



Why extensive research and development did not promote use of peach palm fruit in Latin America

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Abstract

Peach palm (*Bactris gasipaes*) was domesticated as a fruit crop by the first Amazonians in traditional Neotropical agroforestry systems, but research and development (R&D) to date has not transformed its fruit into a modern success story. The fruit is really a tree 'potato,' competing with traditional starches rather than with succulent fruits. R&D efforts have focused more on production than on product transformation, commercialization and the consumer, thus failing to fill gaps in the production-to-consumption chain. Consumer demands are only now getting more consideration, and clear identification of the smallholder farmer as the R&D client is not yet generalized. Too many, often large germplasm collections have biased R&D programs away from smallholder farmers and did not pursue the quality and uniformity that consumers want. The general lessons learnt from 25 years of R&D efforts on peach palm that should guide the development of other indigenous agroforestry fruit tree species are: 1) identify market demands, whether subsistence or market-oriented; 2) identify clients and consumers, and their perceptions of the product; 3) work on food and nutritional security aspects of the species and let entrepreneurs be attracted, rather than *vice versa*; 4) take up species improvement in a moderately sized effort, using a participatory approach tightly focused on clients' demands; and 5) reappraise the priorities from time to time.

Introduction

Eighty years after the first major article highlighting the potential of peach palm (*Bactris gasipaes*) as a fruit crop (Popenoe and Jimenez 1921), 25 years after the U.S. National Academy of Sciences (NAS 1975) again highlighted the potential of peach palm for a hungry world, this crop is no more important as a fruit today than it was in 1921 or 1975. It may be less important in the future, though an intensive research and development (R&D) effort occurred in Brazil, Colombia, Costa Rica and Peru in the past 25

years. These years of R&D did, however, create a new crop: heart-of-palm, grown in high density, high input monocultures (Mora Urpí et al. 1997; Mora Urpí and Gainza Echeverría 1999), and widely traded in American and European gourmet food markets.

Peach palm was fully domesticated in Amazonia in agroforestry systems and it became a pre-Colombian staple with important nutritional qualities (energy from starch and oil, beta-carotene). Native Americans consumed it whole after cooking, or fermented into a thick beverage, or dried and made it into flour. These

products were generally further processed into numerous dishes and drinks (including alcoholic), especially in northwestern South America and southern Central America. This pre-Columbian importance stimulated interest in the crop all through the 20th century.

In modern Brazil, Colombia, Costa Rica and Peru, 40% to 50% of annual fruit production fails to be commercialized in markets and is either fed to farm animals or wasted. Although there is apparently demand for peach palm flour, entrepreneurs have failed to create and maintain even a niche market for this product, and R&D efforts have failed to generate solutions to help change the economics of this niche. The R&D also failed to establish the use of whole fruit or flour in animal feeds and to stimulate a niche market even in areas where commercial animal feeds are expensive. These observations led us to conclude that peach palm today is underutilized.

This chapter attempts to identify the constraints in transforming a starchy fruit into a modern crop attractive to both urban and rural consumers. We will also identify some of the errors and successes of the R&D efforts, which can serve as lessons for the development of other indigenous agroforestry trees.

The crop: peach palm, pupunha, chontaduro, pejibaye, pijuayo

Peach palm is perhaps one of the best-known underutilized crops. Mora Urpí et al. (1997) provided an extensive review on the subject; the following paragraphs provide only updates or minimum information as background for the reader.

Botany

Peach palm is a multi-stemmed palm that may attain up to 20 m height. Stem diameter varies from 15 cm to 30 cm and internode length from 2 cm to 30 cm. The internodes are armed with numerous black, brittle spines, although spineless mutants occur and have been the subject of selection in several areas. The monopodial stem develops suckers at its base and is topped by a crown of 15 to 25 pinnate fronds, with the leaflets originating at different angles. The heart-of-palm is a gourmet vegetable composed of the tender unexpanded leaves in the palm's crown. The inflorescences appear from the axils of the senescent fronds. After pollination the bunch may contain between 50 and 1000 fruits, and weigh between 1 kg and 25 kg.

Numerous factors may cause fruit drop, such as poor pollination, poor nutrition, drought, crowding, insects, and diseases. The fruits that ripen have a fibrous red, orange or yellow epicarp, a moist starchy/oily mesocarp, and a single endocarp with a fibrous/oily white endosperm. Individual fruits commonly weigh between 30 g and 70 g (range of 10 g to 250 g), and seeds weigh between 1 g and 4 g.

Nutritional characteristics of fruit

The fruit is energy-rich, due both to starches and oils (Table 1). The relative proportions of starch versus oil vary inversely along the domestication continuum, with fruits of wild types being rich in oils and the most derived domesticates rich in starches (Table 2). Protein quality is not exceptionally high, but the oil is rich in oleic acid (Yuyama et al. 2003). Peach palm's beta-carotene is almost completely bio-available (Yuyama et al. 1999), as are its energy and protein (although the latter is of only moderate quality (Yuyama et al. 2003)). The fruit contains two anti-nutritional factors, a trypsin inhibitor and calcium oxalate crystals, which can be denatured or dissolved by boiling, respectively. The chemical composition and requirement for cooking make the name peach palm a misnomer, as the fruit is starchy and oily rather than succulent. It is only a fruit in the botanical sense. It can neither be eaten fresh, nor readily transformed into a juice (even though a beverage called *chicha* is made).

