A Global Strategy
for the conservation and use of Coconut Genetic Resources
2018-2028

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COGENT
Coconut genetic resources for enhanced livelihoods

Bioversity International

Using cryopreservation techniques based on embryos, plumules or pollen carries certain constraints. It does not allow reproducing and thus multiplying a genotype, but only the progeny of this genotype. Thus, some of the limitations linked to the reproduction mode of the coconut palm still apply, such as the requirement of costly controlled hand-pollinations to duplicate a Tall-type variety conserved in an *ex situ* collection. For most allogamous Tall-type varieties conserved *ex situ*, embryos will have to be obtained by controlled pollination with bagging.

Therefore, the main constraint to the development of a cryogenebank from *ex situ* field collections remains again the cost of controlled pollinations. However, in some cases, instead of using the palms conserved in *ex situ* collections, it will be possible to access the original source of particular genotypes in farmer's fields. But going back to these sites will also have a significant cost.

2.3 The current global *ex situ* conservation system

Currently, coconut germplasm is only conserved as accessions in one or more *ex situ* collections. Twenty-four of these field genebanks are located in 23 COGENT member-countries. Unique and valuable material is kept in these genebanks. They conserve local traditional varieties, introductions from other collections, and accessions collected directly abroad by institutions from Côte d'Ivoire, France, India and Jamaica.

Information regarding the content of these collections is gathered in the CGRD, managed by the COGENT secretariat. Available on the COGENT website, this database is of crucial importance. It provides the only global compilation of *ex situ* conserved coconut germplasm.

Three surveys aiming to collect information on *ex situ* collections were undertaken by COGENT in 2012 and 2013 to better understand the objectives of the collections, their content (in terms of diversity), the long-term security of the collection, the management of the information, the exchange of materials and the (urgent) needs and priorities to be addressed through a global collaborative Strategy. Annex 6 provides the template of the global survey conducted in 2013 and the list of institutions who responded.

In 2014, a last electronic survey was launched by the COGENT Secretariat to understand the perspectives of the genebank curators on (i) the optimization of the current areas of the 24 collections of the network, (ii) the policy regarding backup accessions, (iii) the support required from the multilateral system, (iv) the level of collecting in each country, and (iv) whether the collection of new cultivars should continue or not during the next 10 years.

The *ex situ* conservation management and activities are described in sections below, based on information from the surveys conducted in 2012, 2013 and 2014, from the content of CGRD and from direct interaction with curators.

2.3.1 Content of *ex situ* collections

Most coconut germplasm international movements before 1940 can be classified in two types:

- Introduction of very small amounts of seednuts, by farmers or scientists, for experimental purposes. Generally only one to ten seednuts were introduced for each cultivar for conservation;
- Introduction of many seednuts to create large plantations with varieties coming from other countries for commercialization.

Most genebanks started by collecting traditional varieties in their respective countries. Then, germplasm imports from abroad began.

The total number of registered accessions in collections reached 1760 in 2017. It is currently estimated that only 1607 accessions[18] are still alive. Detailed lists of the cultivars, populations and accessions, ranked either by site of conservation or alphabetic order, are available on the COGENT website[19].

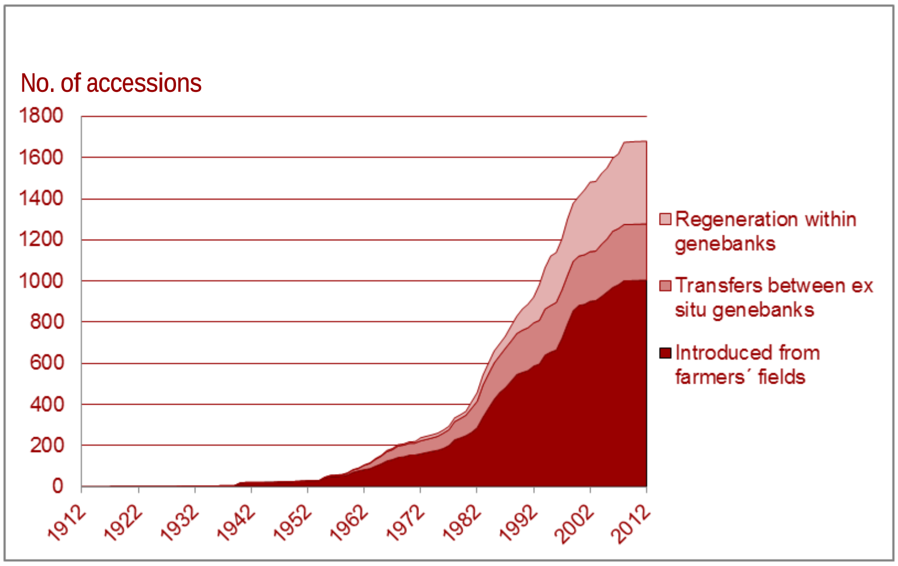

Figure 2.3. Evolution of accessions recorded in CGRD

Figure 2.3 gives the evolution of the number of accessions recorded in CGRD (Coconut Genetic Resources Database), ranked in three categories: introduction from farmers' fields, transfer between *ex situ* collections, and regeneration within these genebanks.

