Status, gaps and strategy in coconut germplasm collecting

R Bourdeix[1], L Guarino[2], V Ramanatha Rao[3] and L Baudouin[4]

[1]Coconut Breeder and [4]Geneticist, Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, Cedex 5, France

[2]Plant Genetic Resources Advisor, Secretariat of the Pacific Community (SPC), Suva, Fiji

[3]Senior Scientist, International Plant Genetic Resources Institute - Regional Office for Asia, the Pacific and Oceania (IPGRI-APO), Serdang, Selangor, Malaysia

Introduction

The International Coconut Genetic Resources Network (COGENT) Steering Committee decided to promote germplasm collecting in areas at risk of genetic erosion at its first meeting in Singapore in 1992. This was expected to fill the gaps in national collections, developing (and refining) both morphometric and molecular markers techniques for efficiently locating diversity and transferring efficient and practical techniques for collecting.

Phase 1 of the COGENT project 'Coconut Genetic Resources Network in Asia and the Pacific Region' was completed in July 1997. A regional network consisting of 13 countries was established to foster the conservation and utilization of coconut genetic resources. In December 1998, the Asian Development Bank (ADB) approved Phase 2 of the project. Its objective was to expand the network to 20 countries, to further promote coconut collecting and sustainable conservation, and to strengthen human resources. During 1997-2000, many coconut accessions were collected and planted in field genebanks in all the network member countries. The main objective of this chapter is to review and assess the strategies used in collecting coconut germplasm and make suggestions for future work.

Status of coconut germplasm collecting

As noted earlier, many coconut accessions have been collected and conserved (see Chapter 5 for more details). Access to information about this coconut germplasm is much better than it was ten years ago. COGENT network members are regularly updating passport information and characterization data of accessions in the Coconut Genetic Resources Database (CGRD). If a new coconut accession is now collected somewhere, there is a reasonably high probability that passport data will be available to the whole network through the CGRD, within one or two years.

In the CGRD Version 5.1 (April 2002), the total number of accession was 1416, of which 216 had no registered accession size (number of true-to-type living palms in the field). This means either that all palms of these accessions are dead or that data on them is missing. Information on dead accessions is kept in the database because it remains essential to researchers. Some general statistics on coconut collections are given below:

- 1186 accessions have a size of one or more palms
- There are only 620 distinct names (of cultivars or populations)
- 74% of accessions are of the Tall type
- 25% are of the Dwarf type, and the remaining 1% are intermediate forms
- 140 000 is the total number of 'living' palms
- The average number of palms per accession is 118 and per cultivar, 225
- About 30% of accessions have already been duplicated in several genebanks or rejuvenated

Another very important piece of information is the 'Date of Last Inventory/Counting' of each accession. It is the most recent date on which the number of living palms was checked. An examination of this field shows the following disturbing trend for the 1193 accessions, which have an accession size of at least one palm:

- For 36%, the Date of Last Inventory (DLI) remains unknown
- For 6%, DLI is during the past three years (2000-2002)
- For 47%, DLI is between 1996 and 1999
- For 11%, DLI is prior to 1995

During the period 1996-2001, visits were conducted to many countries to train and assist researchers to input data into CGRD (Bourdeix 1996; 1997a; 1997b; 1998; Bourdeix *et al*. 1999; Baudouin 2001). Although this improved data management, there is a strong need for continued efforts in this regard. In particular, checking and entering DLI should be done at least once a year. In addition, among the 1416 accessions, 120 (of which 16 were from Jamaica, 32 from Pakistan and 29 for Bangladesh, and 43 from various other countries) do not have any registered 'acquisition date'.

The oldest accession registered in CGRD is a Samoan Tall planted in 1912 in the Solomon Islands. Levers Plantations began there around 1905. Coconut research is said to have begun in India in 1916 and a varietal collection was started there in 1921 (Harries 1978). Twenty-three accessions were planted in India between 1934 and 1946 and are registered in CGRD database. An accession from Mapanget, Indonesia is dated 1927. The Coconut Research Scheme was established in Ceylon

– now Sri Lanka - in 1929. The depressed copra market of the 1930s impeded research, and a varietal survey that began in 1939 was terminated after only a few months (W.V.D. Pieris, personal communication, cited by Harries 1978) and the oldest accessions are dated 1954. In Africa, the Marc Delorme Research Centre began its activities in Côte d'Ivoire in the fifties (Nuce de Lamothe and Wuidart 1979).

Parham (1960) carried out one of the first scientific surveys intended to collect coconut palms and breadfruit trees in the Pacific. As a result, some coconut varieties with very large fruits, such as the Markham Valley Tall, were introduced to various genebanks throughout the world. Whitehead (1966) conducted a survey in the Pacific searching for varieties tolerant to the Lethal Yellowing disease of Jamaica. An indirect result of this work was to inspire Harries (1978) to develop his theory of evolution and dissemination of the coconut palm. Vanuatu began its germplasm planting in 1963 and the Philippines in 1976.

An examination of the CGRD also reveals that from 1912 to date, there have been only 11 years during which 50 or more coconut accessions were collected per year. Five of these 11 years were between 1992 and 1999, (i.e. during the early days of the COGENT). The other years in which at least 50 accessions were collected, were 1981 and from 1983-87. Around 30% of the registered accessions were planted after the COGENT was established (1992 and later). However, no accession acquired between 2000 and 2003 is registered in the CGRD database at the time of writing this paper. This suggests a significant reduction in collecting activities in the past three years.