Nutritionally, peach palm fruits closely resemble edible starchy roots, such as sweet potato (*Ipomoea batatas*) and cassava (*Manihot esculenta*), the two major lowland Neotropical starches (Table 2). Of course, the edible roots, unlike peach palm fruits, have more flexible harvest periods and are easier to store in the field. A comparison with maize (*Zea mays*) is also somewhat misleading, even though their chemical compositions on a dry weight basis are quite similar. Maize can be stored in the field for weeks, which confers flexibility to its harvest time, and if protected against water and rodents it can be stored for long periods, even under very primitive conditions.

Advantageous traits

Peach palm has numerous traits that make it an ideal species for agroforestry as well as monoculture systems. Among these are its rapid juvenile growth (which helps to get a quick crop canopy started), clumping habit with basal off-shoots (so that crown size and fruiting-stem numbers can be managed via

Table 1. Mean chemical composition of peach palm fruit mesocarp^a and of heart-of-palm^b, with percentage of daily dietary requirements in a 10.47 MJ (= 2500 kcal) diet^c

Chemical component	Fruit mesocarp ^a		Heart-of-palm ^b	
	Unit 100 g ⁻¹	Daily Value	Unit 100 g ⁻¹	Daily Value
Calories (kcal)	273.5	10.9	47.6	1.9
Proteins (g)	3.3	4.4	1.5	2.0
Fats (g)	6.0	8.6	1.3	1.9
- saturated (g)	2.2	9.7	0.73	3.2
- monounsaturated (g)	3.3	14.7	0.35	1.3
- poliunsaturated (g)	0.5	2.2	0.22	1.0
Carbohydrates (g)	34.9	8.0	5.2	1.2
Fibers (g)	2.0	10.1	0.9	4.5
Vitamin A (β carotene – mg)	1.1	147.5	n.a.	n.a.
Vitamin C (mg)	18.7	30.0	3.2	5.1
Thiamin (vit. B1 – mg)	0.045	4.5	n.a.	n.a.
Riboflavin (vit. B2 – mg)	0.135	9.1	n.a.	n.a.
Niacin (mg)	0.81	4.6	n.a.	n.a.

^aMesocarp of three fruits.

^bA 9-cm long by 2-cm diameter section.

^cDr Lúcia K.O. Yuyama, INPA, pers. comm., 2002.

n.a. = not available

spacing and pruning), competitive ability after the juvenile phase (both in terms of other crops and weeds), tolerance to acidic soils (reducing requirements for lime), moderate light interception and less shade to the lower components when spaced appropriately (making it an appropriate upperstorey component in mixed systems), relatively free from pests (if grown at a low density in mixed cropping systems), relatively low maintenance costs (due to competitive ability), responsive to fertilizer application (although nutrient imbalances are a problem in chemical fertilization systems) and abundant production of fruits from an early age.

Disadvantageous traits

The fruits must be cooked to eliminate the anti-nutritional factors mentioned above. They require careful and rapid handling after harvest to get them from the farm to the consumer, as they are extremely perishable (three to seven days, depending upon maturity and handling). Considerable variability exists in fruit quality, which may be interesting to biologists and plant breeders but is frustrating for consumers, who complain that selection of high quality fruit is difficult. In Costa Rica, consumers consider the *rayado* fruit as synonymous with high quality (*rayas* are thin lengthwise cracks in the pericarp), but this is not the case in neighboring Panama and Colombia. Mesocarp

water content complicates processing, and the separation of the oil from the starch requires solvents, rather than simple pressing as in the case of oil palm (*Elaeis guineensis*).

Rapid growth continues during the reproductive phase, so clumps must be managed carefully to keep harvest costs reasonable. Harvesting is a costly operation in terms of number of persons required to harvest a bunch without damaging it, especially from tall trees. This can be a problematic operation in complex agroforestry systems due to the presence of species with different architectures. Most peach palms are well armed with spines, which protect them against some pests (and thieves), but pose a problem to harvesters and plantation workers in general. The palms are nutrient loving but soil-fertility management is a problematic issue, as balanced nutrient requirements have not yet been established.

Susceptibility to pests and diseases may become a problem as plantations are intensified. Insect pests have seriously reduced yields along the Pacific coast of Colombia, where *Palmelampus heinrichi* (CIPAV/HV 2001) sometimes caused up to 100% loss of fruit yield. Physical methods, such as blue bags used in banana (*Musa* spp.) or biological control, can reduce losses, but technical assistance does not reach all affected farmers and cost of this technology may be prohibitive for some farmers.

Table 2. Comparison of mean chemical composition of peach palm (Amazonian mean and three landraces), cassava, maize, sweet potato and a set of 21 succulent Amazonian fruits

	Water	Protein	Oil	Carbo.	Fiber	Energy
	(g per 100 g) ^a					(MJ)
Peach palm ^b	45.0	3.5	27.0	19.8	3.8	1.47
Juruá landrace ^c	54.4	3.1	13.8	19.6	8.4	1.04
Solimões landrace ^c	42.7	4.1	12.0	31.2	9.3	1.20
Putumayo landrace ^c	52.6	1.9	3.5	38.0	3.2	0.85
Cassava ^d	65.2	1.0	0.4	32.8	1.0	0.55
Maize (fresh) ^d	63.5	4.1	1.3	30.3	1.0	0.54
Sweet potato ^d	67.2	0.9	0.2	29.6	1.1	0.53
Succulent fruits ^c	82.8	0.9	0.8	11.9	2.9	0.26

^aFresh weights; the difference between the sum of the means and 100 is due to ash content.

^bMora Urpí et al. (1997);

^cClement (in press) and references therein;

^dWu Leung & Flores (1961).