Regeneration within genebanks started in Indonesia in the 1950s and Jamaica in 1960s. In 1980, only 20 accessions had been rejuvenated; this number started to increase to

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18 Accessions recorded in the CGRD with an accession size superior to zero, but sometimes curators do not update this information even over a long time frame.

19 See URL: http://www.cogentnetwork.org/faq/139-exsitu

reach 103 in 1990. The following decade was the most active, with 188 accessions rejuvenated from 1991 to 2000. Then it decreased from 2000 to 2012, with only 111 accessions rejuvenated. However, since 2017 Vanuatu started to regenerate the national collection, showing a continuous interest in the conservation of coconuts varieties.

Most collections need to combat genetic erosion, where significant losses are often associated with poor practices in controlled hand pollination techniques. Deviations from the standard protocol of controlled hand-pollination may cause unwanted mixes between accessions, resulting in useless material being conserved and errors being propagated through germplasm transfers around the world. These deviations can appear when genebank staff are either not well trained or have been replaced. If any new employee is not trained by the departing staff, he/she will lack crucial information to perform tricky and demanding conservation processes. Finally, land-use/tenure issues also threaten the genebanks more often than expected.

Land pressure threats

Material has been lost over the past decade, such as that in the international genebank located in Indonesia, where 15 hectares of coconut accessions were destroyed. Land tenure problems and changes at research stations for coconut conservation have induced a global loss of 54 cultivars, representing 13% of the existing global holdings. In Côte d'Ivoire, about eight hectares of coconut palms were recently felled by the international genebank in order to replant with new accessions. Then, villagers from the neighbourhood came and claimed the land as their own, and preventing replanting. The problem was finally solved in favour of the international genebank, but it forced the curator to modify the design of the whole collection. In order to avoid similar problems in other fields, all the new accessions were planted between the rows of the old living ones. Once new accessions have established, after three to four years, old accessions can be removed.

Most of collections have not started removing duplicated accessions within the collection as part of a rationalization or conscious reduction of the collection at the global level. Although the constitution of international collections has been partially supported by public resources, this support has not yet been secured for the long term.

2.3.2 Mandate of institutes managing *ex situ* collections

All the institutes managing the 24 *ex situ* collections in COGENT member-countries have an official mandate from their government to carry out research on coconut and to conserve coconut at the national, regional or global level. The coconut genebanks mandate includes the following activities:

- Acting as national repository of coconut genetic resources;
- Targeting collecting actions;
- Maintaining field collections of living palms;
- Characterizing and evaluating for important traits;
- Disseminating information about conserved germplasm;

- Providing conserved germplasm to key users;
- Safely exchanging germplasm and all related information.

The prevailing notion that genetic resources are a common heritage for humanity has been replaced by the national sovereignty concept in the Convention on Biological Diversity (CBD) which entered into force in 1993. The implications for crop germplasm exchange were then articulated by FAO, leading to the negotiation of the International Treaty which came into force in 2004.

Coconut is one of the priority crops listed in Annex 1 of the Treaty, which lists the crop species that are subject to such facilitated access under the conditions defined in a Standard material transfer agreement (SMTA). Countries which have ratified the Treaty can access the coconut germplasm declared by hosting countries as being in the public domain and thus included in the multilateral system of the Treaty. For those which have not ratified the Treaty, access can be made through bilateral arrangements.

In order to foster a more efficient and effective system of germplasm conservation, evaluation and safe movement, the COGENT Steering Committee decided in 1995 to establish a multi-site International Coconut Genebank (ICG). The ICG today comprises five regional genebanks hosted by Brazil for Latin America and the Caribbean, Côte d'Ivoire for Africa and the Indian Ocean, India for South Asia and the Middle East, Indonesia for South-east and East Asia, and Papua New Guinea for the South Pacific. However, during the two last decades, most of the germplasm exchanges were done between national genebank without using the multilateral system.

The five ICG field collections are held in trust under the auspices of FAO through a formal agreement between Bioversity, the five countries and FAO (Table 2.1).

The designated germplasm is shared under the terms of the SMTA as part of the multilateral system of access and benefit sharing created by the Treaty or of the Material Transfer Agreement (MTA) specified in the Memorandum of Agreement (MOA) establishing the ICG in the case of India.

An important article of these MOA is related to emergency situations. For instance, in the MOA signed by Papua New Guinea, Article 2g of the agreement (Rights and obligations of the Parties) states that "*if the orderly maintenance of the ICG is impeded or threatened by whatever event, including* force majeure, *the Secretary of the Treaty and Bioversity International, with the approval of the Host Government, shall assist in its evacuation or transfer, to the extent possible*". Such emergency situations have recently occurred in Côte d'Ivoire and Papua New Guinea. These two international genebanks are the most active in providing germplasm, yet within the last few years, they have been threatened by urban pressure and emerging lethal diseases caused by phytoplasmas.

