least in part, for elephant ivory. Vegetable ivory is not only quite similar to elephant ivory, but also, like true ivory, it comes from an exotic source in remote, wild areas. Indeed, the use of a substitute for ivory, which not only protects elephants, but also helps to save critical areas of South American rainforest, is quite attractive.

The endosperm of tagua, the vegetable ivory, is composed of large, thick-walled cells, whose main components are two long-chain polysaccharides -- mannan A (45-48%) and mannan B (24-25%), cellulose (6-7.5%), and other cell contents (Aspinall et al. 1953, 1958; Timell 1957).

Secondary uses

Tagua shavings resulting from button production are ground into a flour, which is exported from Ecuador to the United States and Japan. Prices for flour in 1988 were US$ 1.50 per 100 lb (Barfod et al. 1990).

The leaves of *Phytelephas aequatorialis* and other species of *Phytelephas* are a very durable and widely used material for thatching.

The orangish, thin mesocarp that surrounds the nuts of all species in the genus is edible, and is considered a delicacy where tagua palms are abundant. It's flavor is vaguely reminiscent of coconut. This mesocarp is also actively sought by game rodents, which play an important role in the diet of local communities. Thus, commercial exploitation of the mesocarp might not be advisable, as it would further reduce an important source of protein for rural inhabitants.

No information on the nutritive properties of the mesocarp is available. Although both the outer and inner mesocarp are edible, it is the inner, leathery layer that is really appreciated by local inhabitants, since the outer, powdery mesocarp is rather insipid. Although some oil is present in the mesocarp (Patiño 1977), the thinness of this layer makes it economically unattractive compared to other potential oil palms. Barfod (1991b) states that unless this oil proves to have valuable properties, its exploitation is probably not profitable. It is probably better for tagua gatherers to leave the mesocarp to the rodents, receiving meat and peeled nuts in exchange.

The endosperm of tagua is a clear liquid when the seed is very immature, and is a refreshing drink in the forest. When the fruit is maturing it becomes thicker and gelatinous, and is also edible, tasting like coconut in the same stage of development; it is also considered a delicacy in the areas where palms are abundant.

The palm heart of *Phytelephas aequatorialis* has been reported as a delicacy consumed in some areas of western Ecuador (Acosta Solís 1944a).

Collection methods and yields

Tagua nuts are produced only by the female palms. When ripe, the fruit breaks apart and the woody-spiny epicarp disintegrates, dropping the nuts onto the ground, still covered by the orange fleshy mesocarp. This mesocarp is eaten by rodents *in situ*, or some nuts are taken away and hidden as reserves. Thus, tagua is gathered from the ground, after rodents have taken their part. The heavy nuts are collected in sacks, or in baskets woven with forest fibers, and are taken home, sometimes in dugout canoes when the *taguale* is far away.

Processing of the nuts involves drying, which can be done outdoors, under the house, where nuts are piled, or, in wetter areas, indoors. Drying may take several weeks (at least 4 weeks in tropical wet climates, but artisans in the highlands of Colombia claim that less than one year of shade drying would crack the material). After drying, the outer shell of the nut is brittle, and can be removed by beating the nut at its point of attachment (a prominence familiarly referred to as the navel). Small pieces of shell sometimes remain adhered to the peeled seed, and they are removed with a knife or a machete. After peeling, the seed is still covered by the seed coat, a thin, chocolate-brown layer firmly adhered to the endosperm (the vegetable ivory).

Tagua in Ecuador is sold in the shell to factories, where peeling is done by hand, or by means of peeling machines developed by local industries.

For the button industry, each tagua nut is cut into three slices (sometimes only two are usable depending on the size of the central cavity) with a disk saw, and then dried overnight in an oven heated with tagua wastes. Each slice is then cut with a lathe into a disk, which is the basis for the button itself.

No detailed study of yields were made during the "golden age" of tagua. Nevertheless, figures given by Acosta Solís (1944a, 1948) for *P. aequatorialis* indicate a production of about 30 kg of dry, peeled tagua per palm per year. This figure, however, is probably the upper limit of production of wild palms, and the average may be one-half to one-third that amount.

With a density of 240-500 palms per hectare, one-half of which are females (assuming a sex ratio of 1:1), yields of 1.2-7.5 MT/ha/yr can be expected from a wild, unmanaged *taguale* in the Ecuadoran lowlands. An intermediate figure of about 4 MT/ha seems a reasonable estimate. Claès (1925) estimated a minimum production of 2.25 MT/ha/yr for tagua in the Magdalena River basin, in Colombia. On the Pacific coast of Colombia tagua produces a low number of seeds per fruiting head, and the total production for this species is only ≈ 1-2 MT/ha.