Pre-Columbian versus modern cultural significance

Patiño (1963; 1992) reviewed the ethno-history of peach palm, pointing out both its great cultural significance in the pre-Columbian Neotropics and its importance in indigenous subsistence economies. The contrast between pre-Columbian and modern importance is dramatic, and it was partially the great pre-Columbian importance that motivated the NAS (1975) analysis of peach palm's potential. This review pointed out that pre-Colombians used all parts of the plant. Today peach palm essentially has two uses: the fruit, which has moderate demand for home consumption after cooking, and the heart-of-palm, which is of economic importance.

As a major pre-Columbian subsistence product, there were numerous myths of indigenous origin about peach palm but today they remain in books. Similarly, the harvest season was traditionally celebrated with great fanfare and consumption of *chicha*, followed nine months later by a major peak in births. Today, the harvest may or may not be an economic opportunity, but subsistence consumption is small where market integration is higher.

Potential uses

During the century immediately following European conquest (Patiño 1963), the fruit was used principally as a cooked starchy staple, or fermented for storage (*masato*) and then diluted to make *chicha*. Flour made from the mesocarp was reported in some areas. The wood was also important for hunting, fishing and agricultural implements, and was even used for forti-

fication of villages. Hence, processing was an essential part of the use of peach palm in indigenous subsistence systems. Modern use of peach palm has not kept up this practice.

In the 1980s, the potential of peach palm fruit for animal feed was considered to be significant (Clement and Mora Urpí 1987), but continued R&D and subsidies to maize, sorghum (*Sorghum bicolor*) and soybean (*Glycine max*) in the first world countries have changed the economics of this potential use (Clement 2000). Given the water content of fruits, there may be potential for silage making on a small scale, but readily available technologies for farmers have not yet been developed.

Peach palm was also thought to have potential for oil (Clement and Mora Urpí 1987), particularly when germplasm with mesocarp oil content similar to that of oil palm was identified. Reevaluation in light of the R&D that has occurred with oil palm and the need for a 30-year R&D program for peach palm to equal the yields of oil palm (during which period there may be further developments in oil palm) indicated that peach palm's potential as an oil crop is less interesting than originally thought (Clement 2000).

However, Clement and Mora Urpí (1987) correctly assessed the commercial potential of peach palm to supply heart-of-palm of good quality. A recent review of R&D further confirms this (Mora Urpí and Gainza Echeverría 1999). Clement (2000) pointed out that production of seeds for heart-of-palm could change the economics of fruit production for flour or animal feed in many production areas.

Although no entrepreneurs have stepped forward in Brazil, Colombia, Costa Rica, or Peru, we think that there are at least three niche market opportunities that could be developed for the available fruit: (1) flour for baking cakes, pastries etc., (2) drinks made from mildly or moderately fermented pulp, and (3) animal feed in special situations. Processing needs to be developed if current excess peach palm production is to be marketed.

The demand for flour is evident every year after the peach palm fair in Costa Rica and the television advertising of the harvest season in Brazil. In Turrique, Costa Rica, flour was marketed from late 1980s to mid-1990s, but has since vanished from the market due to an unfavorable benefit/cost ratio. A similar demand for flour over a shorter period occurred in Manaus, Brazil. The processing segment of the production-to-commercialization (p-c) chain needs urgent attention to determine why these efforts failed and what is necessary to make a successful enterprise with peach palm flour. One indication of demand is that the largest women farmers' association (AMUCAU) near Pucallpa, Peru, is asking for training and financing of members to produce an infant formula and other value-added products from peach palm.

An European specialty beer company Mongozo (<http://www.mongozo.org>) is 'modernizing' indigenous African and American *chichas* to sell in the high-end exotic beer market. This appears to be a promising line of investigation, since peach palm's English name, and other European equivalents, are derived from the aroma given off by the preparations *masato* and *chicha*. The first attempt (by an American micro-brewery) yielded a beer with an orange tint and a pumpkin-like flavor (Jeff Moats, Amazon Origins, pers. comm. 2000).

In regions where commercial animal feed is difficult to obtain, there may still be potential for using peach palm as the energy source in silage or dry feed. The cost of drying is a major limiting factor. Mixing fresh fruit with grains and other feed components before milling facilitates drying and improves the benefit/cost ratio for preparing dry animal feeds, which are easier to store (Argüello and Afanador 2002), but a full economic analysis is not yet ready.

Peach palm in four modern Latin American economies

In this section, the status of peach palm in four Latin American countries (Brazil, Colombia, Costa Rica, and Peru) is described as they account for a major share of modern production. Consumers in these countries perceive peach palm somewhat differently due to national traditions and the type of fruit available to them. Although peach palm is a well-known traditional fruit, large amounts of fruit do not reach the fresh fruit market.

Brazil

Peach palm is grown throughout Amazonia, almost exclusively as a smallholder fruit crop in homegardens and swiddens, with a few small orchards. Heart-of-palm plantations have generally failed in Amazonia, principally because of lack of local demand, the high cost of shipping to Brazil's major market in São Paulo, and poor business planning and execution.

In the 1980s, informal observations revealed that consumers in Manaus (Amazonas state) would pay more for moderately large fruits (40 g to 60 g), containing more starch than oil. A closer examination of the preferences of these consumers indicated that most would like to buy moderately large red fruits with more oil than previously thought (Clement and Santos 2002). However, most consumers actually buy fruits that are different from what they claim they want, primarily because of price, but also because of the difficulty in selecting fruits visually for specific quality characteristics. While 'feel' of the mesocarp can help to select fruits with more oil and better texture, most vendors frown upon giving potential customers a fruit to crack open and test. Hence, demand appears to be limited by the variability of fruit characteristics.