In April 2015, the Crop Trust with the help of COGENT and SPC organized a workshop in Papua New Guinea. The objective of the workshop was to design a project proposal to safely move the international genebank. The international experts gathered in Port-Moresby and Madang thanks to the financial support of ACIAR and prepared a five-year work plan to move the genebank to Punipuni, a safe location in the south of the country. The plan was presented to the Papua New Guinea

Government in 2016 and the implementation of this plan is currently under the responsibility of Indonesian department Kokonas Indastri Koporesen (KIK).

Table 2.1. Date and types of Memoranda of Agreement signed by the five countries hosting ICG.

Region	Country	Date of Signature	Signatory bodies of the Memoranda of Agreement	International convention
South Asia and Middle East	India	Oct. 1998	Government of India Bioversity International (IPGRI) FAO - Commission on Genetic resources for food and agriculture	CBD*
South-east and East Asia	Indonesia	May 1999	Government of Indonesia Bioversity International (IPGRI) FAO - Commission on Genetic resources for food and agriculture	CBD
Africa and the Indian Ocean	Côte d'Ivoire	Sept. 1999 (first MoA) Feb. 2007 (Final)	CNRA on behalf of Government of Côte d'Ivoire Bioversity International (IPGRI) FAO on behalf of the Governing Body of the Treaty.	ITPGRFA**
Latin America and the Caribbean	Brazil	June 2006	Brazilian Agricultural Research corporation (Embrapa) Bioversity International (IPGRI) FAO - Commission on Genetic resources for food and agriculture.	CBD
South Pacific	Papua New Guinea	May 2007	Ministry of Agriculture on behalf of Government of Papua New Guinea Bioversity International (IPGRI) FAO on behalf of the Governing Body of the Treaty.	ITPGRFA

* CBD: Convention on Biological Diversity
** International Treaty on Plant Genetic Resources for Food and Agriculture.

2.3.3 Cost of *ex situ* collections

Assessing the cost of coconut conservation was initiated in the framework for preparing this Strategy. A CGIAR costing study, published in 2011, represents the most comprehensive and recent costing study of *ex situ* collections managed under international standards (CGIAR 2011). This study started to be used as a model for costing *ex situ* coconut conservation, together with the strategy document published for Cacao in 2012.

During the 2013 COGENT survey, curators were questioned regarding the financial status of the coconut genebank they manage. Table 2.2 gives an overview of the 15 replies obtained. The current status of funding for routine operations and maintenance is mainly average or inadequate. The staff number is mostly satisfactory but the technical level of staff was not assessed. Some specific tasks, such as climbing palms and making controlled pollination, are limiting factors encountered in all collections conducting pollination programmes. The status of building, facilities and equipment is mainly average to inadequate: most genebanks do not have the facilities and laboratories requested for making controlled pollinations necessary for true-to-type regeneration of Tall-type accessions. The funding for characterizing and collecting germplasm is mostly inadequate. The level of germplasm use by breeders and researchers is good to average.

Table 2.2. Quality of the management of the genebanks (survey conducted in 2013 by the COGENT Secretariat).

Answer options	Very good	Good	Average	Poor	Very poor
Funding for maintenance	0	3	6	3	3
Number of staff	0	7	3	2	3
Status of buildings, facilities and equipment	0	2	9	2	2
Funding for collecting germplasm	0	2	3	6	4
Funding for research on the collection	0	2	4	7	2
Level of use by breeders, researchers	1	4	7	2	1

During the same survey, curators were asked to estimate the annual cost per accession of the activities conducted in the genebanks. The responses were extremely variable, as shown in table 2.3.

Table 2.3. Estimations on the annual cost per standard accession of activities conducted in *ex situ* coconut collections, and following estimation by the COGENT secretariat (check the detailed of calculation in Annex 7).

Activity	Average estimation by genebank curators (US$/accession/year)	Estimation by the COGENT Secretariat (US$/accession/year)	Difference
Field collection maintenance	927	150	+ 777
Morphological characterization	285	100	+ 185
Molecular characterization	775	12	+ 763
Agronomic evaluation	379	200	+ 179
Germplasm health (indexing & eradication)	267	100	+ 167
Information management	154	200	- 46
Total	2787	762	+ 2025

Estimations of average costs were calculated by the COGENT secretariat with the help of Dr Jean-Louis Konan, the curator of the ICG for Africa and Indian Ocean.

The online survey alone was not sufficient to gather comparable and standardized data; and so closer interactions with curators are needed. The huge difference between the estimation cost of the curators and the COGENT Secretariat could be due to several reasons. Firstly, researchers in charge of coconut conservation are often not only coconut researchers. They generally assume other tasks, such as conservation of other tree crops, breeding or other research activities. Thus, it is not always easy to differentiate what should and should not be included as conservation costs. As such, some staff cost could have been over-estimated by the curators.