After tagua lost its value in the 1930's and 1940's, large areas of *taguales* were replaced by bananas in Ecuador, and by African oil palm and rice in Colombia. To date, no figures are available on the extent of the surviving native stands of tagua in either country, so total production is hard to estimate. However, figures of tagua exports at its highest point can give an idea of the upper limit expected: in 1929, Ecuador exported 25,791 MT of tagua, roughly one-third of it to the United States. In the same year, Colombia exported 2,970 MT of tagua to the United States. Since many of the areas deforested in the last decades were extremely rich in tagua (El Oro province in Ecuador, the Tumaco and Urabá regions in Colombia), current potential production is well below these figures.

Assessments of the current extent of the *taguales* and the perspectives for market expansion are necessary before considering plantations as an option. Present demand is met by production from wild stands, but demand is increasing.

Propagation and cultivation methods

Except for small areas in the Santiago River in Ecuador (Acosta Solís 1944ab), tagua has never been cultivated and no information on cultivation techniques or procedures is available. Before the fall of tagua in the 1940's, campesinos in NW Ecuador scattered seeds in old agricultural plots. When the seed sprouted, they removed the weeds and regarded the *taguale* as established (Acosta Solís 1948). Under these conditions palms usually began to produce fruit after 15 years. Once the palm begins to set fruit, it will remain productive for up to one century.

Germination takes 4 to 9 months or even more, and the first seedling leaves are rather large for palms. No seedlings have been observed under palms growing in open areas, which suggests that shade is necessary for early development. Regeneration in *taguales* is abundant, and it offers a good basis for management.

It is probable that some cultural practices may easily increase tagua yields. Male palm trees are often eliminated in Ecuador, in order to leave room for more female palms in the *taguale*, a practice that apparently does not reduce yields. In dense stands, there is often a high percentage of leaf overlapping, a factor that may reduce seed production. Tagua seems to produce well under partial illumination (as under the thin canopy found in riverside forest). However, palms growing in full light usually have smaller leaves than palms growing in shade. Much basic research on the development and production of tagua under different conditions remains to be done. Much of this research is currently being conducted or planned in Colombia and Ecuador.

In Ecuador, tagua is usually associated with tree crops such as cacao (*Theobroma cacao*), breadfruit (*Artocarpus altilis*), and with timber trees like *Cedrela odorata* and *Cordia alliodora*. These associations are the result of agroforestry in what were probably large *taguales* along the alluvial lowlands. In western Colombia, tagua grows under the shade of mixed riverine forest, including a wide array of species used for timber (*Apeiba aspera*, *Chlorophora tinctoria*, *Carapa guianensis*, *Tabebuia* sp., *Virola* sp. and several Lauraceae), for firewood (*Inga*, *Gustavia*, and others), for canoes (*Anacardium excelsum*), and for wild fruits or nuts (*Spondias mombin*, *Dipteryx panamensis*, *Inga* sp., and others). One of the common species associated with tagua is black rubber (*Castilla elastica*), formerly an important forest product. No crops are usually associated with tagua in Colombia, although tagua is occasionally left in small agroforestry systems with chontaduro palm (*Bactris gasipaes*), almirajó (*Patinoa almirajo*) and bananas.

The management of tagua at high densities in agroforestry systems in Ecuador suggests that this could be a good alternative for increasing cultivation, if expanding demand requires it. Agroforesty not only has the advantage of offering local inhabitants other crops and forest resources (including game), but it is also the system that has been used for decades for tagua in Ecuador, and for other crops throughout the Neotropics.

Monocultures, on the other hand, would be more susceptible to pests and diseases, some of which already attack other cultivated palms in tagua producing areas. As a matter of fact, a beetle very similar (and perhaps identical) to the palm beetle (*Rhynchophorus palmarum*) attacks the stems of tagua, killing the palm (Acosta Solís 1948). *R. palmarum* is also the vector of the red-ring disease, that has destroyed thousands of coconut palms along the Pacific coast of Colombia and Ecuador. This disease is reported by local inhabitants of the Chocó, Colombia, to occur also on tagua, and it would be one of the potential threats to monocultures.