Clement and van Leeuwen (in press) estimated that the value of fruit used for subsistence and sold in local markets in an agricultural community in Manacapuru, near Manaus, is worth 2% of a family's income (Brazil's mean annual income in 2001 was \$2170). An Amazonas state extension service report (cited by Clement and van Leeuwen in press) claimed that in 2000 several agricultural communities in Coari (Amazonas) may have been producing 3% of the state's annual production of 13 600 Mg, and earning as much as \$990 per family from 1.5 ha. This represents 45% of mean annual income, which may be an exaggeration by the extension service. This strong

contrast has to do with fruit quality, as consumers in the Manaus market perceive the Coari fruit to be of higher quality than the Manacapuru fruit. While the Coari story is certainly good news, the same extension service estimated that 50% of the state's annual yield is wasted.

In Manaus, a fad for regional foods has seen the establishment of a number of breakfast restaurants that serve indigenous foods, based principally on regional starches and fruits. Nonetheless, peach palm is perhaps the least represented fruit/starch and the majority of the restaurants make no effort to serve peach palm out of season, even though cooked fruit can be frozen with little quality loss, and flour can be preserved dry and in the dark for long periods. Kerr et al. (1997) published a peach palm cookbook, which was a commercial failure, but offered numerous options for these restaurants. Although the Instituto Nacional de Pesquisas da Amazônia (INPA) has been studying the health benefits of peach palm for some years, especially for children, no food industry has stepped forward to take advantage of processing for the school lunch programs and regional markets.

Colombia

As in Brazil, peach palm is grown in homegardens and swiddens throughout Amazonia, and also in small-scale orchards and agroforestry plantations along the Pacific coastal lowlands. Colombia has about 7000 ha of peach palm planted for fruit production, where yields are about 7 Mg ha⁻¹. The area planted for subsistence use is certainly underestimated and difficult to measure, as the palms are generally found as scattered individuals within highly diverse agroforestry systems. There are about 1000 ha for heart-of-palm production.

Peach palm is part of Colombia's folklore (Patiño 1992). People attribute aphrodisiac powers to the fruit. In general, red fruits are preferred to yellow, and oily fruits to starchy. Given its caloric content, a handful of fruits make an adequate lunch at a very reasonable price, which is attracting attention in many urban areas. This expanding interest has caught the attention of major supermarket chains, which further increases urban demand.

Considering that 60% of the fruit does not meet consumer demands, farmers commercialize only 40% of production and earn \$660 ha⁻¹ yr⁻¹ profit when located near good markets (Argüello and Afanador 2002). In 2002, the federally mandated minimum

salary in Colombia was \$115 per month, which means that selling even this 40% is worthwhile. Although Colombian R&D developed processing technologies similar to those used in Costa Rica, the market for these products is a tiny fraction of the fresh fruit market.

In Colombia, there is market at present for about 20 000 Mg of freshly cooked fruit per year and demand is increasing for the better quality fruit. Cali is the city with the greatest consumption, while Bogotá has only a small market. Nonetheless, Bogotá today has twenty distribution centers compared to only five centers five years ago.

Costa Rica

Costa Rica has about 1500 ha planted for fruit throughout the Atlantic and Pacific lowlands, of which about 500 ha is in Tucurrique, an Atlantic region famous for its peach palm. Most of the Costa Rican area is planted by smallholders in low diversity agroforestry or monoculture orchards, and these 1500 ha yield approximately 10 500 Mg of fruit per year (7 Mg ha⁻¹), of which about 40% are *rayados*. Farm inputs and labor costs have risen strongly, especially as the Costa Rican Colon has lost value against the US dollar during the decade, pushing up costs and cutting profit margins. As a result, farmers' interest in peach palm is stagnated. Heart-of-palm plantations occupy 15 000 to 20 000 ha and Costa Rica is the second largest world exporter of canned hearts, after Ecuador.

Costa Rican consumers prefer red fruits with *rayas*, as these are reputed to have good quality. In general, these are the fruit brought to market, while other types are brought less often or used on farm, principally to feed swine. However, Costa Rican demand for peach palm appears to be stagnant and prices are falling in real terms, both for the consumer (which theoretically should stimulate demand) and for the farmer (which should stimulate production of material that consumers are willing to pay for). During the past two decades, production has expanded to all corners of the country, with the result that fresh fruit from different regions are available year round. A major consequence of this is that prices are nearly constant year round in the important San José central market.

Costa Rica was the first country to introduce processed peach palm fruit to the market. Processing was simple, involving little more than traditional preparation, and the range of products was reasonable: whole or halved fruit, both peeled and with peel. The

products were generally sold in glass jars, so that the consumer could see the product and determine if the fruits were *rayado*, and were accompanied by a recipe booklet to guide the new consumer and re-orient the jaded. However, these products have lost market share in the last decade as farmers have made fresh fruit available year round. Consequently, freshly cooked fruits are also available daily, and these are perceived to have better texture and flavor than bottled fruits that may have sat on the shelf for several months. Worse, the bottled fruit cost more than the freshly cooked fruit (a 700 g (net weight) jar costs about \$2.25 while freshly cooked fruit sell for \$1.25 per kg).

In Costa Rica, there is an annual food fair in Turricque that highlights peach palm recipes, complete with television coverage. A major disappointment for interested consumers is the difficulty in finding peach palm flour in the local market. As in Brazil, the national research institute INCIENSA (Instituto Costarricense para la Investigación y Enseñanza de Nutrición y Salud) is involved in studying health benefits of peach palm but no food industry has started processing the fruit for the school lunch programs and regional markets.