The estimation of the manpower needed for characterizing accessions using standard international descriptors is indeed tricky. The total staff time needed ranges from 1,409 hours (Côte d'Ivoire) to 2,395 hours (Indonesia) per accession (see Annex 8). It requires collecting about 19,000 data per accession. As accessions are kept 30 years in the field, the time needed for characterization is 47-80 hours per accession per year. Labour cost varies widely between countries, so the cost will not be the same in all the genebanks.

The other big difference between the survey cost and the COGENT secretariat estimation (table 2.3) is the molecular analysis. For molecular characterization, a standardized kit of 15 molecular markers is presently used for assessing the allelic diversity of accessions. The recommended sampling sizes are 6 palms for Dwarf-type autogamous varieties and 12 palms for other types of varieties. The cost for analysing a Dwarf-type accession was estimated at US$204; the cost for analysing other types of accessions was estimated at US$408[20]. As an accession is kept in the field for 30 years, the annual costs are estimated at US$6.8 per Dwarf-type accession, and US$13.6 for other types of accessions. As a quarter of the accessions are autogamous Dwarf-types, the average cost of molecular characterization was estimated at US$11.9.

Finally, the average annual cost for conserving, characterizing and evaluating a standard coconut accession with the current standardized methods is presently estimated by the COGENT secretariat at US$762. This amount is provisional, has to be refined and will change as the methods and tools will quickly evolve during the next 10 years.

Within the coconut collections, the main expenses normally incurred are for planting, for characterization and evaluation during the first twelve years and for regeneration of the accessions by controlled pollination. As the useful lifespan of an accession is presently 30 years, the total cost has to be divided by 30 to get an average cost per year.

Except during the juvenile phase, which lasts from three to six years depending on the variety, the value of the production generally far exceeds the cost of maintaining the accessions in the fields. After 12 years in the field, the cost of conserving accessions is

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[20] The cost of analysing a palm with a 15-marker kit is estimated at US$34: US$10 per palm for leaflet sampling, managing and/or sending samples and DNA extraction; US$1 per marker for DNA analysis, and US$0.6 per marker for managing and analysing the data.

considerably reduced. In some genebanks, management of these coconut fields is allotted to small private companies. These companies clean and fertilize the plantation; harvest the coconuts and buy them at a lower rate than the market price. This business model may not be suitable for every genebank and should be assessed, taking into account the context and legal environment of the collection.

In 2011 the COGENT secretariat launched a global-level initiative to standardize costs for preparing germplasm for international exchange. This allowed estimating the cost of controlled pollinations (CPs) which is one of the most costly operations needed for genebank management. This cost was estimated at US$8 per controlled pollination. In coconut *ex situ* collections, the recommended sample size ranges from 72 to 96 palms for a Tall-type accession. For regeneration purposes, curators plan making one CP for each palm to be planted in the field. Rejuvenating a Tall-type accession needs 72 to 96 CPs, so a budget of US$576 to $768 is needed just for CPs[21]. This is a one-off expense every 30 years, which is the present average useful lifespan of a Tall-type accession in the field. In order to obtain an annual cost, this budget needs to be divided by 30. So regeneration of a Tall-type accession by controlled pollination costs US$19 to US$26 per annum.

As a whole, COGENT country-members are spending more than US$1.1 million per year for conserving, characterizing and evaluating at least 1,500 coconut accessions in at least 24 *ex situ* collections. A substantial part of this budget is covered by genebanks' self-funding, including selling planting material, selling coconuts, and sometimes selling high-value coconut palm products. This self-funding amount is not currently known, but could achieve a gross annual income of US$4,000 per hectare.

Countries enjoy sustained benefits from the increase of national coconut production linked to the use of these genebanks: the conserved germplasm serves as a basis for breeding activities and allows dissemination of good planting material among farmers. The cost of conserving genetic diversity is high, but the cost of not taking action would be much higher.

2.3.4 Collecting germplasm

According to the information available in the CGRD, 1,005 accessions have been collected in farmers' fields and successfully transferred to *ex situ* collections. The three oldest recorded accessions were planted in the Solomon Islands, Indonesia and Jamaica respectively in 1912, 1927, and 1935. From 1935 to 1955, India played a leading role by starting its *ex situ* collection with 18 local varieties and 26 varieties introduced from abroad; except for dwarf varieties, which are easier to collect, the number of palms per accession was low (7 in average). The focus on collecting and exchanging coconut germplasm strongly increased after 1950. By the early 1960s, about 30 countries had begun to exchange seed or pollen[22].

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[21] Assuming a dedicated laboratory is already fully operational. If a country is just starting to make controlled pollinations, it will be more expensive as the lab needs to be established.