Gaps in coconut germplasm collecting

The foregoing historical survey has established the fact that a substantial number of coconut accessions are being conserved in genebanks around the world. However, there may still be compelling reasons for further collecting. Additional collecting may be justified if:

1. Diversity is still missing or has been lost from existing *ex situ* collections;
2. Diversity is in imminent danger of disappearing from farmers' fields; and
3. Diversity is needed for immediate use and is not available from existing collections.

Related palm species

The palm family (Palmae or Arecaceae) counts about 2800 species scattered among 190 genera. The Cocoeae tribe contains 27 genera and nearly 600 species, including several economically important plants such as *Cocos nucifera* L. (coconut), *Elaeis guineensis* (African oil palm), *Attalea* *cohune* (babacu) and *Bactris gasipaes* (peach palm). Morphologically, the Cocoeae tribe is characterized by having the synapomorphy of presence of three or more pores or 'eyes' on the endocarp (Gunn 2002). It comprises of six sub-tribes, among which the Butiinae includes the *Cocos* genus and seven American genera (plus a recently discovered genus from Madagascar, *Voaniola*). Since most of the related genera are American in origin, in the past it was speculated that coconut also originated in Americas (Cook 1901). In recent classifications, *Cocos nucifera* L. is considered as the only species of the genus. It is generally considered that it cannot be crossed with any other species. However, as far as we know, no published report of such an attempt to date. There is thus an opportunity for research in this field, checking for such possibilities, as resistance to lethal yellowing in allied palms closest to coconut may be a revealing exercise. If nothing else, it would establish that the coconut is indeed a botanical and genetic 'outlier'.

Geographical gap-filling

Most often, gap-filling collecting focuses on uncovered geographical regions, which may be quite extensive, e.g. a whole country. Figures 1, 2 and 3 in the earlier article 'Mapping of coconut genetic diversity' can be used to visualize inadequately covered geographical regions by superimposing the theoretical coconut growing area and the location of collection sites. The zones coloured in grey, which are climatically suitable for coconut, do not seem to have coconut occurring in them, however, this needs to be confirmed by ground truthing (i.e. checking in the field).

It must be noted, however, that some areas may be better represented than they might look in these maps. For instance, India is probably better surveyed than the map implies, but Indian researchers have not yet inputted all the geographic coordinates of their national accessions. A collecting mission was conducted in Madagascar in 1999 by Indian researchers, but collecting information remains incomplete.

Some other areas are probably of low coconut diversity. For instance, for historical reasons, there is probably a low probability of finding unique diversity in African countries such as Congo, Democratic Republic of Congo, Angola, Ethiopia and Sudan. The same could be true in South America – in the central part of Brazil, and the parts of Peru and Bolivia east of the Andes. Nevertheless, all these zones have never been surveyed for coconut, and exploration would be justified.

Some areas remain clearly under-represented in national and international genebanks, which are listed below, in a subjective ranking of priority:

1. The west coast of South and Central America (except Mexico and Panama, which have already been surveyed). Germplasm

collecting is presently being conducted in Guatemala. These studies are essential, considering the problem of the Lethal Yellowing Disease and the history of coconut in this region;

2. A large part of Micronesia, including the Caroline and Mariannas Islands;
3. The eastern part of Polynesia, including the Tuamotu and the Marquesas Islands and Hawaii;
4. Irian Jaya and the Moluccas archipelago;
5. The tropical coasts of Australia and the Cocos/Keelings Islands, where putative wild coconut occurs (Williams 1990; Leach *et al.* 2003);
6. Madagascar. Seafarers from Southeast Asia reached this island probably around the sixth century AD and settled there. Molecular biology studies show that they probably introduced coconut seednuts with them, and new diversity developed thereafter; and
7. Other more localized areas like Somalia, Myanmar, Laos and Sarawak in Malaysia.

Some of the areas that are suggested here (such as Micronesia, eastern Polynesia, and the Cocos/Keelings Islands) represent only a very small part of the coconut world, in terms of cultivated area and economic value. However, these areas could prove to be extremely important for coconut diversity. Pacific Islanders, especially Polynesians, have been involved in coconut cultivation and transportation for a very long time. Coconut diversity is more endangered in these areas, precisely due to its comparatively low economic importance and due to the possible effects of global warming and other human activities.

It is interesting to note that the Arab traveller Ibn Batutta reported the presence of coconut in Yemen in 14th century. Climate is considerably drier at present than in antiquity (and probably than at the time of Ibn Batutta), and Yemen is not reported as a producing country. However, contact with local botanists could reveal the presence of a few remnants of this historically interesting population.

Targeted surveys and under-represented phenotypes

The various existing *ex situ* collections are still not fully representative of the germplasm available in farmers' fields, especially with regard to the diversity of climate under which coconut is grown. Occasionally, specific environmental conditions may be targeted. For example, high-altitude or cold-tolerant varieties remain under-represented in coconut collections. Finally, missing genotypes are sometimes targeted, e.g. named varieties of known appearance, which are not found in collections.

Most of the old surveys, such as those of Parham (1960) or Nuce de Lamothe and Wuidart (1979), intentionally focused on varieties with large, thin-husked fruits. Many farmers indeed prefer big round nuts. However, the use of the coconut husk is making a comeback, and it seems very important for the future to further safeguard and study the thick husked varieties.