Peru

Peach palm is grown throughout Amazonia where farmers use more than 150 indigenous tree species and consider peach palm as a top-priority species for agroforestry systems (Sotelo Montes and Weber 1997). It is produced in small agroforestry plots, generally established in association with annual crops and later intercropped with other fruits (Arévalo et al. 1993). In communities around Iquitos and Yurimaguas, approximately 50% of the peach palm fruit produced by farmers is sold in the markets, either directly by farmers themselves or through intermediaries, which can generate on-farm income equal to or greater than the sale of traditional crops (Labarta and Weber 1998). Consumers consider red and orange fruits to have more oil, and better texture and flavor, while yellow fruits are considered second rate and used to make flour or fed to animals.

During the 1990s, farmers were attracted to heart-of-palm production through the enthusiasm of the Ministry of Agriculture, USAID (U.S. Agency for International Development) and other agencies, even though marketing studies questioned whether Peru could compete with Costa Rica and Brazil (Vockins 1999). Saturation of the international heart-of-palm

market lowered the price offered by the processing plants, however, making the necessary intensive management and inputs much too expensive for smallholders. Consequently, many farmers changed the management of their plantations for fruit production.

At the same time, new markets were opened for fruit in areas that did not produce the fruit, so that the expanded production found demand in markets outside the production areas. Near Yurimaguas, some members of small communities are earning nearly \$2000 per season selling their best quality fruits into these new markets, and this is a major increase in income (Peru's mean annual income in 2002 was \$900). The response of the Peruvian R&D community has, however, been timid, principally because of economic problems in Peru and the government's lack of priority for supporting R&D on underutilized crops, even with new market demand. ICRAF (International Centre for Research in Agroforestry) and INIA (Instituto Nacional de Investigación Agraria), however, have joined together in recent years to change this scenario.

In Peruvian Amazonia, a peach palm food fair was organized in the year 2000, complete with a peach palm queen, contests and prizes for the best new dishes and the best fruit bunch, in terms of phytosanitary quality, size and fruit appearance. Although this event attracted a lot of attention, it did not attract the attention of local agro-industrialists, despite the presence of numerous local food industries in Iquitos and other Peruvian Amazonian cities, and the fair was discontinued in 2002. Part of the problem is certainly peach palm's seasonality, although flour production (a necessary starting point for more elaborate industrialization) could solve this. Hence, it is not yet clear why peach palm attracted significant popular attention but no agroindustrial attention in Peru.

The market and the R&D efforts

Modern development policy is aimed at integrating producers into markets, so as to enhance their livelihoods and reduce poverty. As market integration increases, the impact of R&D and political decisions also increases. Misconceptions about which markets to explore and how to go about this are major weaknesses of most peach palm R&D programs.

Subsistence versus commercial fruit markets in tropical America

A continuum exists between purely subsistence 'markets,' such as those of isolated Amerindians along the Javari River in the state of Amazonas, Brazil, and purely commercial markets of national and international consumers, for which production generally is in high input monocultures. In each country and region within the country, different sections of this continuum are most representative of the fruit market into which peach palm is sold. In most of Amazonia, traditional communities tend more toward subsistence, especially as the distance to urban markets increases, while settler communities are more market-oriented; nevertheless, the lack of infrastructure, energy, agroindustry, investment etc. often restrict possibilities. Many farmers of Costa Rica and the Pacific-coast of Colombian are strongly market-oriented, while Peruvian farmers vary as much as Brazilian farmers.

As market integration intensifies, the swidden/fallow fields often become low-diversity agroforestry fields and finally monoculture orchards, especially when local extension agencies are involved, and farmers' perceptions of costs, benefits and opportunities also tend to change. Their choices of which crops to produce and how much effort each is worth are dictated by personal preferences, circumstances and perceptions of the market, which in turn affect crop diversity within and between fields (de Jong 1996). Dealing with the varying needs of farmers along this continuum is the challenge of R&D institutions in Latin America.

Who are the clients?

In Brazil, the modern phase of peach palm research started in the mid-1970s at INPA, targeting entrepreneurial farmers, who supposedly required technological packages adapted to local edaphic and climatic conditions. Hence, a conventional crop development program was thought to be appropriate, with large germplasm collections and agronomic research designed to produce peach palm efficiently in monoculture or low diversity agroforestry plantations. The imagined entrepreneurs never appeared on the scene, while, in the meantime, insufficient attention was paid to smallholders and their ways of farming. As elsewhere in tropical America, smallholders produce the bulk of peach palm fruit that reaches market. This model serves to explain the situation in Colombia and Costa Rica, and part of what occurred in Peru also.

In contrast, the more recent ICRAF/INIA program in Peru recognized that their clients are smallholders, who have traditionally used the fruits produced on their farms and, where possible, have also sold part of the production into local markets. Surveys in Peruvian Amazonia indicated that approximately 50% of the fruit production was used on-farm - roughly half of this for human consumption (Labarta and Weber 1998). Not surprisingly, on-farm use of the fruit is higher in areas where markets for the fruit are less well developed (e.g., Pucallpa) than in areas where markets are well established (e.g., Iquitos and Yurimaguas). Having correctly identified its clients, the ICRAF/INIA program seems to have a promising future.