[22] FAO report. In: Batugal, P., Ramanatha Rao, V., Oliver, J. (eds). 1996. Coconut genetic resources. Available from the URL: https://bioversityinternational.org/uploads/tx_news/Coconut_genetic_resources_1112.pdf

A survivor of an old traditional landrace

In Tuvalu, a unique and remarkable genotype was discovered with striped fruits and almost no husk. Mature fruits had only 10% husk, whereas most coconut varieties possess 20 to 50% (35 % on average). Such a fruit quality is highly desirable for some coconut uses. This combination with striping may indicate that this unique palm might be a survivor of an old traditional landrace. A few other palms in the same field also had striped fruits, with good but less exceptional fruit quality. Embryos were taken from these palms and sent to the Papua New Guinea genebank via the Fiji SPC lab, but they all died due to high contamination and low rooting rates. Farmers and agricultural officers had been advised to multiply the best palm locally. As a result of both the cross-pollination habit of the palm and the short duration of the project, researchers do not know if the farmers succeeded in true-to-type reproduction.

"Lady coconut" variety in the Nui Island, Tuvalu archipelago, with stripped fruits and very low content of husk. (R. Bourdeix, CIRAD)

In the case of coconut, it is indeed challenging to collect and use individual palms having favourable traits. Twelve to 15 years are needed between discovering rare palms with favourable traits in farmers' fields and creating a population usable by breeders. When such palms are found, researchers generally succeed in collecting 2 to 20 seednuts or embryos and not all of these will germinate. As many coconut varieties are mainly cross-pollinated, hardly any of this progeny will reproduce the targeted characteristics. Those that do reproduce will come mainly from selfing, which generally induces a strong inbreeding depression on yields. If lucky, a few targeted progenies will be available in the *ex situ* collection six to seven years later. In this event, another generation will be needed to breed and multiply this progeny. Pollen can also be collected but this is rarely done by surveyors. The lifespan of pollen in natural conditions is no more than five days. Hence pollen collected in farmer's field would need to be immediately cryopreserved.

The early international surveys were based on rather specific objectives such as: tolerance to Lethal Yellowing Disease (LYD) conducted by Jamaica and Tanzania, or searching for varieties with large fruits conducted by Côte d'Ivoire, and so forth. Thereafter, more systematic surveys based on geographical grids and/or participative approaches were launched, including in the Philippines and in Vanuatu. According to Pernes (1984), the best germplasm collecting programmes are carried out in two stages: an initial exploration and preliminary survey is conducted and used for planning a second, more systematic campaign. Such a two-step programme was conducted in Mexico. Fruit analyses were first realized in 47 locations, and collecting was then carried out in only 19 locations, mainly on the Pacific coast, where the greatest fruit variability was found (Zizumbo-Villarreal et al. 1993). However, restricted budgets seldom permit conducting such two-step surveys.

COGENT recently analysed the extent of coconut conservation at country-level. Accessions conserved in *ex situ* collections come from 44 countries and territories. According the FAO, they are 92 coconut producing countries and territories (CPCT), so 47 CPCT (51%) are not yet represented[23] in the germplasm conserved in the 24 COGENT *ex situ* collections.

Ratios between the area under coconut and the number of accessions conserved *ex situ* were calculated. On average, this index is 84 accessions per million hectares, as shown in Table 2.4. At the regional level, this collecting index varies from 64 (in Africa) to 282 (in the Pacific Ocean) per million hectares of coconut plantation.

Table 2.4. Collecting index by region (number of accessions conserved in *ex situ* collections per million hectares).

Region	Harvested area* (Million hectares)	Number of accessions in *ex situ* collections	Collecting index (Using areas data from FAO*)
Asia	9.7	721	74
America and the Caribbean	0.6	45	75
Africa	1.1	70	64
Pacific Ocean	0.6	169	282
Global	12.0	1 005	84

* FAOSTAT data for year 2014.

The calculated index is based on the assumption that data is representative. Some countries with important coconut production have quite a low collecting index, such as Mozambique (12), Ghana (17), India (29) and The Philippines (37). On the contrary, those countries devoting more effort to coconut germplasm collecting have higher collecting indices: Bangladesh (977), Malaysia (626), Fiji (366) and Sri Lanka (306).

Most of the coconut genebanks have plans for collecting germplasm. They are mainly planning to collect materials from farmers' fields in their own countries. For instance, in Kenya some new high yielding accessions of Dwarf-type and Tall-type varieties have recently been collected from farmers' fields. But there is no information regularly collected and gathered at the COGENT Secretariat for the moment on this important activity.

[23] This includes eight COGENT countries namely, by importance of cultivated surface: Myanmar, Venezuela, Colombia, Haiti, Costa Rica, Honduras, Cook Islands, and Oman.

Additional collecting is strongly encouraged and is still in demand by 87% of the network genebank curators (based on 2014 COGENT survey) since:

- Most COGENT experts and curators estimate that not more than a third of the existing useful diversity has been adequately transferred to *ex situ* collections;
- In some countries and regions, diversity is disappearing from farmers' fields as a result of drastic social changes, urban pressure, lethal diseases, rising sea-levels and other hazards linked to climate change;
- Diversity, such as that embracing Compact Dwarfs, is needed for immediate use and is not available from the existing collections.