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Conclusions - Developing Markets for Forest Products

Jason W. Clay & Charles R. Clement

This volume identifies a number of general issues that relate to the successful harvest, processing and marketing of non-wood forest products in ways that not only do not destroy the forests from which they came, but generate employment and income. The creation of income-generating forests in Amazônia that sustainably produce numerous forest products would do much to solve the region's problems. In addition, 19 species have been highlighted that already produce value products or that can produce value without undue additional research. This volume attempts to identify what needs to be done. Clearly there is considerable work ahead. The costs, however, are not exorbitant and if forest residents can work together with botanists, ecologists, development experts and marketeers, alternatives to some of the more destructive economic activities in the region can be achieved.

Developing markets for forest products is not easy; nor does it simply happen on its own. A considerable amount of time and money must be invested to expand or create markets in ways that return significant revenues to forest residents and the countries in which they live. Sustainable development, rainforest conservation, biodiversity conservation, etc, are also key marketing concepts that can differentiate some forest products from others and raise this market segment above a purely free trade orientation. This, in turn, allows the return of a greater portion of the consumer price to the forest producers.

Most development programs in Amazônia, and elsewhere in the world tropics, take a production oriented approach. Such programs focus on selling into the market rather than attempting to obtain a higher value in the market or changing the market entirely. Because of their production orientation, they frequently have the net effect of creating an increased supply of commodities, thus reducing prices, profitability and new income to producers. During the past two decades, the world market prices for cacao, rubber, oil palm and other tropical plantation crops have tended constantly downward. While this is well received by consumers, the environment is suffering and producers are looking for alternatives. A successful marketing orientation for forest products, on the other hand, should increase demand and value, thus allowing more product to enter the market without reducing the overall price of the commodity.

Numerous constraints and guidelines for marketing forest products are featured throughout this volume. Some of them, however, should be underscored at this point. While each community or regional association should attempt to market a number of different products and find a number of different markets for each product, one or two products will still account for most income for most producers. Sometimes groups may be able to market their own products in local, regional, national, or even international markets. At other times, local groups will want to limit or specialize their marketing efforts in certain areas and turn the rest of the marketing over to others.

Funders or donors who support forest production and processing initiatives should insist that local groups consider from the outset how their goods will be marketed and what role the groups will play, even if it takes years to get to that point. To be sure, forest producers will probably always be able to sell their products, but if they want good markets they will have to work to create them. Often at least one full-time staff person is necessary for each commodity traded. The marketing of each commodity works best if the person designated to trade it comes on staff at least one year prior to the start of trade.

If Amazonian groups wish to market their own products, they will need to establish offices and warehouses in each market they intend to penetrate (e.g., the south of Brazil, New York, Europe, Japan). It would probably be more efficient if several Amazonian groups worked through a single broker so as to spread the costs of such an operation over a large number of commodities. Setting up and running such an office will cost about US$1 million in Brazil, about US$4 million in the US, and about US$6 million each in Europe and Japan. These figures are based on Cultural Survival's past experiences. They represent an "educated" guess.

Even if local groups decide not to open such offices on their own, the more their representatives travel to the US and Europe to study such operations and understand their workings, the more informed they will be. In the short term, Amazonian groups will probably be forced to market the bulk of their products through others. There is simply too much to be learned about harvesting and processing at this stage, without adding another whole dimension of complexity. Nonetheless, any forest resident that shows an entrepreneurial bent must be encouraged to develop this, so that the forest peoples can eventually take over the entire operation.

A brief summary of Cultural Survival Enterprises'(CSE) market experiences is enlightening regarding the potential of NWFPs. While CSE's efforts have been under-capitalized, US$2 million has been spent on the trading program. In the same period, however, CSE generated more than US$3 million in trade and more than US$1 million in grants, loans and technical assistance to local groups. When CSE started its program it was unable to source any commodities of export quality directly from local communities. Now, thanks to our efforts and those of other like-minded funders, 9 of the 15 commodities traded come entirely from local groups. Four are purchased partially from local groups, with the balance supplied by existing commercial sources. Only two are purchased entirely from commercial sources.

If marketing work on forest products is done carefully, existing markets and market forces can be harnessed to change these markets in favor of forest residents and the non-destructive use of forest resources in regions like Amazônia. But, these efforts are neither easy nor inexpensive in the short term and it takes several years for trade volumes to reach levels that offset the costs.

Since commencing trade in forest products in late 1989, Cultural Survival has shown samples of nearly 1,000 forest products to nearly 200 manufacturers in North America and Europe. Fifteen commodities are now traded on a regular basis to some 50 companies who manufacture more than 150 products. Another 50 companies are at various stages of product research and development and about 70 companies are still in the initial contact stage.