The production-to-commercialization chain

In industrialized countries and increasingly in developing countries, such as those in tropical America, investments in R&D covering production-to-commercialization (p-c) chains for crops currently dominating the international markets have given these crops a distinct advantage over the lesser-researched crops. Such economic investments have turned out to be very efficient even for resource-poor nations. This explains the current expansion of soybean into the southern fringes of Brazilian Amazonia, for example, as the mere existence of such a p-c chain gives Brazilian soybean an advantage over crops without such a system.

Production-to-commercialization chains are also tools for identifying priorities for agricultural R&D. Commonly, p-c chains for minor crops such as peach palm are poorly known or unknown. Clement and Leeuwen (in press) outlined a simple p-c chain in Manacapuru, near Manaus, identifying what the major components of the system are and how value is added as the product moves from the farm to the city. Concurrent work is examining the preferences and perceptions of the Manaus consumer. Further work will be necessary to examine the costs and benefits of each step in the p-c chain in order to identify priority areas for the attention of R&D institutions to enhance the overall functioning of the p-c chain. This analysis will also allow the R&D institutions to evaluate benefit/cost ratios of their interventions.

R&D institutions have rarely used the p-c chain adequately while working with underutilized crops, and when considered, they viewed it starting with production and ending with the consumer. In reality, this

is looking at the system the wrong way, as the consumer really drives the system. As a consequence of this incorrect interpretation, much emphasis has been placed on the biology, genetics and even agronomy of peach palm (Mora Urpí et al. 1997) and appropriate processing technologies and consumer demands have been poorly investigated. If processed products are ever to be marketed successfully, even in specialized markets, the processing and consumer sections of the p-c chain must be better understood, and they should have benefit/cost ratios that attract entrepreneurs. Generating this type of information on a piece-meal basis is inadequate to address the challenge.

What do the consumers say?

As with the consumers of any product, peach palm consumers would prefer to have high and uniform quality fruit at a low price. It seems that those who like peach palm would continue to buy it and those who do not like will not buy it even as prices fall, because of lack of uniformity (and its corollary - difficulty in selecting from what is available), which is the major problem with peach palm. This consideration seems to be common to all Latin American countries, with Costa Rica being a partial exception.

A relatively high price is not necessarily a problem, however. Consumers are willing to pay more, as demonstrated by the high prices of fruits from Fonte Boa, Amazonas, Brazil (Clement and Santos 2002). But consumers will pay more only if they get the expected quality fruit. The real problem in many localities where peach palm is grown and sold is the customer's inability to buy peach palm fruit of guaranteed quality. The R&D institutions have not met this challenge even after 25 years of work on this crop.

Excessive emphasis on germplasm banks

A breeding program for an underutilized crop should necessarily be of modest size and tightly focused on its clients' demands. Unfortunately, the first step of the genetic improvement programs in these four countries was the creation of large germplasm collections (see Mora Urpí et al. 1997 for details). Worse, germplasm characterization and evaluation were never completed due to budget and personnel constraints. Such collections would be useful for programs designed around controlled crossing, which cannot be justified for a minor crop (Clement 2001). As resources dwindled due to lack of practical results, the

germplasm banks became white elephants consuming the meager available resources.

Clement (2001) estimated the costs for collecting, establishing, characterizing and maintaining the 450 accession INPA germplasm bank over a 20-year period, as well as those necessary for a single conventional controlled-pollination breeding program for heart-of-palm over a 10-year period. The benefit/cost ratio of a germplasm bank for the heart-of-palm program worked out to be 7.6, on the assumptions of adequate genetic diversity at the beginning of the program and that it would increase yields by 25% over two five-year cycles. In addition to the large collection at INPA, Brazil has many small germplasm collections and programs that are trying to make headway in heart-of-palm breeding. Clement (2001) concluded that benefit/cost ratio of these small collections and programs was probably insufficient to justify their maintenance compared to the overall benefit/cost ratio of maintaining one collection for the whole peach palm improvement program in the country. The benefit/cost ratio for a fruits program would be negative because of numerous mistakes outlined in this chapter.

The same logic can be applied to the germplasm collections in other countries in the region. In Costa Rica, the large University collection can probably be justified by heart-of-palm results, but not on fruit results. The CATIE (Centro Agronómico Tropical de Investigación e Enseñanza, Costa Rica) collection cannot be justified on either grounds, and the institution has rightly de-emphasized peach palm. In Colombia, the database of one of the collections was lost a decade ago and that collection essentially ceased to exist, while two other small collections in Amazonia have not generated practical results, and therefore are difficult to justify. The same holds for Ecuador and Peru. Nonetheless, once a germplasm collection exists, it becomes a sacred cow that cannot be eliminated and consumes institutional resources.

In contrast, ICRAF and INIA followed a different approach in their program that was started in Peru in 1997 (Weber et al. 2001). Researchers asked farmers in different communities to select their best palms based on fruit characteristics, and then collected seed from these palms to establish on-farm progeny trials in the Yurimaguas and Pucallpa regions. To date, the trials include progenies from 400 selected mother palms (two plants per progeny in each replication). The trials will be rogued after five years, leaving one plant per progeny for production of selected seed (to maintain variability, no between family selection is foreseen).

The farmers are the owners of their replications; they plan to sell the selected seed, use the seed to establish more palms on their farms, or use the fruit to prepare value-added products on farm. This program is relatively less expensive and is expected to have a high benefit/cost ratio.

Entrepreneurs and market creation

As economists say, markets do not appear from nowhere - they need to be created by people. Establishment of markets costs money, which is a risky enterprise for poorly known species and for products having major competition. In the case of underutilized and new crops, there is a need for crop champions or entrepreneurs who could pressure the R&D institutions to fill gaps in the p-c chain and create new markets for the products. The crop champions are expected to transform ideas into profitable enterprises. To date, peach palm researchers have tried to fill this role, and failed.

