Edible Aroid Conservation Strategies

January 2010

Disclaimer

This document, developed with the input of a large number of experts, aims to provide a framework for the efficient and effective *ex situ* conservation of globally important collections of edible aroids.

The Global Crop Diversity Trust (the Trust) provided support for this initiative and considers this document to be an important framework for guiding the allocation of its resources. However the Trust does not take responsibility for the relevance, accuracy or completeness of the information in this document and does not commit to funding any of the priorities identified.

This strategy document (dated January 2010) is expected to continue to evolve and be updated as and when circumstances change or new information becomes available.

In case of specific questions and/or comments, please direct them to the strategy coordinator mentioned in the document.

1. Introduction

1.1 Process for developing a conservation strategy

The Secretariat of the Pacific Community (SPC) is an intergovernmental organization with headquarters in Noumea, New Caledonia, and a division for agriculture in Suva, Fiji. Approached by the Global Crop Diversity Trust (the Trust) to coordinate the development of a global conservation strategy for edible aroids, SPC agreed and, in turn, sought the assistance of experts worldwide to form a consortium to bring about a consensus on each of the edible aroid crops of concern. A consultant with long experience of root crops research – Dr Grahame Jackson – was engaged to facilitate the process.

The process started in November 2006 with the consultant attending the Triennial Symposium of the International Society of Tropical Root Crops, Thiruvananthapuram, Kerala, India. This provided an ideal opportunity to meet experts, to explain the aims of the Trust in supporting the development of conservation and use strategies for crops in Annex 1 of the International Treaty for Plant Genetic Resources for Food and Agriculture in collaboration with the CGIAR Centres, and to elicit support for edible aroids in particular. An outline of a conservation and use strategy for one of the edible aroids, (taro, *Colocasia esculenta*) was presented to the meeting.

Subsequently, a questionnaire was developed (Annex 1) and sent in December 2006 worldwide to over 80 curators of aroid collections and others with expertise in the crops to obtain the information upon which a comprehensive strategy could be developed. The persons to whom the questionnaire was sent, as well as those requested to take part in the development of the Strategy, are provided (Annex 2). The information provided by recipients has been incorporated into the Strategy, which was then circulated for review and comment.

This global conservation strategy for edible aroids gives pride of place to taro, *Colocasia esculenta*, about which most in known scientifically, but this is not to deny the importance of other edible members of the family, the most common being species of *Alocasia*, *Amorphophallus*, *Cyrtosperma* and *Xanthosoma*. These are extremely important in parts of the word, and in need of attention. *Xanthosoma* is in fact probably as, if not more, important than *Colocasia* in terms of production. Some initial notes are provided on these species.

1.2 Origin and taxonomy of *Colocasia* sp.

Colocasia esculenta – taro – is cultivated throughout the tropics, but also in temperate latitudes, for instance in China, Japan, Korea, the Mediterranean and New Zealand. It is thought to be an ancient crop in Eurasia (Matthews 1991; 2002a), and an early introduction to Africa, entering from Asia via the Nile or Madagascar (Shaw 1976). Plucknett (1970) considers it reached Egypt about 2000 B.P., subsequently reaching Spain, tropical America and West Africa. It was taken to the West Indies with the slave trade (Coursey 1968). In order to distinguish it from *Xanthosoma*,

Colocasia is referred to as "old yam" in West Africa, whereas *Xanthosoma* is "new yam" (FAO 1990). *Colocasia* is a staple food in many islands of the South Pacific, such as Tonga and Samoa (where it has returned to prominence after devastation by leaf blight in 1993), and parts of Papua New Guinea. *Colocasia* and *Xanthosoma* tolerate shade and are often planted under banana, coconut, citrus, oil palm and, especially, cocoa. They are sometimes collectively referred to as cocoyams (Wilson 1984; FAO 1990).

A commonly accepted view was that the centre of origin and domestication of taro was in Southeast Asia, in particular the region occupied by Myanmar and Bangladesh (Plucknett 1976), the putative area of origin of several other *Colocasia* species (Matthews 1990; Edison *et al*. 2006), and that Papua New Guinea represented a major centre of diversity. However, for some authors a wider area is more probable: Matthews (1990), for instance, suggests “somewhere within northeast India or southeast Asia”. However, there is a growing consensus that domestication occurred in many places across the natural distribution of the wild precursor (Matthews 2004).

A western Melanesian centre of origin and domestication has been largely accepted for several other crops (for instance, banana, coconut and sugarcane) and there is now circumstantial evidence that *Colocasia* may have been domesticated in that area too. Attention has mainly focused on Papua New Guinea, with evidence of human settlement in that country as far back as 40,000 years, and of agriculture for at least 6500-7000 years (Golson 1991; Golson and Hughes 1980; Denham *et al*. 2003; Denham 2004). This has increased speculation as to the food plants used. The discovery of fossil pollen grains thought to be those of *Colocasia* and *Alocasia* on stone tools in deposits in northern Solomon Islands dated at 28,000 years B.P. has added to the debate (Loy *et al*. 1992). Presumably, this does not preclude later introductions of cultigens with Austronesian migrations.

Thus, most cultivars found throughout the Pacific were not brought by the first settlers from the Indo-Malayan region as previously thought (Plucknett *et al*. 1970; Leon 1977; Kuruvilla and Singh 1981), but were domesticated from wild sources existing in Melanesia. *C. esculenta* var. *aquatilis,* a species that is a component of the natural eastward extension of the Indo-Malaysian flora (Yen 1982; Coates *et al*. 1988), is a possible progenitor of cultivated taro (Matthews 1991; 1995). From Melanesia, cultivars were taken eastwards to Polynesia during prehistoric migrations, with a progressive decline in their number and diversity (Yen & Wheeler 1968; Yen 1993; Lebot 1992).

Thus, with domestication also occurring in southeast Asia and with the separation of the land masses of Sunda and Sahul, two genepools came about, with overlap in Indonesia (Matthews 1990, 1991, 1995, 2003; Yen 1991a,b, 1993; Lebot 1992, 1999; Kreike *et al*. 2004; Lebot *et al*. 2005a).

Within these genepools, two botanical varieties of taro have been recognized: *C. esculenta* var. *esculenta*, commonly known as dasheen, and *C. esculenta* var. *antiquorum*, commonly known as eddoe. Dasheen varieties have large central corms, with suckers and/or stolons, whereas eddoes have a relatively small central corm and a large number of smaller cormels (Purseglove 1972). There are also said

to be differences in floral morphology. However, this separation of the cultivated taros into these two varieties has also been challenged in recent years (Hay 1998; Lebot 2004). Hay (1998) argues that if the two varietal names are to remain, then there is a "nomenclatural requirement" that all other taros – wild, feral and ornamental – be described to varieties too, and this can only be done if the division between var. *esculenta* and var. *antiquorum* is practical, i.e. if it works. Hay (1998a) maintains that it does not: there are cultivars intermediate between the varieties defined as dasheen and eddoe. Botanically, all taros should simply be called *C. esculenta*. This view is supported by the lack of any consistent difference between the two varieties on the basis of isozymes, AFLP, RAPD or SSR markers (Vincent Lebot, CIRAD, pers. comm.). Additionally, AFLPs showed no evidence for an association between corm shape (as exemplified by var. *esculenta* and *antiquorum*) and ploidy level (Kreike *et al*. 2004). In general, triploids are more common at high altitudes and latitudes, environments that are marginal for diploids, suggesting that such conditions promote the occurrence of unreduced gametes (Zhang and Zhang 2000).