2.3.5. *Ex situ* collection management

Coconut genebanks from COGENT member-countries, in addition to collecting and conserving genetic diversity within their jurisdiction, also have a responsibility to curate the collection to an internationally acceptable level. This entails maintaining the collection, safeguarding it from genetic erosion, regenerating accessions using controlled pollination or by re-collecting seeds from the original source (if that is cheaper and still feasible), characterizing the collection, documenting and sharing information so that the accessions can be utilized, and sharing the genetic resources to support coconut-breeding programmes worldwide.


Nut labelling. (RL Rivera, PCA)

All the institutions surveyed in 2013[24] reported that coconut accessions were maintained only in field collections. Within a country, all the locations devoted to coconut *ex situ* conservation are more frequently (72%) under the same national institution. The average number of conservation sites per country is 2.8 for the 14 countries which provided information.

Genebanks' teams do carry out field maintenance and labelling, although 40% of the collections reported inadequate financial resources to support routine operations and maintenance. The genebank survey demonstrated that the level of collection management varies widely depending on the country and the resources available. Excepting Brazil and India, it seems that genebanks do not use irrigation facilities. Many genebanks do not systematically fertilize the palms. Annual fruit yields per palm vary from 55 to 147 according to genebanks, with an average value of 80. India reports annual commercial nut yields as high as 400 per palm. Intercropping is practiced in only a third of *ex situ* coconut collections. For instance, in Papua New

[24] See Section 1.3 and Annex 6 for detailed information on the survey conducted in 2013 by COGENT Secretariat.

Guinea, at the Stewart research centre, the coconut genebank is intercropped with cocoa. The Stewart research centre also manages a cocoa field genebank but, although in the same plantation, this genebank is not located in the same fields as the coconut collection. In India, at CPCRI Kasaragod, some of the old coconut germplasm plantations are intercropped. Within the coconut genebanks, crops are generally intercropped for demonstration or research purposes, or for increasing income. Plantations are generally designed only for the conservation of coconut genetic resources and not for conservation of other crops.

Most of the collections do not have post-entry quarantine facilities and do not carry out systematic virus and phytoplasma indexing. There is no information on the business models of these structures so it is impossible to know today if they can be cost-effective or, at least, cost-efficient. Similarly, there are no studies on the social, cultural and environmental impacts and nor on the ecosystem services these collections account for.

2.3.6 Germplasm identification, characterization and evaluation

Characterization according to standard descriptors is carried out on a routine basis in about 60% of the collections and occasionally in most of them. All genebanks generate some degree of evaluation and/or characterization data for their accessions. Evaluation data comes primarily in the form of duration to planting and flowering, production of fruits and bunches, fruit component analysis and disease tolerance. In some genebanks, fruit theft disrupts yield evaluation.

Marc Delorme Coconut Research Centre, Côte d'Ivoire. (R. Bourdeix, CIRAD)

The coconut palm is a polymorphous plant whose appearance varies considerably depending on the soil, climate and time of year[25]. Genebanks differ widely regarding which data are regularly recorded, occasionally recorded or not recorded at all, and as to the duration of observation. For instance, in Côte d'Ivoire and Vanuatu, fruit analysis data available in the CGRD database are averaged over four years of observation. Most of data from the international genebank in India come from a unique harvest of fruits. In the Indian ICG, morphological growth characters are recorded annually on the juvenile palms as well as period to inflorescence initiation. The annual yield is computed from their fruit-harvest records

Misidentification of palms within a genebank arising from errors in establishment is a significant problem. In 2011, DNA fingerprinting using microsatellites or simple sequence repeats (SSR) markers was introduced for checking the pedigrees of

[25] At the outset, a coconut palm often produces a few larger and rounder fruits than those it will produce later. Once mature, fruit production often follows discontinuous rythms, especially for dwarf cultivars cultivated under average management. A coconut loaded with more than 200 nuts may produce fewer than 10 nuts the following year.

accessions conserved *ex situ*[26]. The first studies were conducted on progenies obtained by using controlled hand-pollination in India and Côte d'Ivoire, countries which both are hosting international coconut collections. Such misidentifications are caused by deviations from the standard protocol of controlled hand-pollination. As well as inadequate isolation, other errors can occur at every stage, from pollen handling to nursery management and field establishment or recording planting data. Current practices therefore need to be reviewed and improved. Lack of fidelity within collections can result in conservation of useless material and errors being propagated through germplasm transfers around the world.

The majority of collections carry out screening for pest and disease resistance. This reflects the objectives of the collections and the key traits of interest for breeding. However systematic evaluation of *ex situ* collections for such important traits has only been partially achieved. Uptake of accessions in breeding programmes has been restricted. The main limiting factors mentioned by the collection curators for the germplasm to be used in breeding are: 1) constraints in accessing materials (quarantine and policies) 2) lack of precise information and knowledge (particularly evaluation) on the material, 3) dearth of breeding programmes and breeders and 4) lack of funding for research and breeding programmes.

Characterization using molecular markers is not routinely carried out. This may be due to inadequate resources and facilities, or to the fact that such an evaluation does not appear as a priority to curators.