Coconut from India and Africa has, on average, higher husk content than most of the coconut from Asia and the Pacific. In the Pacific, 'Niu Kafa' types are an exception. However, there are references from everywhere, including Southeast Asia, describing a few coconut varieties with a high percentage of husk. In 1978, Harries developed a theory about coconut evolution, dissemination and classification of the coconut. He used the name Niu Kafa to describe a putative wild coconut palm with a large husk. "First came the natural evolution and dissemination by floating of a variety with large, long, angular, thick husked and slow germinating fruits. From this thick-husk type, selection under cultivation produced a spherical fruited variety, not necessarily larger but with increased endosperm, reduced husk thickness, earlier germination and disease resistance" (Harries 1978). However, according to Foale (1987), islanders also selected other palms bearing fruits that contained long fibres to make strong twine and ropes for use in the construction of both buildings and boats. Consequently, the huge fruits presently known as Niu Afa in Samoa, Niu Kafa in Tonga and Magi Magi in Fiji are no longer wild coconuts; they are varieties highly selected by the Polynesians for the utilization of husk. This is particularly clear in Samoa, where the variety seems to occur in its purest form, and where the palms are located near houses and are all of a homogeneous green colour.

An important theoretical question that arises is whether there is a link between the Indo-African Coconut group and the Pacific and Asiatic cultivars with high husk content. Molecular techniques may help to resolve such a question. However, so far only a very few samples of the Niu Kafa type have reached laboratories in good order. Only one typical sample could be analyzed, and it appears that it is not closely related to the Indo-Atlantic coconuts. At least 20 to 30 more samples of thick-husked varieties originating from different parts in Asia, the Pacific and Oceania should be collected and DNA-analyzed. These varieties could be of Niu Kafa types, but they may also give smaller fruits of quite different shapes. Some varieties from the Tuvalu archipelago have high husk content but with a shape that, although elongated, is very different from those of Niu Kafa (Labouisse and Bourdeix 2003). It is important to collect different putative 'wild' coconut types and analyze them using molecular markers. Such a study may enhance our knowledge about dissemination and help in refining collecting strategies and even the design of coconut breeding programmes.

Another endangered special phenotype is a class of coconut varieties described as 'Sweet Husk'. The husk of young fruits of this type is soft and sweet and can be chewed like sugarcane. When over-mature, the fruits can be husked easily. Fruits of these varieties are generally eaten by children, flying foxes and rats before nuts mature. It is almost impossible to collect them in a classical survey, as no seed is usually available. Local people are no longer interested in them as in the past as consuming them due to changes in social norms. For example, Tiara Mataora, from the Cook Islands said "I like it but do not want somebody to see me chewing sweet husk, because these people will think I am a poor man". A special effort to collect and study these types must be made. Such special variants could be useful for making high value products for the tender nut market.

Two important collecting programmes were known to focus on particular traits: drought adaptation in Sri Lanka (Liyanage *et al*. 1988), and selection for Lethal Yellowing Disease (LYD) tolerance in Tanzania (Schuiling *et al*. 1992). It seems that these two programmes have not really been successful. The accessions from areas in Tanzania with high LYD pressure continue to die from the disease during the next generation. Accessions collected in Sri Lanka from both dry and wet zones were compared under dry conditions, but no significantly different reactions were noted.

Other interesting types will probably emerge from the results of the farmer participatory approach (see related section below).

Losses from existing *ex situ* collections

The life span of coconut accessions is sometimes shorter in germplasm conservation centres than in farmers' fields. Some example will illustrate this. Indonesian accessions registered in the CGRD are conserved at four different sites: Mapanget (Manado City), Pakuwon, Bone-Bone and Sikijang, Selakau (West Kalimantan), Makariki (Molluccas) and Marihat (North Sumatra) (Rognon and Batugal 1998). However, Indonesian researchers in Manado informed us that these conservation sites are no longer in use. The remaining accessions in Marihat are said to be original populations and to date, these have not been duplicated anywhere else and thus become important for future rejuvenation and planting in current genebanks.

In CGRD Version 5 (2002), 55 Indonesian accessions out of 156 do not have any data for the accession size field (number of living palms) and the date of the last inventory/counting. Some of these accessions, such as the 1995 planting in Manado and those conserved at the Bone-

Bone Station, appeared to have been destroyed and later was no longer considered as a coconut germplasm centre. According to Indonesian researchers, the 41 accessions (1682 palms planted between 1984 and 1988) are considered lost. At Sikijang, at least 25 accessions, with 100 palms each, were planted in 1998 and 1999. Because of various factors, including fire, in January 2001 (i.e. only 3 years later) 77% of these palms were either dead or in a poor condition. Due to the change of status of Sikijang station, it is assumed that the 30 accessions at that station were mostly lost. However, as some palms remained, they have not been removed from the inventory. Indonesian germplasm now stands at 170 accessions (including some new ones), of which 61 can be considered as lost. Therefore, the real number of living accessions for Indonesia cannot be more than 109, with 4976 palms (on average, only 46 palms per accession). At least 65 accessions from Indonesia are now lost and should be re-collected (after having found a way to safely conserve them for the future).

In Papua New Guinea, demonstration plots of various cultivars were planted during the early 1930s at the Bubia Lowland Agricultural Experimental Station. In 1964, it was decided to plant a new trial at Kapogere Agricultural Station in the Central District, Papua. The scope of the trial was broadened to include at least nine foreign introductions: New Hebrides, Solomon Islands, Malaysia, Rennell Island, Singapore, Ceylon-Random, Ceylon-Selected, Maldives and Fiji Talls. The status of these accessions remains unknown. They are not registered in CGRD and they were not transferred to the international collection in Madang. The accessions collected in the past and planted in old, possibly now neglected, field genebanks should be safeguarded.

In Thailand, it seems that some old accessions were cut without being rejuvenated in order to plant oil palm experiments. The sustainability of germplasm banks seems better in Côte d'Ivoire, India, the Philippines and Sri Lanka.