A taxonomic review of the genus *Colocasia* is required. Currently, several species, for instance *C. fallax*, *C. affinis* and *C. gigantea*, are recognized, but their centres of origin are not well defined. Mathews (2004) has reviewed the evidence and showed a South or Southeast Asia distribution, largest for *C. gigantea* (eastern China, Indonesia, Myanmar, Sri Lanka, southern Japan, Thailand and Vietnam) and more restricted for *C. fallax* and *C. affinis* in an arc from the Himalayas of India and Nepal to Myanmar. Three others, *C. gracilis* (Sumatra), *C. mannii* (Assam) and *C. virosa* (eastern India) are known only from single herbarium specimens (Matthews 1991, 2004).

Wild taros are of considerable interest as they have more allelic diversity than the cultivated forms, which, on the other hand, are more variable in agro-morphological characteristics (Lebot and Aradhya 1991; Lebot *et al*. 2004). DNA analyses are needed on these wild (but occasionally used) types to determine their relationships, in particular with *C. esculenta*. So far, little work has been done, but for example mitochondrial DNA tests on *C. gigantea* suggest closer affinity to *Alocasia* (Matthews 1990).

Studies on *C. esculenta* var. *aquatilis,* the putative ancestor of cultivated forms of *C. esculenta*, are likely to be particularly rewarding. First described from Java, it is found from India to China, Japan, Malaysia, Indonesia, Papua New Guinea, northern Australia and Polynesia, although the natural range is likely to be less than its present distribution (Matthews 1991, 1995, 1992a,b, 2004). *C. esculenta* var. *aquatilis* flowers profusely and sets viable seeds (Matthews 1991). Ribosomal DNA analysis has shown diversity in Australian and Papua New Guinea populations (Matthews 1990; Matthews *et al*. 1992a; Matthews and Terauchi 1994; Lebot *et al*. 2000), suggesting "wild populations differentiated in partial isolation in diverse ecological circumstances" (Matthews 1991). From DNA studies in Japan it seems possible that *C. esculenta* var. *aqualitis* is a progenitor of present day diploid taro from Japan and some triploids (Matthews *et al*. 1992a). More genetic studies are necessary to clarify the link between the living cultivars, living wild types and hypothetical ancestor(s) (Matthews and Naing 2005). Interestingly, evidence from Myanmar has shown that the wild form is used for pig fodder and occasionally as

human food, raising the intriguing suggestion that use of wild types as fodder was involved in the domestication of both taro and the pig (Matthews and Naing 2005).

Other wild forms, apparently distinct from the wild types of Melanesia as well as local cultivars, are reported from New Caledonia (Ivanic and Lebot 1999). They may represent an earlier domestication before the present-day cultivars were introduced. Or possibly they are endemic to New Caledonia, remnants of Gondwanaland, and therefore potentially a useful source of novel genes. What is required is a thorough DNA analysis of the diversity in wild and cultivated taro. This will provide evidence of the origin, domestication and dispersal of the crop (Matthews 1995; Matthews and Naing 2005; Vincent Lebot, CIRAD, pers. comm.). DNA work will also help clarify the taxomony of wild taros, in particular decide if they are best divided in a number of species or can all be referred to *C. esculenta*.

1.3 Genetic diversity of *Colocasia esculenta*

The genetic diversity of cultivated forms of *C. esculenta* was initially quantified by looking at morphological and cytological characters (Yen and Wheeler 1968; Kuruvilla and Singh 1981; Tanimoto and Matsumoto 1986; Coates *et al*. 1988). There are diploid (2n=2x=28) and triploid (2n=3x=42) forms. Next, isozymes were used on major collections assembled in five Southeast Asian countries and two Pacific countries (Indonesia, Malaysia, Papua New Guinea, Philippines, Thailand, Vanuatu and Vietnam) under TANSAO, the Taro Network for Southeast Asia and Oceania. The results from these analyses suggested that:

- There are two distinct genepools, in southeast Asia and the southwest Pacific.
- Diversity is low overall, except in Indonesia where the genepools overlap, and
- The allelic diversity of the wild taros included in the study was similar to that of cultivated forms.

A core sample of 168 accessions was identified based on these data (Lebot & Aradhya 1991, 1992; Lebot *et al*. 2000; Lebot *et al*. 2004a). The final TANSAO core did not contain accessions from PNG because of the chance of distributing viruses in the alomae/bobone complex; instead 16 from Vanuatu were added (Lebot *et al*. 2004a)

Similar conclusions were drawn from further studies using RAPD, AFLP and SSR markers: genetic variation is greater in southeast Asia than in the Pacific, with Indonesia again the most diverse, and diversity within most countries is low (Kreike *et al*. 2004; Quero-Garcia *et al*. 2004; Noyer *et al*. 2004). These studies also showed that there is little genetic variation in Polynesian taros, in contrast to those from Asia and Melanesia. The high level of phenotypic variation in Polynesia is thought to be due to somatic mutations occurring in this vegetatively propagated crop, suggesting that the numerous Polynesian varieties are clones all derived from very few original mother plants (Lebot and Aradhya 1991; Lebot *et al*. 2004). The results of a molecular study of taro genetic diversity using RAPDs confirmed that although cultivars in the Pacific region exhibit remarkable morphological variation, the genetic base appears to be very narrow (Irwin *et al*. 1998). This is of critical concern, as a narrow genetic base is likely to leave the crop vulnerable to pests and disease attack (Lebot 1992).

Further studies on Pacific genetic diversity were made under TaroGen (Taro Genetic Resources: Conservation and Utilisation), a regional project funded by AusAID which, among other things, established a core collection which is maintained *in vitro* at the Regional Germplasm Centre, Secretariat of the Pacific Community, Fiji (now the Centre for Pacific Crops and Trees, CePaCT). This is representative of the genetic diversity within Pacific Island countries (Cook Islands, Fiji, New Caledonia, Niue, Palau, Papua New Guinea, Solomon Islands, Tonga, Samoa and Vanuatu (Mace *et al*. 2006a,b). DNA fingerprint data using SSR markers showed that great allelic diversity exists in Papua New Guinea and Solomon Islands.

2. Networks

2.1 Taro Network for South Asia and Oceania – TANSAO

TANSAO Phase I (Taro evaluation and breeding for rain fed cropping system) began in 1998, funded by the European Commission INCO-DC programme of DGXII. Its objective was to improve taro in Southeast Asia by selecting varieties with high commercial potential as a table food and for processing. Network members included Indonesia, Malaysia, the Philippines, Thailand, Vietnam and the Pacific countries of Papua New Guinea and Vanuatu, working in collaboration with Wageningen Agricultural University. TANSAO was administered by CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) and coordinated from CIRAD's research station in Vanuatu. The project finished in December 2001, having successfully established taro genebanks in all member countries, complete with passport and characterisation data. From the 2,300 accessions collected, a core of 168 has been selected based on morphological and isozyme data, which is representative of the genetic diversity of the countries involved. The core has been exchanged among members and parts are being used by national breeding programmes in Vanuatu and Samoa.