Conclusions

The past 25 years have seen major advances in knowledge about peach palm, thanks to the R&D efforts, but not a proportional increase in the use of fruits of the palm. The lack of success is due to several reasons, including overly broad objectives (a focus on production of fresh fruits would have been better than trying to accommodate multiple uses, such as beverage, flour and animal feed), failure to understand consumers' demands (uniform varieties with desired fruit characters), and incorrect identification of the research client (the smallholder is the appropriate client, not the agricultural entrepreneur). What lessons can we learn from Latin American experiences with peach palm that might be useful for R&D on other underutilized agroforestry species?

Let markets determine demand

CATIE de-emphasized its considerable peach-palm-germplasm-R&D effort in the 1990s because markets were stagnant or nonexistent in the countries where they work in Central America and part of the Caribbean. With stagnant markets, CATIE wisely decided that duplicating the R&D effort of the University of Costa Rica was inappropriate, as one institution was more than sufficient to meet demand. CATIE maintained its concentration on peach palm in agroforestry

systems, however, because of the prevailing demand for this type of information. The lesson: do not take up a research program for a product that markets do not want. The implication is that some kind of market research must precede any decision to invest in R&D. This kind of cold business-logic needs to be central to R&D decision making and planning in Latin America, and possibly elsewhere in the tropical world. A corollary follows.

Clear identification of clients and their perceptions

For peach palm, the smallholder is, at least for the time being, the main research client. This means that his/her way of farming and its consequences for peach palm production have to be understood. Important items are: risk avoidance, family food security, limited access to capital, cheap family labor, and limited access to external labor. This leads to the numerous production options observed in tropical America: intercropping of peach palm with many species (often peach palm is not the most important), combination of production goals (fruit and heart-of-palm), moderately tall stems with moderate number of suckers, low number of palms per production unit, and limited use of external inputs. Unfortunately, the smallholder is seldom seen as the main research client by national R&D institutions in tropical America. Hence, most research tends to be of moderate relevance to these clients. The lesson: know the clients' requirements first. A possible exception is to be proactive if a client and an opportunity can be clearly identified, and work in participation with the client to guarantee this.

Perceptions of farmers' welfare

International development agencies and many national agencies (e.g., of the Brazilian government) often consider producing for export markets as a more prosperous and dynamic source of growth (i.e., the *potential* for increased income) than producing for subsistence or domestic markets. In contrast, an emphasis on food security implies a decreased dependence on the vicissitudes of large-scale markets in order to feed one's family and community. The unstable outcome of a 20-year legacy of 'structural adjustment' policies reveals a much greater risk to food security via market integration than maintaining the production of diverse foodstuffs in subsistence systems (Hammond et al. 1995). A more holistic form of market integration would allow for the maintenance of semi-subsistence systems,

instead of forcing their abandonment, inadvertently or otherwise.

In Peru, for example, many farmers think that there is too much risk in heart-of-palm production, even though this is encouraged by international and national development agencies, and they believe that they can still rely on the fruit to improve their food security. The fact that many farmers in Peru have transformed their heart-of-palm plantations into fruit production supports this contention. Instead of investing in projects for heart-of-palm production in small farming communities, it would seem reasonable to invest in projects to process the fruits for a value-added product, such as infant formula and school lunches, that can be produced and processed in farming communities, and sold by farmers' associations in the local and national markets. In other words, disconnecting fruit production from international markets while focusing on local and national markets for food security may be a route to avoid starch competition and start attracting entrepreneurs. The lesson is that for peach palm and other similar crops, R&D institutions should work locally on food security and let entrepreneurs be attracted, rather than aim for entrepreneurs who may not exist.

Size the program to the species' importance

An analysis of demand for subsistence needs and market allows definition of the importance of the species in question. The strategy for a breeding program should be developed accordingly. In such a program, the accent will be on mass selection and comparison of land races/provenances and open-pollinated progenies (see Simons and Leakey, this volume, for a dicotyledonous view). In the first phase of such a program, there is little or no need for large germplasm collections. Consequently, these should not be established, even if funds are easily obtained. The plant improvement program needs to have a strong participatory component (at least for on-farm trials), and the first generation of improved seed should be available as soon as possible, in order to get feedback from farmers and consumers. The lesson is that a breeding program for an underutilized crop should necessarily be of modest size and tightly focused on its clients' demands.

History need not be a guide to the future

Just because the native Americans considered peach palm a staple does not mean that modern Euro-American-centric markets will agree. Modern mar-

kets, even in the interior of the third world, may have different demands now than in the past. The decline in the usage of native American foods and vegetable oils in Amazonia is a clear example of this, and peach palm is only one case. The lesson is that researchers should keep reappraising priorities from time to time, in keeping with the changing socioeconomic conditions, and should not be the sole arbiters of program objectives.