Targeted exchanges between germplasm conservation centres can help in duplicating accessions in different genebanks for safety and in promoting the sustainability of coconut genetic resources conservation. Exchange of germplasm immediately after a collecting mission is also advantageous as many freshly collected embryos would be available and could be exchanged safely. The exchange of coconut germplasm among coconut-producing countries remains very limited. For example, from 1995 to 1999, only one coconut variety was exchanged between the Philippines and Vietnam. In contrast, more than 80% of the foreign cultivars existing in Brazil, Indonesia, Philippines, Tanzania, Thailand, Sri Lanka and Vietnam came from the Marc Delorme Research Centre in Africa in the past.

India is an exception, with a strong collecting programme abroad. But only a few palms remain from the survey conducted by Indian researchers in Madagascar. Five accessions were collected in 1997 from a single location in Sambava province. Many plantlets died before reaching the field planting stage. These may have to be re-collected to have a representative population of these accessions.

More than 3000 coconut embryos were collected from Tuvalu, Cook Islands, Marshall Islands and Kiribati and sent to the Secretariat of the Pacific Community's (SPC) Regional Germplasm Centre (RGC) in Suva, Fiji. Unfortunately, almost all these embryos died during the *in vitro* culture and/or the transfer to the International Coconut Genebank (ICG) in Papua New Guinea. The reasons for these losses were the high rate of contamination and low rate of rooting. Some of these accessions need to be collected again.

An FAO report by Pieris (1966) indicated that the concern for collecting exotic germplasm was high in the early 60s, as about 30 countries reported seed or pollen exchange. This period contributed indeed to the richness of present genebanks. However, many of the cultivars are no longer reported in the receiving country. For example, the Philippines received planting material from 14 countries primarily for resistance trials against Cadang-Cadang. Apparently, nothing is left from this introduction and some of these cultivars had to be re-sampled about 20 years later.

Genetic erosion

To understand on a smaller scale the mechanisms that build diversity and the factors that influence the evolution of coconut types, a study was undertaken in Vanuatu, a remote archipelago in the South Pacific (Caillon 2003). There were 60 variants named based on a particular aspect describing distinct character from the rest of the population (Labouisse and Caillon 2001). Of these 60 variants, 45% may not be selected but are still recognized, 20% are chosen for their social importance (e.g. a coconut brought by a local mythical hero), 15% to make copra, 13.3% for their nutritional qualities and 6.7% for non-food uses (e.g. containers, ropes). In a remote village of a northern island (Vanua Lava), where 30 variants are found, only 5% of all the coconuts planted by 25 farmers are named (Caillon, pers. com.). Coconuts selected for their domestic and social interest are the least numerous (7.4% and 8.5% of the planted variants, respectively) whereas 46.9% are planted for food purposes. The most striking example concerns the variant with a large proportion of husk traditionally used to make ropes. These specific coconut types are currently ignored as other types of ropes have become more prominent. At the same time, the importance of copra for cash has increased. As a result, truly 'high husked' variant can only be found on old plantations dating from the time when farmers still used coconut ropes. This exemplifies genetic erosion due to changes in farmers' preferences.

The number of named variants in a field depends on a farmer's willingness to select and plant variants with characteristics other than high copra, in order to respond to other uses for food, shelter or social needs. Generally, planting material for new plantation comes from farmer's own garden or from a nearby plantation. However, the most remarkable variants come from other plantations, sometimes distant, where the farmers might have seen while helping other villagers/farmers making copra and brought a few seednuts back. However, that level of diversity also varies greatly depending on the degree of knowledge of a farmer about his/her own coconuts. Thus, young plantations planted by the current generation owner in which immature fruits are accessible and where copra is frequently made will be the richest ones in terms of genetic diversity. Consequently, the reduction of named variants at a village scale is due to the combination of cultural erosion through the loss of traditional uses and through the younger generations' loss of ability to identify variants. Such loss caused by social process could further be demonstrated more clearly by molecular techniques to assess real genetic erosion even if variants are not readily identified but are still growing around and are able to exchange genes through allogamy. Such an approach is currently underway.

Changes in land use patterns, urban migration, industrialization and replacement with other species (such as oil palm) or with introduced and/or improved varieties (hybrids) are contributing greatly to the loss of coconut diversity. Natural calamities (cyclones, drought, diseases such as cadang-cadang and lethal yellowing) as well as human induced ones (pollution, war, etc.) are also agents of genetic erosion.

Strategy in coconut germplasm collecting: Towards a diversity of approaches

No single approach is likely to be effective to collect and conserve the full range of variation within a target gene pool and making it available to breeders and other users, and coconut is no exception. Collecting germplasm for *ex situ* conservation should thus be regarded as simply one of the components in a comprehensive strategy for conservation of the target gene pool.

Until recently, coconut surveys were faced with two constraints linked to the biology of the plant. The first is the large size of the fruits; a sample of a hundred fruits often weighs more than 150 kg. The volume of the fruits considerably restricts the number of samples that can be transported, or leads to a reduction of the effectiveness of the samples. Another constraint is the nature of the seed. The coconut, with recalcitrant seeds (Roberts *et al.* 1984), looses germination capacity rapidly. Most cultivars have no dormancy period; the seeds start to sprout 1-3 months after reaching maturity. Moreover, the coconut seed is relatively sensitive to cold. Due to these characteristics, numerous samples of coconut varieties have been lost partly or totally for various reasons: survey conditions did not allow for sufficient sampling or ships transporting the fruits passed through zones that were too cold, or duration of transport and customs clearance exceeded the survival time of the seeds. For these reasons, in all research stations some coconut accessions can be found that are represented by numbers that are too low to constitute a good population for conservation, though originally large number of nuts might have been sampled. The application of new technologies makes it possible to get around some of these problems (see Engelmann, Chapter 2). However, much care needs to be exercised to avoid what happened recently in the Pacific.