2.2 Taro Genetic Resources Network – TaroGen

The TaroGen project, funded by AusAID, and with support from ACIAR and Bioversity International, established a network of Pacific Island countries (Cook Islands, Fiji, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu), coordinated by SPC, to develop and implement a regional strategy for taro genetic resource conservation and crop improvement. The project assisted participating countries to collect, describe and conserve taro germplasm and to put the genetic resources to use in plant improvement programmes in Papua New Guinea and Samoa. It came about in large part as a response to the ravages of taro leaf blight in Samoa, an emergency that is likely to recur in other Pacific countries and for which they will now be better prepared. The project commenced in mid-1998 and ended in late 2003. The objectives were to complete the description and conservation of the bulk of taro genetic diversity in the Pacific Region; and to provide growers in Pacific Island countries with taro varieties with improved resistance to taro leaf blight. Some 2199 accessions were collected and described by partners, and 211 accessions were recommended for inclusion in a regional core collection based on phenotype and molecular characterization. A majority of these (over 857, December 2009) are safely stored at the Centre for Pacific Crops and Trees (CePaCT), formely known as the Regional Germplasm Centre (RGC), Fiji, and some

have been virus-indexed and found free of infection (Annex 3). Taro breeding continues, now supported by NARI in Papua New Guinea and by SPC and USP at the University of the South Pacific (USP), Samoa.

2.3 What did the networks achieve?

These taro networks were extremely successful and there is much to learn from their operation. They highlighted the basic research needs of taro and other edible aroids, and that these are similar in both Asia and Pacific countries: no one country is sufficient in genetic resources of these crops, so collaboration is essential. Above all, they showed that, as there is no international institute with a mandate for the conservation and improvement of edible aroids, other ways of structuring the required research is necessary. The networking arrangements developed were a pragmatic, relatively low-cost alternative to a single centralized institute (Lebot *et al*. 2001; Lebot *et al*. 2004b). Once donor support ceased, the formal networks did not continue. However, the work initiated by the networks continued through support from SPC, USP, NARI, VARTC and CIRAD. The taro collections are shared mainly through the operations of CePaCTand taro breeding is still active in Papua New Guinea, Samoa and Vanuatu

Analysis of the two taro networks shows that there were important factors that contributed to their success (Lebot *et al*. 2001):

- Countries had common needs that could be more effectively and efficiently resolved in collaboration than in isolation.
- Common policies on plant quarantine, access to germplasm and intellectual property rights were in place so that germplasm could be safely and easily moved among partners.
- The coordination mechanism ensured effective interaction among national programmes, other partners and funding agencies. Two approaches were used:
  - Coordination through a national programme (TANSAO) had the advantage of embedding the project within an on-going research programme and provided the flexibility of working with national partners in different political regions with different taro genepools.
  - Coordination through a regional organization had the advantage of tapping into an existing political structure with considerable experience of working with multiple partners, but it did mean that collaboration with countries outside the region, with material from another genepool, was not possible, though this could have been accommodated through project design.
- A regional germplasm centre, or transit centre, such as the CePaCT, is crucial to networks dealing with vegetatively propagated crops. Conservation of core collections to back-up national holdings is required as well as a facility to virus index (and possibly DNA fingerprint), multiply and disseminate germplasm.
- Use of modern biotechnologies to solve crop improvement problems, linking countries, regional institutions and universities, with centers of excellence within and outside the region that specialise in DNA fingerprinting, virus indexing, cryopreservation, etc.
- Participation of international technical assistance agencies (ACIAR, CIRAD, Bioversity International, SPC) in the network. Not only does this ensure

technical competence, but also it improves the chance of funding for crops that have relatively low priority compared to other food crop staples.

Since the end of these networks, breeding and other research has continued in Vanuatu, Papua New Guinea and Samoa, but it is done mostly in isolation, though with some exchange of information and material among the programmes through PAPGREN (and there are of course links to CePaCT). Networks require resources to maintain them.

"TANSAO Phase II: Exploiting the Genetic Resources" was written but not funded. The project endeavored to maintain the momentum created by TANSAO and TaroGen that had collected and described the aroid genetic resources of Southeast Asia and the Pacific. The main focus was on taro, *Colocasia esculenta*, but the project also included tannier or cocoyam, *Xanthosoma sagittifolium.* It was a 5-year project, with nine countries (importantly, the Indian Central Tuber Crops Research Institute, Thiruvanathapuram, Kerala, was included), coordinated by CIRAD.

The main activity of TANSAO Phase II is participatory plant breeding, with reciprocal exchanges of germplasm between national programmes within the Asia and Pacific genepools, and crossing with indigenous varieties to provide seed for distribution to farmers through government and non-government organisations. It was intended to establish the Network as an independent organisation, to encourage long-term support and project sustainability. The use of seed is an important departure from existing taro breeding programmes that produce only clonal material. Seed has several advantages: it can be produced in large amounts, it is easily distributed within and between countries, and because it is genetically variable allows farmers to make selections in different agro-ecological environments for favoured plant types and eating qualities. Those countries that cannot make crosses between Asia and Pacific accessions would rely on others to supply seed for evaluation.

TANSAO Phase II intended to include *Xanthosoma sagittifolium.* The extent of the genetic variability of *Xanthosoma* appears to be much less than that of *Colocasia* and research and development has been minimal, in spite of the fact that its importance is equal or more than that of *Colocasia* in many countries, in Africa and South America in particular, and it is gaining in popularity because it is less susceptible to drought, pests and diseases. The only breeding programme reported is that in Cameroon to produce plants resistant to *Pythium* root rot (Agueguia *et al*. 1994). The attempt was unsuccessful, but there is merit in countries re-evaluating TANSAO Phase II in relation to the needs of both *Colocasia* and *Xanthosoma* identified under this Strategy.

Xanthosoma improvement can take advantage of the progress that has been made with taro in recent years by TANSAO (Phase I) and TaroGen. The number of cultivars is low and most are already in collections, albeit dispersed worldwide. They can be brought together, described and DNA fingerprinted. Crosses can be made among the most diverse and distributions made. There is an urgent need to assist the work on the devastating root disease of the Caribbean, West Africa and Central America.