References

- Arévalo L.A., Szott L.T. and Perez J.M. 1993. El Pijuayo como componente de un sistema agroforestal. pp. 267–285. In: Mora Urpí J., Szott L.T., Murillo M. and Patiño V.M. (eds), IV Congreso Internacional sobre Biología, Agronomía e Industrialización del Pijuayo. Editorial Univ. Costa Rica, San José, Costa Rica.
- Argüello H. and Afanador G. 2002. El Chontaduro – Un Negocio Potencial para la Industria de Concentrados y la Producción Animal. Universidad Nacional de Colombia, Bogotá, Colombia, 36 pp.
- CIPAV/HV 2001. Control Integrado del Barrenador del Chontaduro *Bactris gasipaes* H.B.K. Fundación CIPAV / Fundación Herencia Verde, Cali, Colombia, 20 pp.
- Clement C.R. 2000. Pupunha (*Bactris gasipaes* Kunth, Palmae). Série Frutas Nativas 8, Fundep, Jaboticabal, São Paulo, Brasil, 48 pp.
- Clement C.R. 2001. Melhoramento de espécies nativas. pp. 423–441. In: Nass L.L., Valois A.C.C., Melo I.S. and Valadares-Ingles M.C. (eds), Recursos Genéticos & Melhoramento – Plantas. Fundação de Apoio à Pesquisa Agropecuária de Mato Grosso – Fundação MT, Rondonópolis, Mato Grosso, Brasil.
- Clement C.R. In Press. Fruit trees and the transition to food production in Amazonia. In: Balée W. and Erickson C. (eds), Time and Complexity in the Neotropical Lowlands: Studies in Historical Ecology. Columbia University Press, New York.
- Clement C.R. and Mora Urpí J. 1987. The pejobaye (*Bactris gasipaes* H.B.K., Arecaceae): multi-use potential for the lowland humid tropics. *Econ Bot* 41: 302–311.
- Clement C.R. and Santos L.A. 2002. Pupunha no mercado de Manaus: Preferências de consumidores e suas implicações. *Revista Brasileira de Fruticultura* 24: 778–779.
- Clement C.R. and Leeuwen J. van. In Press. Underutilization of pupunha (*Bactris gasipaes* Kunth, Palmae) in Central Amazonia: history, production-to-consumption system, implications for development and conservation. In: Alexiades M. and Shanley P. (eds), From Forest to City: Tracking Non-timber Forest Products along the Production to Consumption Chain. Latin American volume. CIFOR, Bogor, Indonesia.
- Hammond D.S., Dolman P.M. and Watkinson A.R. 1995. Modern ticuna swidden-fallow management in the Columbian Amazon: ecologically integrating market strategies and subsistence-driven economies? *Hum Ecol* 23: 335–356.
- de Jong W. 1996. Swidden-fallow agroforestry in Amazonia: diversity at close distance. *Agroforest Syst* 34: 277–290.
- Kerr L.S., Clement R.N.S., Clement C.R. and Kerr W.E. 1997. Cozinhando com a Pupunha. INPA, Manaus, Amazonas, Brasil, 95 pp.
- Labarta R.A. and Weber J.C. 1998. Valorización económica de bienes tangibles de cinco especies arbóreas agroforestales en la

- Cuenca Amazónica Peruana. *Revista Forestal Centroamericana* 23: 12–21.
- Mora Urpí J., Weber J.C. and Clement C.R. 1997. Peach palm. *Bactris gasipaes* Kunth. Promoting the conservation and use of underutilized and neglected crops. 20. Institute of Plant Genetics and Crop Plant Research – (IPK), Gatersleben and International Plant Genetic Resources Institute – (IPGRI), Rome, 83 pp.
- Mora Urpí J. and Gainza Echeverría J. (eds) 1999. Palmito de Pejibaye (*Bactris gasipaes* Kunth): Su Cultivo e Industrialización. Editorial Universidad de Costa Rica, San José, Costa Rica, 260 pp.
- NAS 1975. Underexploited Tropical Plants with Promising Economic Value. National Academy of Sciences, Washington, DC, 188 pp.
- Patiño V.M. 1963. Plantas Cultivadas y Animales Domésticos en América Equinoccial. Tomo I. Frutales. Imprenta Departamental, Cali, Colombia, 547 pp.
- Patiño V.M. 1992. An ethnobotanical sketch of the palm *Bactris* (*Guilielma*) *gasipaes*. *Principes* 36: 143–147.
- Popenoe W. and Jimenez O. 1921. The pejobaye, a neglected food-plant of tropical America. *J Hered* 12: 151–166.
- Sotelo Montes C. and Weber J.C. 1997. Priorización de especies arbóreas para sistemas agroforestales en la selva baja del Perú Agroforestería en las Américas 4(14): 12–17.
- Vockins K. 1999. Analysis of the U.S. Food Market-Opportunities for Heart of Palm. KV Marketing Incorporated, International Centre for Research in Agroforestry, Nairobi, Kenya, 109 pp.
- Weber J.C., Sotelo Montes C., Vidaurre H., Dawson I.K. and Simons A.J. 2001. Participatory domestication of agroforestry trees: an example from the Peruvian Amazon. *Development in Practice* 11: 425–433.
- Wu Leung W.-T. and Flores M. 1961. Tabla de Composición de Alimentos para Uso en América Latina. INCAP-ICNND, Ciudad de Guatemala, Guatemala, 157 pp.
- Yuyama L.K.O., Yonekura L., Aguiar J.P.L. and Sousa R.F.S. 1999. Biodisponibilidade de vitamina A da pupunha (*Bactris gasipaes* Kunth) em ratos. *Acta Amazonica* 29: 497–500.
- Yuyama L.K.O., Aguiar J.P.L., Yuyama K., Clement C.R., Macedo S.H.M., Fávaro D.I.T., Afonso C., Vasconcellos M.B.A., Vanucchi H., Pimentel S.A. and Badolato E.S.G. 2003. Chemical composition of the fruit mesocarp of three peach palm (*Bactris gasipaes*) populations grown in central Amazonia, Brazil. *Int J Food Sci Nutr* 54: 49–56.