Bourdeix *et al.* (1999) described case studies that were conducted in 14 countries involved in coconut germplasm surveys during the 1994-1999. These detailed studies cannot be reproduced *in extenso* here but some of the most general conclusions and thoughts are discussed in the next section.

The Coarse Grid Strategy

In 1997, a manual on coconut breeding research techniques (STANTECH) was published and distributed to coconut-producing countries (Santos *et al.* 1996). This manual describes the bases of the recommended collecting method in its Chapter 3 on 'Germplasm exploration and collecting' and Chapter 10 'Generalized sampling strategy'. The Coarse Grid Sampling strategy described here has been applied systematically to cover the coconut areas in the Philippines (Santos 1987) and Malaysia (Jamadon 1987). The basic elements of this process is described below by Guarino *et al.* (1998).

As noted earlier, the COGENT member countries have collected significant amount of coconut genetic diversity during 1993-2000, with support from ADB. A research team from the French Agricultural Research Centre for International Development (CIRAD) was mandated to review and assess the effectiveness of the collecting strategies followed in the first phase of this project. This study noted that only one country, the Philippines, made use of grid sampling technique. No country used 'coconut importance value' suggested in the collecting strategy. It must

The Coarse Grid Strategy

How can a national, regional or international coconut research programme assess the relative importance of the different reasons for collecting? It will clearly need some basic information on its mandate region:

- Where is the crop growing, in relation to agro ecological zones of the region?
- How much genetic variation is already present in genebanks?
- What are the main agents of genetic erosion and where are they most threatening?
- Who are the principal users and what are their needs?

The sources of this information will include agricultural censuses and atlases, the databases of genebanks, local extension agents and their records and coconut breeders. Based on this information, it should be possible to identify (and prioritise among) areas of the following types within the mandate region:

1. Under-represented areas. These can be identified by mapping passport data of existing collections, and include areas where collecting has been inadequate or has not occurred at all.
2. Complementary areas. These are areas, which are genetically, or environmentally different from areas from which collecting has already taken place, based on passport and characterization data.
3. Environmentally or genetically diverse areas. In previously uncollected or under-collected areas, it is advantageous to collect over wide range of agroecological conditions because genetic diversity is partially correlated with environmental diversity. Preliminary characterization and evaluation (including genetic diversity studies) of conserved material may have identified areas, which are particularly diverse genetically.
4. Areas with target genetic material. This may be inferred from environmental conditions, known from previous characterization and evaluation work and/or revealed by local knowledge.
5. Threatened areas. These may be identified by local people, repeat visits, etc.

Based on the points derived from the brief survey of patterns of genetic diversity in coconut, the following basic elements of a coconut collecting strategy are proposed:

Choosing the sites

1. Divide the coconut-growing region in 40x40 km grids. This should be done separately and independently for each sub-regional grouping (stratified sampling). In general, collecting in the SE Asian region should be more intensive, so smaller grid sizes could be used.
2. Superimpose the location of the different types of areas listed above on

the grid. This can be done using a GIS. Calculate a 'coconut collecting importance value' (CCIV) for each grid square based on the presence and priority value of each type of area in the grid area.

3. If possible, carry out a preliminary exploratory visit to 2-3 sites per grid square and collect morphological information to complement characterization information from germplasm already conserved. Use this information to further refine the CCIV.
4. Collect germplasm systematically at a minimum of two sites in all grid squares. If the material is of the same ecotype and/or environmental conditions are similar, leave a minimum of 15 km between sites.
5. Collect more intensively (up to six sites) in grid squares that have a higher CCIV.

however be noted that much of the collecting in Phase I was over in 1997, while the strategy was developed in 1998. Most of the surveys were conducted by following, more or less precisely, administrative divisions such as regions, subregion and districts. Major constraints noted for the implementation of the collecting strategy were the time and capacity to build geographical grids that need well documented information such as climate, soil and population data. CIRAD team then recommended that the International Plant Genetic Resources Institute (IPGRI) should prepare, for national researchers, computerized maps with standardized geographical grids already documented with general information and national researchers to focus on gathering plant-specific information. However, it is not possible for IPGRI to undertake such country specific activity and training national partners to develop their capacity to make the grids, etc., will be more appropriate. This is also appropriate in the light of other developments in the area of climate and other data that are now available on the web (see below).

Independent of the report by the CIRAD team, CIP (International Potato Center) and the IPGRI have collaborated since 1999 in developing the software DIVA-GIS. This software is a Geographical Information System tailor-made for genetic resources applications. The DIVA-GIS may be downloaded free from the Internet at http://diva-gis.org/. The question of availability of collecting grids remains open and is currently being discussed with the DIVA-GIS developers. In the future, it will be useful to standardize the use of these grids at global level - not only for the coconut palm, but also for all crops. It is suggested here to use a grid of 20′ of latitude x 20′ of longitude instead of 40 km x 40 km squares. Such a grid is easier to draw using a GIS or even a commercial map, by interpolating available parallels and meridians. At the equator, the side of cell is about 1852 km x 20= 37 km. As latitude increases, the N-S sides remain constant, while the E-W sides decrease progressively. However, it is still close to 35 km at latitude of 20°. Thus, at least at subtropical latitudes, it is almost equivalent to using grids measured in km or in minutes. Discussion on this proposal is in progress.