3. Overview of 'major' collections of taro and their use

Up-to-date information on collections of taro and other edible aroids is difficult to obtain. That this is the situation is not surprising: it is no different today then it was when past reviews were done (Jackson, 1994; Rao *et al*. in press). Much of the difficulty is that the collections come and go so quickly because of the limited resources that countries put into their maintenance; and they are very vulnerable to pests, diseases and civil unrest. These losses are rarely reported in the scientific literature. Table 1 provides an overview of the main taro collections and Table 2 lists the collections assembled under TANSAO. The survey undertaken in December 2006 provided a number of points of interest:

- Few major collections of taro exist in the Pacific and Southeast Asia. All countries have some, but most are unrepresentative of the genetic diversity present.
- Some major collections have been abandoned, while others have been reduced substantially. Collections are now smaller in Indonesia, Thailand and Vietnam; absent in Malaysia; whereas in Vietnam the number is about the same.
- It would appear that the collection in Papua New Guinea has increased in size, but this is due to the addition of accessions from both the TaroGen and TANSAO collections, such that in 2002 the number of accessions totaled 859, but with much duplication.
- Not only has the number of farmers' varieties in collections decreased overall, but so too has the number of wild types. Only the collection maintained at Phichit Horticultural Research Center, Thailand, has a significant number (17).
- Apart from India and China, some varieties of all collections are duplicated. These varieties are part of the core samples/collections of the Pacific and Southeast Asia genepools, and are conserved *in vitro* at the CePaCT (Table 3), with duplication at USP, Samoa.
- Disappointingly, the survey found no collections of any size in the Caribbean, Africa or South America. There is a small breeding programme for *Xanthosoma* in Puerto Rico, but that in the Cameroon was abandoned long ago.
- Major PGR databases (SINGER, GRIN) do not contain entries for edible aroids and, although they figure on FAO and Bioversity International databases (eg WIEWS and Directory of Germplasm Collections) the information is mostly out of date. This needs to change.

Table 1. 'Major' collections of taro, *Colocasia esculenta*: December 2006-7 survey

Country	No. traditional varieties	No. wild type varieties	% local/ exotic	*Duplication of the varieties	Comments
Pacific					
Fiji	*c.*70	0	100	TaroGen (8)	
New Caledonia	82	0	81/19	TaroGen (9)	
Papua New Guinea	700	0	95/5	TaroGen (82); TANSAO (22)	
Vanuatu	*c.*200	1	50/50	TaroGen (34)	Used to develop a genetic map/QTLs
Southeast Asia					
Indonesia	64	0	96/4	TANSAO (38)	
PR China	296	4	98/2	None	
Thailand	202	17	78/22	TANSAO (29)	
Philippines	Unknown	Unknown	Unknown	TANSAO (17)	
India	1118	0	100	Not present	
Vietnam	350	2	100	TANSAO (2)	

*All the duplicates (except those from India) are conserved *in vitro* at CePaCT and at USP, and are selections from national collections for the core sample (TANSAO) or regional core collection (TaroGen). Note, there are 12 varieties from Malaysia in the TANSAO core sample, but the national collection no longer exists

Table 2. Major collections of taro, *Colocasia esculenta,* in Southeast Asia and the Pacific assembled under TANSAO 1998-2001 (source: Rao *et al*. in press, based on Lebot *et al*. 2005a).

Country/ collections	Philippines	Vietnam	Thailand	Malaysia	Indonesia	PNG	Vanuatu
No. of accessions	172	350	300	135	685	278	260
Germplasm type (%)							
Traditional cultivars	77.9	94.0	78.3	45.3	61.5	100	-
Wild genotypes	7.56	0.86	21.7	54.1	23.7	0	-

In addition to the concerns listed above, most collections are maintained only in the field; no collection is duplicated in full, and few use *in vitro* technologies as complementary methods of conservation. Seed is not mentioned as part of any conservation strategy as there is no evidence that it can be used for cultivars[1]. Importantly, the collections of most countries are not being used, and this adds to their vulnerability because of the high costs involved in their upkeep. Only in India, the Philippines, Papua New Guinea and Vanuatu are the collections part of crop improvement programmes.

In India, breeding using local germplasm has continued for a decade at the Central Tuber Crops Research Institute (CTCRI) to overcome susceptibility to taro leaf blight and to improve other important characteristics (Sreekumari and Abraham in press). Several novel genotypes have been produced, for instance, lines that are erect, others that are early maturing and some with resistance to taro leaf blight, with the result that one variety was released in 2004. Other hybrids are undergoing advanced trials, in different agro-climatic zones to check their potential adoption by farmers.

In Papua New Guinea, under TaroGen (and previously in Solomon Islands), local cultivars and a single introduced wild variety were used in recurrent selection programmes, with a relatively narrow genetic base, to search for taro leaf blight resistance (Patel *et al*. 1984; Singh *et al*. 2004). Some breeders' lines have been released (Singh *et al.* 2006), but it appears from recent analyses that selections have reached a plateau in terms of yield, and to make further gains there is a need to introgress local varieties with taro of different genetic backgrounds (Guaf and Komolong in press).

Breeding for taro leaf blight resistance has also been a goal in Samoa, using varieties from the Philippines and Micronesia and, more recently, varieties from the TANSAO collection, after an outbreak of the disease destroyed the crop grown for domestic consumption and export (Iosefa *et al*. 2004). The programme, carried out

[1] A recent paper by Price *et al*. (2007) suggests seeds of wild types and cultivars can be stored for at least 2 years if dried to certain limits. Unfortunately, the 'cultivar' chosen was var. Bangkok, a wild type.

with the participation of farmers, is producing useful results. Breeding in the Pacific has also had minor successes previously, with cultivar releases in Samoa (before the introduction of taro leaf blight) and also in Fiji (Sivan and Tavaiqia 1984; Wilson *et al*. 1992).

Vanuatu has taken a somewhat different approach, realizing that there is need to combine genotypes from the two major genepools to establish a broad base for any breeding programme (Lebot and Aradhya 1991). To do this, elite cultivars for desired agronomic characteristics have been identified, based on an ecogeographic survey of the genetic variation existing in the region and systematic characterisation using morphological, agronomic and molecular characters, and then exchanged between participating countries (the Philippines, Vietnam, Thailand, Malaysia, Indonesia, Papua New Guinea and Vanuatu (Lebot *et al*. 2004a; Lebot *et al*. 2005b). In addition, the collections have been used to study heritabilities of the main agronomic traits (Quero-Garcia *et al.* 2006a), and to develop a genetic map to detect QTLs for yield (Quero-Garcia *et al.* 2006b). The work in Vanuatu is important, not only for the results that have been obtained, but also for its multidisciplinary approach, confirming what has been stated above under networking (Lebot *et al*. 2001).

Hawaii has also made use of the TANSAO collections and in 1997 imported a number of selections from Southeast Asian countries to hybridise with local varieties (Cho 2004). The programme is seeking pest and disease resistance as well as improved vigour and different tastes. Crosses between local varieties and those from Indonesia were of interest, as they showed evidence of transgressive segregation. Some varieties from this programme have potential for the ornamental trade. However, the University of Hawaii programme is currently embroiled in a complicated legal controversy with local groups about the legitimacy of taro breeding in the context of traditional indigenous culture.

4. Taro and other edible aroids in the regional conservation strategies

Taro and other edible aroids find a place in the *ex situ* conservation and utilisation crop diversity strategies of the Pacific and South, Southeast and East Asia. In the Pacific strategy they have a high priority.

4.1 The Pacific strategy

The strategy for the Pacific, developed by PAPGREN – Pacific Plant Genetic Resources Network – during meetings in 2004 and 2005, prioritized the Annex 1 crops of the International Treaty on Plant Genetic Resources for Food and Agriculture (Table 3).