Cultural Survival Enterprises' current 5-year marketing strategy (based solely on its work in the US, for example) shows costs of US$3.4 million, to be covered by grants. During the same period, the program will generate US$48 million in overall trade, of which US$5.7 million while be returned in the form of grants and profit-sharing to local groups. CSE grew 450% in 1990 and 350% in 1991. If CSE averages 30% growth for 20 years, starting in 1990, by 2010 nearly US$1 billion will be returned to forest-based groups each year, either through direct purchases, environmental premiums or profit sharing agreements.

Thus, in the short term at least, funders should support some of the international efforts to develop markets for forest products, sustainably harvested timber, or medicinals that benefit local populations. These funds, however, should only be given to those national or international NGOs or groups that guarantee a decent return to forest residents and other NGOs working in areas such as Amazônia. After all, forest residents will only conserve forests if it is worth their while. Cultural Survival, for example, guarantees that 100% of the funds generated through licensing and environmental premium agreements with companies that use Amazonian forest products and that use the concept of saving rainforests as a selling tool will be returned to Amazonian forest residents or their support groups.

If the marketing of forest products is undertaken with companies who agree to use their packaging to inform consumers about rainforest issues, then consumers will become informed about the positive impact their consumer habits can have on rainforest conservation. Since beginning its program, Cultural

Survival has helped manufacturers reach an estimated 50 million consumers through their packaging. In addition, we have helped generate nearly 1,000 articles, as well as dozens of radio and television programs, to inform the public about CS's marketing program, what the connections are to tropical forests and what they as consumers can do to support these activities. Our approach has been to have the media run stories about the concept, rather than attempt to reach the public through regular advertising channels.

Considerable groundwork has been laid to create markets for forest products in the United States and to a lesser extent in Europe. It is these markets, ultimately, that will determine the viability of selling forest products as an alternative to using the same lands for agriculture or cattle in places like Amazônia. There is a delicate balance that must be maintained, however, between creating demand and stimulating production. Without that balance manufacturers could be left without product or producers could glut markets, forcing prices down. In either instance, the resulting problems would probably contribute to the further impoverishment of rainforest residents, thus prompting them to turn to more destructive uses of forest resources.

Unfortunately, however, any forest product that becomes successful will inevitably be taken out of the forest to be produced in conventional agricultural systems (see chapter 3). Consequently, not only must there be a continual influx of new forest products to the market but these must continually be differentiated from similar non-forest products and similar products obtained from non-sustainable systems.

While there are currently a number of organizations working to develop markets for sustainably produced forest products, there are few sources of information about "new" forest products. As pointed out in chapters 2 and 3, considerable information about each new product must be available to both the marketeers and the industries that are thinking of buying the material. Therefore, various Amazonian institutions should be strengthened or new ones created to provide this information on a priority basis.

Given the importance of Amazônia to global climate change and biodiversity, it makes sense to have an institute that would serve Amazônia, an improved forest extractivism, and the rainforests, much as the CGIAR institutes serve specific commodities. In fact, Clement (1989, 1991) has already suggested this to work with Amazonian crop and forest genetic resources and Amerindian and caboclo agroecosystems. Based upon the ideas presented in this report, it is clear that this institute must also interact with agents of the market economy, especially entrepreneurs, processors, and traders.

The institute should concentrate on many of the topics outlined in this report, but specific details would have to be worked out in conjunction with government officials, forest residents, researchers, and other end users of the information. This multimillion dollar investment would only work if several bilateral and multilateral agencies supported it; none of the Amazonian nations have a strong enough economy to support it alone. It would cost US$5 million to US$10 million per year during the first few years. Given the potential benefits expected, i.e. sustainable economic development with forest and biodiversity conservation (and slowed global climate change), these costs are more than reasonable. In fact, these costs are less than US$1 per Amazonian inhabitant per year.

The institute must base its objectives on the needs of local communities, not only the forest communities, but also agricultural and urban communities, in determining the problems to be addressed, as well as the types of solutions considered. To avoid a top-down orientation, specific links between research and development/extension would have to be created from the outset. Perhaps a small budget could be set aside that would allow local groups to undertake their own research with institute supervision.

The combination of one or several public institutions working with forest entrepreneurs should provide a new model for sustainable development, as well as fueling sustainable economic growth and social equity in Amazônia. As pointed out in the introduction, however, social equity will only be obtained with changes in the social-political environment also. The combination of a sustainable economic model and an equitable social and political system will allow for the development of Amazônia without the loss of the forests. This short report is intended to contribute to this effort.

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