Germplasm collecting programmes are best carried out in two stages. The first phase consist of exploration and preliminary survey to collect information on sites and material that occurs in those sites which will permit better planning of the second phase. The second phase is the more systematic collecting mission. Following the geographic grid approach, the first step will be to gather considerable data *in situ* (such as fruit component analysis, evidence of erosion, etc.) and samples for DNA testing. The data gathered during the exploration phase will then be analyzed, including using GIS tools. The next step will consist of returning to a limited number of specific sites that are expected to have high, unique, new, useful or threatened coconut genetic diversity, based on the information gathered in phase I, in order to harvest seednuts and bring them back to the genebank(s). The information from areas where no collecting takes place will have value for ground-truthing the theoretical distribution of coconut cultivation (see section on geographical gaps in this article), as well as for determining future on-farm conservation sites and monitoring genetic erosion. Up to now, there is no example of such a strategy using both *in situ* field characterization and DNA analysis as a decision-making process. However, with the microsatellite tool kit ready for use, this is expected to occur in the near future.

Although the two-phase collecting as described above would be ideal, for practical reasons including financial and time constraints, it may be impossible to visit the same place twice as suggested. An alternative method would be to collect directly seednuts and/or the embryos, and leaflet samples, at the same time, along with *in situ* characterization data such as fruit components. Back at the germplasm centre, DNA from the leaflets or from nuts germinated in the nursery should be analyzed to decide on which samples to include in the genebank as ‘accessions’ i.e., all the populations sampled may not be planted in the genebank. The objective is to use the diversity and other observation data to enable planting only the accessions representing particularly high, unique, new, useful or threatened genetic diversity. This is important as the maintenance of large number accessions in field genebanks by national organizations is very difficult and very expensive. Therefore, genebanks with a minimum number of accessions that capture maximum useful genetic diversity are needed.

It must be noted, however, that although some samples may not be included in the genebank, the data (including the collecting data) on all samples would be very useful to maintain for mapping purposes.

The farmer participatory approach

There is a growing recognition that the effective conservation of biodiversity will depend on the long-term participation and understanding of local communities. Participatory Rural Appraisal (PRA) comprises a set of techniques aimed at shared learning between local people and outsiders (Baker 2000). Collectors require training in specialized participatory methodologies such as PRA, in particular the use of visual methods (sketches, ranking, diagramming, and cognitive mapping). Important considerations include how to choose informants, the best time for consultations, whether individual interviews should be complemented with group discussions, and ethical issues such as informed consent and anonymity (Ramanatha Rao *et al*. 1998; Eyzaguirre and Batugal 1999).

An example from India may reveal a quite surprising aspect of the PRA method, however. This example was found in a research report distributed during the 1998 COGENT Steering Committee meeting held in Kuala Lumpur, Malaysia. The report states that in India, farmer's participatory survey was conducted in eight sites representing the three major agro-climatic regions of Kerala. At each site, the interaction was based on a semi-structured questionnaire and lasted some 6-8 hours. The popularity of various coconut varieties was evaluated, including: Tall types, Dwarf x Tall hybrids such as COD x WCT (Chowgat Orange Dwarf x West Coast Tall), and the 'Natural Cross Progeny of the Chowgat Orange Dwarf' (NCD). According to participants, many farmers produced NCDs by sowing their own Dwarfs nuts and selecting off-types based on their brown petiole colour for their own use as well as for sale within the locality.

In all the eight study sites, the participants favoured off-types of COD (NCDs) in place of TxD and DxT hybrids for cultivation. However, these NCDs are nothing more than natural DxT hybrids! The brown colour of NCDs petiole indicates that the Red Dwarf, as mother palm, is naturally crossed with Green or Brown Coconut palms, i.e. the West Coast Tall coconut available all around in farmers' fields as male parents. So, the two cultivars compared – Hybrids and NCDs – are in fact the same genetic material. This point was not underlined by the researchers in charge of the PRA survey and analysis. Anyway, it demonstrates that the farmers indeed practice a certain amount of crop improvement and are able to generate their own hybrid seednuts. But the only difference between NCDs and Dwarf x Tall hybrids is that research centres release 'hybrids', while

NCDs are selected by farmers in their own gardens. That may explain the farmers' preference.

Application of PRA methods to obtaining crucial information on the origin and extent of the genetic diversity that is being collected would be most useful in areas where people maintain the closest relationship with their coconut palms. Surveys conducted in archipelagos such as Cook Islands and Tuvalu indicate that germplasm diversity and knowledge seem to be higher in the most isolated islands (Labouisse and Bourdeix 2003; Caillon 2003). This type of information helps in the collecting process, in particular:

Locating and accessing target areas and material. Locating target germplasm means being in the right place at the right time. Specialist local knowledge is often the best guide not only to where a particular variety may be found, but also to the optimal timing of collecting.

Deciding what to collect and how. When material with particular characteristics is being sought, indigenous knowledge can provide crucial clues.

Assessing the completeness of collecting. Local men and women know which varieties are grown in their village or district or are being sold in the local markets. A checklist compiled on the basis of such information can act as a guide to collecting in a given area, providing a benchmark for comprehensive sampling of the available diversity.

Understanding the origin and distribution of diversity. Landraces are at least partly shaped by what may be referred to as the informal plant breeding and seed production and supply systems. Thus, understanding the diversity within a crop in an area (which is crucial to developing a conservation strategy) means understanding the practices of the people who grow it.