The main criteria for priority ranking, in order of importance, were:

- role in food/nutritional security (especially if the crops were important throughout the region or specifically important in atolls);
- levels of genetic diversity and of genetic erosion (both in the field and in existing genebanks);

- cultural value; potential for income generation (especially through value-added products).

PAPGREN identified the priority collections for taro and *Cyrtosperma*. There are three taro collections:

- the field collection of taro in Papua New Guinea assembled in recent years with the assistance of TaroGen and TANSAO;
- the *in vitro* collection at CePaCT; and
- the field collection of *Cyrtosperma* in Pohnpei, FSM (Table 4).

Table 3. Edible aroids of priority to Pacific Island countries and reasons for their importance (source: *Regional strategy for the ex situ conservation and utilization of crop diversity in the Pacific Islands region*, February 2006).

Crop	Countries	Important factors
Taro (*Colocasia esculenta*)	All countries	▪ Food/nutritional security: high importance throughout region ▪ Diversity: primary centre, unique diversity (separate genepool to southeast Asia); being replaced in some countries by sweet potato, threatened also by taro leaf blight and virus diseases (in Papua New Guinea, Solomon Islands) ▪ Income generation: important cash crop in most countries and export crop in several ▪ Cultural value: high
Giant swamp taro (*Cyrtosperma merkusii*)	Atolls (Kiribati, Tuvalu, Tokelau, & parts of other countries[2])	▪ Food/nutritional security: high importance in atoll countries and also in parts of Melanesia ▪ Diversity: primary centre (Micronesia, atolls) ▪ Cultural value: high in Micronesia

The Strategy outlines crop conservation/use activities for both taro and giant swamp taro. Those for taro that relate to conservation and use are taken from the recommendations of the Third Taro Symposium (Guarino *et al*. 2004) and include, *inter alia*:

Conservation:

- Research to develop a reliable cryopreservation protocol for taro.
- Research on seed conservation, including induction of flowering.
- Validate TaroGen, TANSAO cores and compare with other genepools using standardized molecular markers.
- Molecular characterization of germplasm from India.
- Seek long-term funding for the CePaCT, e.g. through the Trust.
- Ensure safety duplication of taro core collections.
- Provide short-term support to national programmes for field genebank maintenance or *in vitro* conservation of base collections.

[2] Not only is *Cyrtosperma* a traditional food of atoll countries, but it is also a reserve food in parts of Melanesia. In fact, in some parts it is gaining importance as pests and diseases limit production of taro and yam, and sweet potato is constrained by adverse environments.

Evaluation:

- Participatory evaluation and selection of germplasm currently available (TaroGen and TANSAO cores, breeding lines) to investigate relationships among chemotypes, genotypes and organoleptic properties.

Exchange:

- Exchange 'clean' material within region and outside.
- Develop virus indexing capacity within region.
- Convene meeting to update safe transfer guidelines.
- Monitor PT clones after field release.

Table 4. Priority collections of taro and giant swamptaro identified by PAPGREN (source: *Regional strategy for the ex situ conservation and utilization of crop diversity in the Pacific Islands region*, Strategy February 2006).

Crop	Organisation	Priority and reasons for choice	Passport data available?
Taro	1st priority		Yes (for most countries)
	CePaCT Secretariat of the Pacific Community, Suva, Fiji	▪ One of the largest in vitro taro collections in the world (ca. 857 accessions) ▪ Collection unique and fully characterized (with the exception of breeding lines) ▪ Represents genetic diversity of many countries in the region (national and regional cores) ▪ Collection duplicated at University of the South Pacific, Alafua Campus, Samoa ▪ The majority of accessions in the regional core are virus indexed	
	National Agriculture Research Institute, Papua New Guinea	▪ Largest national collection in the region, ▪ Maintained in the field (859 accessions) ▪ Includes genetic diversity found in other countries of the region ▪ Many accessions collected from remote areas ▪ Molecular characterization data on 20% of national collection ▪ Not fully evaluated ▪ Used in on-going breeding programme	Yes
Giant swamp taro	Agriculture, Pohnpei, Federated States of Micronesia	▪ Only collection (23 accessions) ▪ Duplication of collection required (in vitro)	Yes

Improvement and use:

- Marker-assisted selection.
- Ensure sustainability of current breeding programmes in the Pacific.

- Strengthen coordination among breeding programmes in the Pacific.
- Prepare catalogue of main taro diversity in region.
- Establish an international network on taro to facilitate exchange of information.

The Pacific Strategy does not mention the collections – local and introduced – and the breeding programme at the VARTC, Vanuatu. This programme, as stated above, is hybridizing genotypes from Pacific and Southeast Asia genepools. There are many hundreds of breeders' lines under evaluation (approx. 3000). It is well supported locally and by donors, and brings together expertise from several scientific organizations and institutions. It has produced an impressive numbers of research papers over several years.

For giant swamp taro, *C. merkusii*, the need is to duplicate the Pohnpei (a state of the Federated States of Micronesia) collection *in vitro* at CePaCT, to develop a descriptor list, to collect germplasm throughout the region, to develop a safe transfer protocol and to establish a collection of varieties specifically for atoll countries. However, as mentioned above, it is not only the atoll countries that need the germplasm, but high islands, too.

4.2 The Strategy for South, Southeast and East Asia (SSEEA)

Taro was ranked 21 out of 24 crops in the regional Strategy of the South Asia Network on Plant Genetic Resources (SANPGR), and 9 of 11 crops by the Regional Cooperation for Southeast Asia on Plant Genetic Resources (RECSEA-PGR). Some 1800 accessions are maintained in India, Malaysia, the Philippines, Sri Lanka and Vietnam. Two countries, the Philippines and Vietnam, considered that taro has first priority in terms of need for support (Table 5). This was based on several criteria, including, *inter alia*: centre of diversity; importance as a food (for human and livestock use); regional and/or international collections; usefulness in marginal areas, subsistence agriculture and the security of the livelihoods of smallholders.

Papua New Guinea and Vietnam are identified in the Strategy as the countries to lead the coordination of the conservation of taro within RECSEA. The taro collections of the Philippines and Vietnam are identified as those of greatest importance and in need of priority support (Table 6). There is no mention of collections in China, India or Papua New Guinea[3], possibly the largest and most important collections in the Asian genepool.

Taro is not mentioned specifically in the work plan of the South and Southeast Asia region, but would presumably be supported by the following activities:

- Target collecting from specific areas for specific traits, inventory and mapping of genetic diversity.
- Conserve, characterize and document genetic diversity of identified priority crops; evaluation of germplasm for nutritional traits; molecular characterization.
- Build capacity and upgrade genebank facilities.
- Enhance knowledge on database management, *in vitro* conservation and cryopreservation.

[3] It may have been considered that Papua New Guinea was best served as a member of the Pacific Strategy.

- Improve the management of collections of identified crop; strengthening field genebanks for conservation of perennial wild relatives.
- Identify materials with desirable traits for base broadening for utilization (presumably in breeding programmes).