2.3.7 Safety duplication of germplasm

When germplasm is not duplicated in a separate and distant location, accessions are further threatened by natural and anthropogenic disasters. Coconut genebanks do not have intentional safety-duplication through a formal agreement with another institute, outside of the country. Although this duplication is a key aspect in FAO genebank standards, carefully elaborated for international genebanks, the MOA signed with any coconut international genebank does not mention such duplication. The only case where duplication is considered in these documents is the clause relative to "emergency" cited in section 2.3.2.

For COGENT curators, the lack of safety-duplication agreements with other institutes is caused by limited funding and by a lack of international and national policies for the conservation of coconut genetic resources. Furthermore, pests/diseases are an increasingly serious impediment to the overall welfare of the collections, resulting in high levels of genetic erosion and severely constraining the ability to safely transfer germplasm.

The 24 COGENT genebanks referenced in CGRD conserve numerous accessions, which prove useful to their national programme. Genebanks will continue such vital

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[26] Basically, this consists of selecting at random a subset of the female and male parents and of analysing DNA from parent palms and their progenies. This technique can be only used when the precise pedigree of each palm planted is safely recorded, and when the progenies are obtained by crossing parent palms one by one, and not by mixing pollen from several male parents. Less than 20% of COGENT genebanks presently meet these two conditions.

conservation work, although using a network approach is critical to such conservation at the global level.

At present, some cultivars are found only in 1 genebank while some other cultivars are conserved in more than 15 countries. According to the CGRD, among the 338 living cultivars conserved in COGENT *ex situ* genebanks, 269 are conserved in only 1 country. A further 25 cultivars are conserved in 2 genebanks. Another 44 cultivars are conserved in at least 3 genebanks.

The analysis presented hereunder aims to assess the *global* efficiency of the present *ex situ* conservation system (*sensu stricto)*. The information in the CGRD provides a crucial global overview. As illustrated in Table 2.5, only a third of the palms referenced in CGRD can be considered as really effective for conservation of the species at the global level.

There are 1,760 coconut accessions registered in the CGRD, totalling 144,559 palms referenced as alive and covering about 900 ha. When removing the accessions which have been already cut (because already regenerated or for another reason), and those for which no number of palms have been reported[27], there remain 1,374 accessions with an average of 105 living palms per accession.

Table 2.5. Analysis of accessions for global efficiency of conservation (Analysis carried out in 2013).

Level of analysis	Description	Total number of "globally useful" accessions	Total number of "globally useful" palms	Palms per accessions
1	All living palms	1374	144,559	105
2	Excluding over representation due to excessive accession sizes: - over 96 palms for Tall-types - over 45 palms for Dwarf-types	1374	65,460	48
3	Excluding (2) and cultivars duplicated in the same genebank	987	53,647	54
4	Excluding (2),(3) and limiting the conservation of cultivars at no more than 3 replications worldwide	857	47,816	56

Some accessions registered in the CGRD have a number of living palms which is too large for conservation purposes. For instance, the highest accession size was recorded on an accession of Malayan Yellow Dwarf in Tanzania with 6,400 palms; this rather coincides with a full seed garden and not with an accession planted for conservation. So it is important to differentiate between the numbers of palms currently registered in the

[27] There are 153 old accessions removed from the fields with 0 as accession size; and more than 153 accessions do not have a recorded size (data not sent by curators).

database, and the numbers of palms really useful for conservation purposes. The recommended sample size for an accession ranges from 72 to 96[28] palms for heterogeneous, allogamous Tall populations, and 45 palms for autogamous, homogeneous Dwarfs.

A survey[29] conducted by the COGENT Secretariat in 2014 and 2015 among the 39 country members received a 49% response. Seventy-nine percent of the 24 genebanks (national + international) and 4 out of the 5 ICGs replied. This survey established that among the 19 genebanks which replied, 80% of survey respondents agreed that a backup should be applied to a selected set of priority cultivars, chosen to represent global diversity. Not every cultivar would be secured, although every existing cultivar would be represented in the priority set by at least one cultivar with a very similar gene pool.