Assessing the reasons for, extent and danger of genetic erosion. Oral testimony is often the only source of information on change in the extent of cultivation of a crop, and in the cultural practices being used. Older farmers will sometimes remember the names and attributes of landraces, which they no longer grow, and which may have entirely disappeared from their area.

Documenting and using the collection. Local knowledge should form an important part of the documentation of germplasm samples. Farmers are aware of the many characteristics and properties of varieties.

Documenting such local knowledge of the appearance, properties and adaptations of germplasm should be seen as an integral part of the characterization and evaluation process, and as such as an important way of facilitating and accelerating the use of conserved germplasm.

Conclusion

Though it is now well recognized that a significant amount of coconut diversity has been collected and conserved in several coconut research organizations, especially since the establishment of COGENT, their representation and availability of associated data are still incomplete. There is still substantial uncollected indigenous germplasm, and some of it is under threat of genetic erosion. The most important reason for the continued occurrence of coconut diversity is that farmers have interest in and possess knowledge about their coconut varieties. However, along with the diversity, such knowledge is rapidly eroding in some areas as so-called modernization and globalisation reach into even the most remote parts of the world. Researchers will have to focus on breeding and germplasm utilization to benefit from the investment made in collecting and conserving.

Emphasis should be placed on the use of molecular techniques and morphological characterization to rationalize large collections in order to reduce the actual number of cultivars in the germplasm centres from around 350 to 150-200, so that the genebanks are more manageable, both in terms of financial and human resources and scientific backstopping. Then additional collecting, using these new screening techniques, should allow adding 150-200 more priority accessions. The use of Geographical Information Systems tools will facilitate the task of the collectors.

Some elements were discussed regarding the effectiveness of targeted collecting, as compared to comprehensive grid sampling and farmer participatory methods. Use of the concept of CCIV could further help in identifying the priority accessions to be included in genebank collections and training to implement collecting strategy and the use of GIS tools is considered important to enhance the efficiency of collecting. Thick-husked varieties from Asia/Pacific and sweet husk varieties are two endangered phenotypes that should be targeted. Surveys that are more systematic should be conducted in areas that have not been covered during previous collecting programmes. Some important accessions that have been lost in collections should also be re-collected. Farmer's participatory methods should be applied in communities where people know a great deal about every coconut palm in their gardens (such as very isolated islands) to document the knowledge and practices farmers use to maintain coconut diversity in their fields.

References

Ashburner, GR, MG Faure and MA Foale. 1994. Methods for coconut germplasm prospection. Pp. 41-43. *In:* MA Foale and PW Lynch (eds). Coconut improvement in the South Pacific. Proceedings of a workshop held in Taveuni, Fiji Islands, 10-12 November 1993. ACIAR, Canberra.

Baker, JL. 2000. Evaluating the impact of development projects on poverty: A handbook for practitioners. LCSPR/PRMPO, the World Bank, Washington D.C.

Baudouin, L. 2001. Soutien technique et recherche de coopérations éventuelles en amélioration du cocotier dans le cadre de l'accord bilatéral entre le Cirad et le CATAS (Chinese Academy of Tropical Agricultural Sciences) -Appui aux chercheurs locaux dans le cadre de leur participation au réseau Cogent, collecte de de données pour le logiciel CGRD.

Bourdeix, R. 1996. Coconut germplasm in Jamaica, Mexico and Brazil. Mission report, March 1997, Doc CIRAD-CP 548, France. 53p.

Bourdeix, R. 1997a. Coconut germplasm in Tanzania, Sri Lanka and India. Mission report, March 1997, Doc CIRAD-CP 739, France. 49p.

Bourdeix, R. 1997b. Actions de formation en Afrique et Amérique Latine/Caraïbes. Cours de formation des formateurs à l'utilisation du manuel Stantech (Techniques Standardisées de Recherches pour l'Amélioration du Cocotier). Mission Report, August 1997, Doc CIRAD-CP no. 857, France. 49p.

Bourdeix, R. 1998. Coconut germplasm and breeding in Papua New Guinea and Vanuatu. CIRAD 1997 Annual Review Report, March 1998, Doc CIRAD-CP No. 998, France.

Bourdeix, R, L Baudouin, J Ollivier and JP Labouisse. 1999. Consultancy report on coconut collecting strategies submitted to COGENT/IPGRI. IPGRI-APO, Serdang, Malaysia.

Caillon, S. 2003. Gestion traditionelle et conservation *in situ* de l'agrodiversité : cas du cocotier (*Cocos nucifera*) et du taro (*Colocasia esculenta*) au Vanuatu (Pacifique Sud). Thèse de Doctorat, Département de Géographie, Université d'Orléans. (non publié).

Caillon, S. 2003. Réflexion méthodologique sur la conservation in situ de la diversité phytogénétique: cas du cocotier et autres plantes cultivées au Vanuatu. Thèse de Doctorat, Université d'Orléans. (non publié).

Cambel, H and RJ Braidwood. 1970. An early farming village in Turkey. Scientific American. pp. 51- 56.

Darwis, SN and HT Luntungan .1992. Status of existing coconut collections in Southeast Asia. Industrial Crops Research Journal 4: 27-39.

Eyzaguirre, P and P Batugal (eds). 1999. Farmer participatory research on coconut diversity: Workshop report on methods and field protocols. IPGRI-APO, Serdang, Selangor, Malaysia.

Eyzaguirre, PB. 1999. Farmers' contribution to improving the value and uses of coconut through the maintenance and use of genetic diversity. Pp. 1-15. *In:* PB Eyzaguirre and P Batugal (eds). Farmer participatory research on coconut diversity: Workshop report on methods and field protocols. IPGRI-APO, Serdang, Selangor, Malaysia.