Table 5. Importance of taro in southeast Asia: Philippines and Vietnam (source: *Regional strategy for the ex situ conservation and utilization of crop diversity in the South, Southeast and East Asia region*, Strategy Draft December 2005).

Crop	Countries in the region	Factors/indicators of importance
Taro (*Colocasia esculenta*)	Southeast Asia (the Philippines, Vietnam)	▪ Food and nutritional security: high importance as famine foods in poor areas ▪ Crop used as food and vegetable ▪ Value for sustainable agriculture in midland and upland areas ▪ Center of diversity: primary ▪ Cultural value: taro production closely links to different traditional customs of many ethnic minorities

Table 6. Taro collection of the Philippines and Vietnam and reasons for priority support (source: *Regional strategy for the ex situ conservation and utilization of crop diversity in the South, Southeast and East Asia region*, Strategy Draft December 2005).

Institutes holding collections	No. of accessions	Factors/indicators of importance
Vietnam National Crop Genebank (PGRC)	400	▪ Endemic crop, Vietnam is in the primary centre of diversity ▪ Important to be exploited for sustainable agriculture and food security ▪ Existence of rich wild relatives ▪ Large collections in field genebank with rich genetic diversity ▪ Collection almost fully characterized ▪ Duplication of collection (and in-vitro conservation) required ▪ Some ethnobotanical research completed
Philippines (main collections at NPGRL & PRCRTC)	283	▪ Vulnerability of ex situ collection due to threat of genetic erosion ▪ Comparative advantage and importance of collection ▪ Need for utilisation and crop improvement

4.3 Collaborative arrangements

4.3.1 Pacific

The Pacific Strategy has been developed by PAPGREN, a collaboration between countries, SPC's plant genetic resources team and Bioversity International. PAPGREN, drawing upon representatives from the 22 member governments of SPC, meets annually to review its activities both nationally and regionally. Vital to the operation of SPC's PGR activities is the CePaCT, which has extensive holding of taro and other crop collections conserved *in vitro*. The CePaCT has a Manager, Curator and technicians and is supported by agriculture professionals from many disciplines, including plant health. In collaboration with the Institute of Applied

Sciences of the University of the South Pacific, CePaCT has developed a capability in virus-indexing. More than 850 taro accessions are maintained at the CePaCT, including the regional core of 191 accessions from the TaroGen core and also that of the TANSAO core, (118) allowing member Countries and Territories (and countries elsewhere) access to a wealth of germplasm free from pests and diseases. The regional core is duplicated at the USP School of Agriculture, Alafua, Samoa.

4.3.2 Asia

Coordination and facilitation of the SSEEA Strategy have been developed through collaboration of three networks, namely: the Regional Network for Conservation and Utilization of Plant Genetic Resources in East Asia (EA-PGR), the Regional Cooperation in Southeast Asia for Plant Genetic Resources (RECSEA-PGR) and the South Asia Network on Plant Genetic Resources (SANPGR). Although implementing arrangements have not yet been decided, the guiding principles for effective conservation at the regional level are:

- Credibility and trust amongst the collection holders in the region.
- Willingness to collaborate with partners within and outside of the region.
- Links with existing collaborative frameworks and networks.
- Adequate funding to support the system.
- Agreed conservation standards.
- Sharing of conservation responsibilities amongst partners.

The Strategy suggests that the best way to organize conservation activities effectively is through existing crop networks, and TaroGen is listed among many others. Unfortunately, TaroGen, as such, no longer exists, although some activities continue, for instance taro breeding in Samoa and Papua New Guinea and the distribution of the collections held *in vitro* at CePaCT. None of TaroGen's past activities extended to the region covered by SSEEA. However, the expectation is that TaroGen (or another entity to be identified) will develop, "taking note of the regional strategy and the collections identified at the regional level" (i.e. the Philippines and Vietnam). It is further suggested that research and conservation programmes within the different sub-regional networks establish regional field genebanks for vegetatively propagated crops, as well as carrying out *in vitro* and cryopreservation activities.

Table 7. Upgrading and capacity building needs of priority organisation of the Pacific to meet Trust criteria for support (based on *Regional strategy for the ex situ conservation and utilization of crop diversity in the South, Southeast and East Asia region*, Strategy Draft December 2005).

Trust eligibility criteria	NARI, PNG	SPC CePaCT
The recipient has effective links to users of plant genetic resources	NARI has one of the few taro breeding programmes in the region and NARI has strong links to farmers.	CePaCT is active in distribution of germplasm both to NARES and NGOs in 22 SPC member countries.
The collection is important	PNG is a putative centre of domestication of taro and with a collection of more than 700 accessions, collected over several years at considerable expense, it represents great diversity - including that of all other Pacific Island countries.	The CePaCT maintains a unique (Pacific) regional collection of taro, major parts of some national collections, and the (ASIA) TANSAO core (not replicated in Asia, but at USP, Alafua)

Trust eligibility criteria	NARI, PNG	SPC CePaCT
The legal status of the collection and holder are such that their ability to meet the eligibility principles with respect to access and benefit-sharing, and their commitment to long-term conservation are assured	NARI, established by an act of parliament in 1996, is a publicly-funded statutory authority, committed to the development of food crops, including taro, and the maintenance of important collections of germplasm. PNG is ready to ratify the ITPGRFA.	CePaCT has been using an MTA based on that used by INIBAP. In the future, the SMTA of the ITPGRFA will be used, subject to agreement by SPC member countries.
The recipient is willing to act in partnership with others to achieve a rational system for conserving plant genetic resources and making them available	PNG has been very active in every regional PGR initiative over a number of years and has offered to act as "plant breeder to the region" through the PARCIP[4] concept.	CePaCT has been collaborating with national, regional and international partners since its establishment.
The recipient has the human resources and management systems needed to maintain the plant genetic resources and can demonstrate conformity with agreed scientific and technical standards of management	Need for capacity building and strengthening in: ▪ Management of collections of vegetatively propagated crops: NARI, PNG ▪ PGR data management: SPC ▪ Genetic resources use (especially breeding): VARTC/CIRAD	
The facilities in which the collection is maintained are adequate to ensure long-term conservation	Need strengthening and/or expansion, hence the high priority given to upgrading in the Pacific Strategy.	

4.4 Upgrading and capacity building needs

4.4.1 Pacific

The region has identified two institutions, both of which have important taro genetic resources, for priority support in order to fully meet the criteria of the Trust for long-term assistance. These are the regional and international taro collections of the CePaCT and the national collection of NARI, Papua New Guinea (Table 7). The activities (conservation of collections, distribution and research) of the CePaCT have expanded significantly in recent years and the work of the facility is limited by space. Significant funding has been sourced to relocate the collections at a new facility, which was opened in late 2009; however, additional funding is necessary to ensure that the new facility maintains the standards required.

4.4.2 Asia

The Strategy states that "for effective and efficient conservation of priority crop germplasm collections, it is extremely essential to upgrade/build national capacity in different countries of the region …. All the countries in the region do not possess the regional infrastructure and facilities to conserve the germplasm and need

[4] PARCIP, Pacific Regional Crops Improvement Program is a proposal of NARI and SPC to develop a collaborative research agenda between Papua New Guinea and other Pacific Island countries acknowledging the cost-benefits to be achieved through pooling of resources, including plant germplasm. The concept was endorsed by HOAFS 2006.

assistance". Of particular concern in this regard is the reported destruction of the Philippines National Plant Genetic Resources Laboratory genebank by Typhoon Milenyo in October 2006, including most of the root crop collections[5].