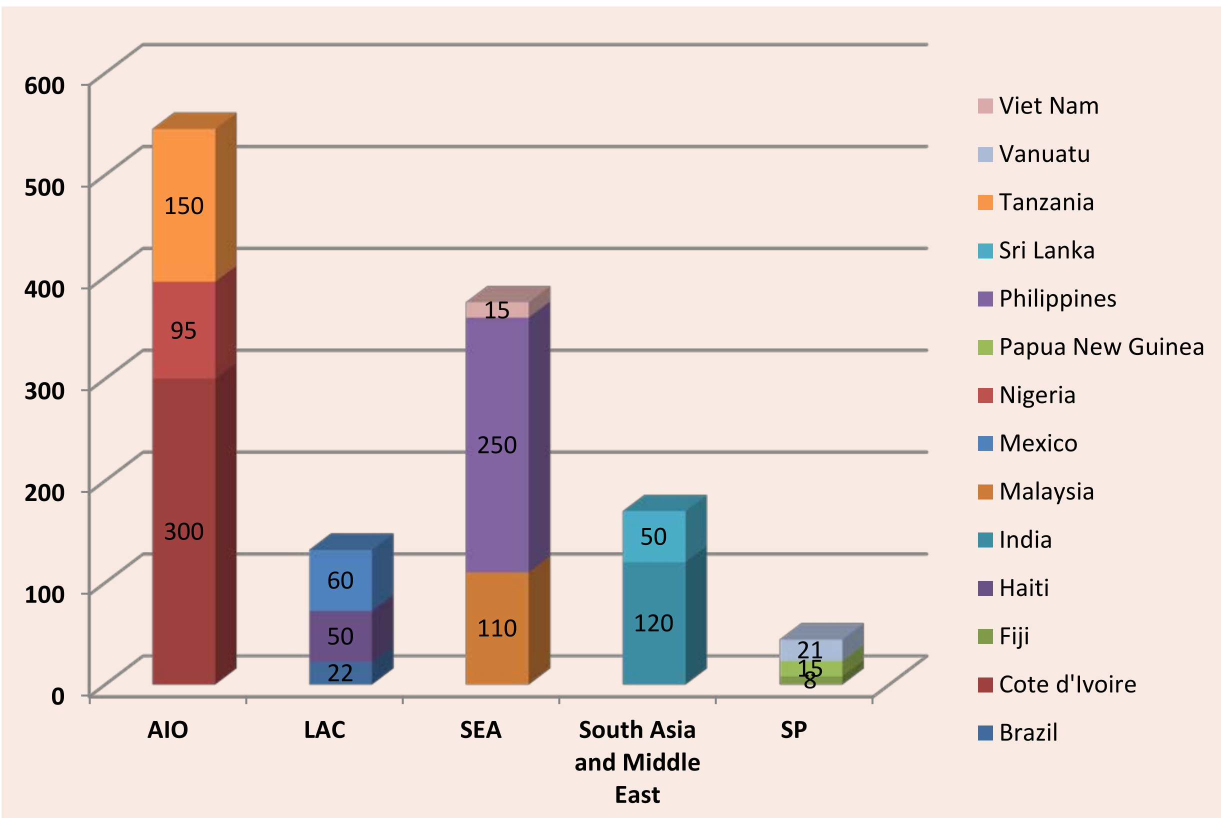

Figure 2.4. Hectares currently devoted to the genebanks (concerns 19 genebanks out of the 24)

Sixty percent of respondents estimate that support from the multilateral system should be provided for a priority subset of the extant accessions proven to be distinct, based on phenotypic observations. Due consideration should be given to the geographic repartition of the origins of priority accession (to maximize genetic diversity).

[28] 96 palms per accession of Tall-types were considered for the present calculations.

[29] See the results of the survey at http://www.cogentnetwork.org/images/publications/StrategyCOGENT_MadangApr2015.pdf

Accessions of high agronomic or market quality values for the country would be funded, irrespective of whether they are sufficiently represented elsewhere or not.

Thus, it seems important to distinguish between what is needed at country level and what is needed *sensu stricto* for conservation of the species at global level. Most of the genebanks are interested in acquiring the same set of well-known, well-performing and representative varieties. Indeed, this is useful for their national breeders, as it serves as a core collection and basic material for breeding programmes. But when conservation is assessed at the global level, there is no need for the same germplasm to be conserved in more than two (according to FAO international standards) or three genebanks (according to some coconut genebank curators)[30].

2.4 Genetic resources information management

In a perennial plant such as the coconut palm, the constraints linked to its biology increase the cost of scientific progress and worsen the consequences of possible errors. Consequently, coconut research and conservation not only need high financial and human resource investments but also a secure and sustainable information management system[31].

2.4.1 Local genebank management systems

In various countries, many years of field observation data have been lost as a result of different types of calamities and constraints, such as fires, floods, revolutions, staff turnover or simply the lack of funds leading to termination of the breeding programme. In some cases, due to the very long period between the start and completion of a breeding project, the data from initial years of bearing have been lost even before full project completion. High staff turnover has fortunately now reduced with greater concomitant stability and sustainability.

Data on characterization of accessions can be lost. This was recently the case in some COGENT member-countries. Acting on the advice of the COGENT secretariat, in 2013 and 2014 CRP-FTA and Bioversity International funded three internships (two MScs and a PhD) to assist researchers in cleaning, reconciling, improving and analysing the available data on genebanks and genetic experiments.

Tagging palms. (R. Bourdeix, CIRAD)

Some genebank curators often use home-made software or Microsoft Excel to store their data, which are

[30] Except for some varieties serving as international reference controls. For Dwarf-types, the Malayan Yellow Dwarf; for Tall-types, there is no consensus yet.

[31] A coconut accession is presently kept in the field during 30 years, although most of the characterization is conducted during the first 12 years. A genetic experiment frequently covers an area of 8 hectares for a minimum period of at least 12 years. A coconut breeder often analyses the experiments established by his/her predecessor and establishes experiments for his/her successors.