Foale, M.A. 1992. Coconut genetic diversity: Present knowledge and future research needs. Pp. 46-58. *In:* Coconut genetic resources. Papers of an IBPGR Workshop, Cipanas, Indonesia, 8-11 October 1991. International Crop Network Series No. 8. IPGRI, Rome.

Guarino, L, V Ramanatha Rao and P Batugal. 1998. Collecting coconut genetic diversity. Elements of a strategy for COGENT germplasm collecting activities. Paper presented at the annual meeting of ADB- and IFAD-funded projects, 28-4 November 1998, Kuala Lumpur, Malaysia.

Gunn, BF. 2002. Phylogeny of the Cocoeae (Palmae), with emphasis on *Cocos nucifera* L. [Poster]. *In:* Annual Scientific Conference Botany 2002 "Botany in the curriculum: Integrating research and teaching", 4-7 August 2002, Pyle Conference Center University of Wisconsin, Madison, Wisconsin, USA. http://www.botany2002.org/section15/abstracts/13.shtml.

Harries, HC. 1978. The evolution, dissemination and classification of *Cocos nucifera* L. The Botanical Review 44:265-320.

Labouisse, JP and S Caillon 2001. Une approche de la conservation *in situ* par l'étude d'un système semencier informel: cas du cocotier au Vanuatu (Pacifique Sud). Oléagineux, Corps gras, Lipides 8(5):534-539.

Labouisse, JP and R Bourdeix. 2003. Coconut germplasm collecting, characterization and conservation in Cook Islands, Kiribati, Marshall Islands and Tuvalu. Final project report. CIRAD, Montpellier, France.

Leach, BJ, MA Foale, GR Ashburner. 2003. Some characteristics of wild and managed coconut palm populations and their environment in the Cocos (Keeling) Islands, Indian Ocean. Genetic Resources and Crop Evolution 50 (6): 627-638

Liyanage, DV, MRT Wickramaratne and C Jayasekara. 1988. Coconut breeding in Sri Lanka: A review. Cocos 6: 1-26.

Meunier, J, G Benoit, M Ghesqiere and M Jay.1992. Genetic diversity in coconut: A brief survey of IRHO's work. *In* Coconut genetic resources. Papers of an IBPGR Workshop, Cipanas, Indonesia, 8-11 October 1991. International Crop Network Series No. 8. IPGRI, Rome. Pp. 59-

62.

Moss, H and L Guarino. 1995. Gathering and recording data in the field. pp. 367-417. *In:* L Guarino, V Ramanatha Rao and R Reid (eds). Collecting plant genetic diversity. CAB International, Wallingford. Pp. 367-417.

N'cho, YP, A Sangare, R Bourdeix, F Bonnot and L Baudouin.1993. Assessment of a few coconut ecotypes by a biometric approach. Study of tall populations. Oléagineux 48:121-137.

Nuce de Lamothe, MW de and W Wuidart 1979. Les cocotiers Grands à Port Bouët (Côte d'Ivoire). I. Grand Ouest Africain, Grand de Mozambique, Grand de Polynésie, Grand de Malaisie. Oléagineux 34:339-349.

Ohler, JG. 1984. Coconut: Tree of life. FAO plant production and protection paper No. 57. FAO, Rome.

Parham, RW. 1960. Coconut and breadfruit surveys of the South Pacific region. Technical Information Bulletin No 1, South Pacific Commission, Suva, Fiji.

Ramanatha Rao, V, L Guarino and G Jackson. 1998. Collecting taro genetic diversity: Elements of a strategy. Paper presented at the Collecting Workshop Report, 7-11 December 1998, Lae, Papua New Guinea. SPC, Suva, Fiji.

Ramanatha Rao, V, KW Riley, JMM Engels, F Engelmann and M Diekmann. 1998. Towards a coconut conservation strategy. Pp. 4-20. *In* V Ramanatha Rao and P Batugal (eds). Proceedings of the COGENT Regional Coconut Genebank Planning Workshop, 26-28 February 1996, Pekanbaru, Riau, Indonesia. IPGRI-APO, Serdang, Selangor, Malaysia.

Rognon, F and P Batugal. 1998. Evaluation of Indonesia as a regional coconut genebank host country. Pp. 41-47. *In:* V Ramanatha Rao and P Batugal (eds). Proceedings of the COGENT regional coconut genebank planning workshop held at Pekanbaru, Indonesia, 26-28 February 1996. IPGRI/COGENT, Rome. Pp 41-47.

Santos, GA, PA Batugal, A Othman, L Baudouin and JP Labouisse. 1996. Manual on standardized research techniques in coconut breeding. IPGRI-COGENT, Singapore. 46pp.

Schuiling, M, DA Kaiza and HC Harries. 1992. Lethal disease of coconut palm in Tanzania. III. Low resistance of imported germplasm. Oléagineux 47(12): 693-697.

Sokal, RR and RF Rolf. 1981. Biometry. Freeman, San Francisco.

Whitehead, RA. 1966. Sample survey and collection of coconut germplasm in the Pacific islands, 30 May- 5 September 1964. Ministry of Overseas Development and HMSO, London.

Williams, DG. 1990. An annotated bibliography of the natural history of the Cocos (Keeling) Islands, Indian Ocean. Atoll Research Bulletin 331:1-17.

Zizumbo-Villareal, D, F Hernandez and HC. Harries. 1993. Coconut varieties in Mexico. Economic Botany 47:65-78.