5. Overview of importance and uniqueness of major collections of taro

The priority field collections of the SSEEA and Pacific Strategies are Papua New Guinea, the Philippines, Vietnam, and the *in vitro* collection of the CePaCT. However, there are other collections that have to be taken into consideration: Indonesia, Thailand, India and The People's Republic of China all have important collections. Presently, the collection in Indonesia, at Bogor Research and Development Center for Biotechnology, contains only 64 accessions of taro from 685 established during TANSAO (Table 7). Indonesia is of interest, however, as the variation there is relatively high and indicative of overlap of the two genepools (Lebot et al. 2004; Noyer *et al*. 2004). The collection at Phitchit Horticultural Research Center, Thailand, has also suffered losses, and now has 202 accessions compared to 300 under TANSAO. The collection is of interest because of the country's proximity to the putative centre of origin. In addition, the collection has 17 wild forms.

Analysis of the genetic diversity of 198 accessions of taro from the Philippines Root Crops Research and Training Centre, Baybay, Leyte, chosen on morphoagronomical descriptions and isozyme analysis, showed that the genetic base was so narrow that it was difficult to avoid selecting cultivars with the same zymotypes for the core (Lebot *et al.* 2004a). In an earlier paper, taro in the Philippines was considered an "introduced crop" (Lebot and Aradhya 1991), and similar in genetic diversity to those of the Pacific. More variation was observed in the isozyme analysis of accessions from the Vietnam Agricultural Research Institute (Lebot *et al*. 2004a); however, many taro from this collection are triploids. By contrast, the few diploids fom the same collection analysed by AFLPs were similar to taro of the Pacific genepool (Kreike *et al*. 2004).

The collections of taro in India and China are without doubt extremely important, so much so that there has been speculation that distinct genepools may be present in this region (Lebot *et al*. 2004b). There are many collections in India, but the main one is at the CTCRI, Trivandrum, under ICAR, which from its inception in 1963 has included taro in its mandate (Edison *et al*. 2004). The collection is considered to be representative of the germplasm of the country and has been characterized morphologically (Table 8).

Table 8. Number of accessions of taro maintained at CTCRI, India and their origin (source: Edison *et a*l., 2004)

Region	No. accessions
South	148
Central	78
North	84
North-east	114
Total	424

[5] Philippines Inquirer.net, 9 October 2006: http://newsinfo.inquirer.net/inquirerheadlines/regions/view_article.php?article_id=25599

More recently, the collection has been enlarged with further collecting missions, including those to the northeastern hill region, Andaman and Nicobar islands, Western Ghats and Bastar regions for wild relatives. The number of accessions has risen to more than a thousand, and includes 7 wild accessions (Edison *et al*., 2006). The collection has diploids and triploids; the latter were found to be more common at higher latitudes.

The collection of taro in China is at the Wuhan Vegetable Research Institute, Hubei Province. There are 296 accessions. The main centre of diversity is in the southwest in Yunnan, bordering Myanmar; some varieties from this Province have been analyzed with molecular markers (Shen *et al*. 2004).

Apart from a small study on 28 Yunnan accessions, genetic diversity in the India and China collections has not been assessed, but they have been described morphologically using the Bioversity International descriptor list. The next step is to stratify the collection based on phenotypic characterization, select the most diverse (10-20%) and subject these to genotypic analysis (Lebot *et al*. 2004b; Mace *et al*. 2006a,b), and then devise a core sample using statistical methods.

The collection of taro at CePaCT is unique. In responding to its mandate to assist Pacific Island Countries and Territories conserve the region's genetic resources, and to provide access to the germplasm they need, the CePaCT is using *in vitro* techniques for conservation, and priority is given to taro and other food crop staples. It has more than 850 accessions of taro, including the TaroGen core and the TANSAO core. Techniques for cryopreservation have been developed by CePaCT (Sant *et al*. 2006), but as yet no accessions have been cryopreserved. The taro core collections maintained at CePaCT are duplicated at the USP School of Agriculture, Alafua, Samoa. Any crops held by CePaCT and not duplicated elsewhere, such as in an IARC, will also be duplicated there.

6. Conservation status of taro

Information on the seven major taro collections selected for discussion and possible support by the Trust is provided in Tables 9 and 10. Most of the collections have passport data, and have been characterized using the Bioversity International descriptors (or a dichotomous morphological key) sufficient to stratify them before molecular analysis to define a national core (Lebot *et al.* 2004b; Mace *et al*. 2006). The exceptions being those collections of India and China, for which no molecular studies have been done and no core samples/collections identified. A substantial part of the collections from the Pacific and Asia have been duplicated, in particular those belonging to countries that took part in TANSAO and TaroGen.

While taro breeding continues in Papua New Guinea and Samoa, mostly for taro leaf blight resistance, albeit at a slower pace than previously under TaroGen, neither programme is equivalent in scale to that of Vanuatu. Here the aim is to introgress the genetic backgrounds of selected varieties from the two genepools of the Pacific and Asia. The TANSAO core sample has been introduced (Indonesia, 27; Malaysia, 7; the Philippines, 12; Thailand, 4; Vietnam, 2; and 43 from Vanuatu), multiplied to

choose the best for breeding purposes (Lebot in press) and more than 3000 seedlings are in the field under evaluation. This programme has considerable potential to assist other countries, with breeders' lines and seed.

Table 9. Details of 'major' taro collections of the Pacific and Asia as provided in 2006/07 survey: 1) number of accessions in field and in *in vitro* storage

Collection	No. accessions in field / replications				No. accessions in vitro				No. slow growth / Cryo
	Farmer vars.	Wild vars.	Breeder vars.	Breeder lines	Farmer vars.	Wild vars.	Breeder vars.	Breeder lines	
Pacific									
PNG	700	0	4	83	0	0	0	0	0
Vanuatu	*c.*200	0	100	3000	0	0	0	0	0
SPC CePaCT	0	0	0	0	586	0	15	126	0
Asia									
India	1118*	2	6	10					
PR China	296	[6]4	1	0	0	0	0	0	0
Thailand	202/10	17/3	0	61/1	0	0	0	0	0
Vietnam	350	2	2	0	0	0	0	0	0

*700 are maintained in a screenhouse; 436 are iin the field.

Table 10. Details of 'major' taro collections of the Pacific and Asia as provided in 2006/07 survey: 2) descriptor, duplication and documentation information

Collection	Documentation				Collection duplicated	Data storage system	Info on Internet?
	Passport	Characterisation data					
		IPGRI descriptors	Molecular (%)	System			
Pacific							
PNG	Yes	Yes	20	Isozyme/ SSR/ISSR	†CePaCT	Excel	No
Vanuatu	Yes	Yes	100	Isozymes/ SSR/AFLP	†CePaCT	Excel	No
SPC CePaCT	Yes, for core & non-core	Yes	20	SSR	USP, Samoa	Excel	No
Asia							
India	Partial	Yes	10	RADP	*c.*50%	Excel	No
PR China	Partial	Yes	0	N/A	No	Excel	
Thailand	Yes	Yes	0	Isozymes/ AFLP	*CePaCT	Excel	No
Vietnam	Yes	Yes	0	Isozymes/ AFLP	*CePaCT	Excel	No

*No. accessions at the CePaCT selected as part of the TANSAO core sample (now at the CePaCT): Thailand, 29 and Vietnam (2); †No. accessions at the CePaCT selected as part of the Pacific regional (TaroGen) core: PNG (82) and Vanuatu (34); N/A not applicable

[6] In addition, Wuhan Vegetable Research Institute holds five accessions of *C. gigantea*, and 10 accessions of *C. tonoimo* (Ke Weigon, Curator (pers. comm.).

7. Distribution status of taro collections

All the institutes with major collections distribute taro germplasm within their country, albeit a modest amount, but none outside, except for Vanuatu and the CePaCT (Table 11). Other researchers, including breeders, are the most common recipients, rather than farmers and extentionists. There is an indication from most genebanks that the amount of germplasm distributed is on the increase. Additionally, the majority of institutes would provide germplasm to others if asked, but there are conditions: first, a majority required such transfers to be done under an MTA; and second, some costs might be sought for processing, etc (Table 12).

Table 11. Distribution of germplasm by major collections of the Pacific and Asia (source: 2006/07 survey)

Collection	Distribution of germplasm (no. accessions in last 3 years)						No. samples / shipment	More than 5 years ago?
	Farmers	Breeders	Researc-hers	NGOs	Gene banks	Exten-tionists		
Pacific								
PNG – *in	<10	0	<10	<10	0	<10	?	Yes
Vanuatu - in	>200	50-200	50-200	10-50	10-50	0	10-50	Yes
Vanuatu - †out	0	>200	>200	0	0	0	1-5	
SPC CePaCT - out**	0	117	736	31	219	21	1-850	Yes
Asia								
India	<10	<10	<10	0	0	0	10-50	Yes
PR China	<10	0	>200	0	0	<10	6	?
Thailand	<10	<10	<10	<10	0	<10	1-5	Yes
Vietnam	0	<10	<10	0	10-20	0	1-5	Yes

*In = internally within the country; †out = outside the country

** = SPC has a mandate to work with governments – through the formal research-extension network germplasm reaches the farmers

All countries (except Vanuatu) said that there were diseases that might restrict distribution. It is well known that taros, as other clonally propagated plants, are infected with viruses, and other internally borne pathogens, that are of concern, and most countries enact quarantine measures in an effort to prevent their further spread. A majority of countries prohibit the unrestricted introduction of taro propagating material and follow the FAO/IBPGR Technical Guidelines for the Safe Movement of Edible Aroid Germplasm (Zettler *et al*. 1989), which recommends that plants are virus-tested and transferred between countries as sterile tissue cultures.

To date, only part of the core sample of TANSAO and the regional Pacific core collection of TaroGen has been virus-indexed. In the case of the TANSAO collection, the plants were indexed for *Dasheen mosaic potyvirus* at WAU, Wageniingen, the Netherlands; those of the Pacific collection (TaroGen) have been indexed for five viruses: (*Dasheen mosaic virus*, *Taro bacilliform virus, Taro vein chlorosis virus*, *Colocasia bobone disease virus* and *Taro reovirus*) at 3 and 6 months (Anon 2003) when held in quarantine by AQIS and indexed by QUT. Of the 118 TANSAO varieties, 91 have indexed negatively for five taro viruses, 9 tested positively for one

or more viruses and 17 need to be indexed; and of the 191 varieties of the TaroGen collection, 58 tested negatively for all five viruses, 72 were positive to one or several viruses, and 61 need to be indexed. Table 13 shows both the number of accessions to be indexed from each country and the number of accessions tested negatively for pathogens (bracketed figures)

Table 12. Policies of major taro collections for sharing germplasm (source: 2006/07 survey)

Collection	Policies for accessing germplasm			
	Distribute to all users?	Conditions?	Payments?	Long term commitment?
Pacific				
PNG	All countries	After signing MTA	Charges to some users	NARI corporate plan; PGR strategic plan; national conservation strategy
Vanuatu	All countries	After signing MTA	Request to contribute processing & shipping	Unknown
SPC CePaCT	All countries	After signing MTA	Charges to some users, and/or payment of shipping costs	SPC germplasm policy
Asia				
India	All countries	After signing MTA & mutual agreement	No costs: reciprocal exchange; charges to some users	Institutional constitution
PR China	All countries	China agricultural plant germplasm regulations	According to type of material & quantity	Wuhan National Germplasm Repository constitution
Thailand	All countries	After signing MTA & mutual agreement	Yes, for some: contributions for processing & costs/accession	Unknown
Vietnam	All countries	After signing MTA	Request to contribute processing & shipping	Unknown

Table 13. Taro from the TANSAO core sample and TaroGen core collections conserved at CePaCT, some of which are available free of known viruses

Collection	Country	No. pathogen indexed
Asia		
(TANSAO)	Indonesia	38 (30)
	Malaysia	12(11)
	Philippines	17(12)
	PNG*	22(11)
	Thailand	29(26)
	Vietnam	2(1)
Total		120(91)
Pacific		
(TaroGen)	Cooks	2 (1)
	Fiji	8(1)
	FSM	1(0)
	New Caledonia	9(1)
	Niue	6 (0)
	Palau	4(2)
	PNG	82(51)
	Solomon Islands	38(1)
	Samoa	4(0)
	Tonga	2(0)
	Vanuatu	34(1)
Total		190 (58)

8. Smaller taro collections

Apart from the major taro collections discussed above, many other countries have some, albeit few, accessions, which have been considered in developing the Pacific core collection (Mace *et al*. 2006a,b). There are a number of small collections in Asia too. The recent survey identified collections in Sri Lanka (seven accessions at the Horticultural Crops Research and Development Institute, Peradeniya), and there are probably some in Bangladesh, Myanmar and Nepal, but there was no response to enquiries. The genetic diversity in these collections is likely to be largely covered by others. Similarly, obtaining information from Japan was problematical and no material has been recorded. Information on Japanese taro diversity is provided in Lebot and Aradhya (1991). It appears that a common Pacific zymotype is present in Japanese taro and this might be explained by introductions from Indonesia in recent years.

The situation in Africa, the Caribbean and South America is also disappointing. There are collections in Puerto Rico (five accessions at the Agricultural Experiment Stations, University of Puerto Rico College of Agricultural Science); Nigeria (three accessions at the National Root Crops Research Institute, Umudike); and South Africa (20 accessions at the Department of Agriculture, Pretoria). Cuba has a relatively large field collection of 52 accessions, 21 of which are maintained *in vitro*; they are characterized morphologically and with isozymes, available for sharing (although not pathogen-indexed), and are being used in a breeding program (Marilys Diley Milián Jiménez, Curator, INIVIT, pers. comm.). Extensive efforts to identify collections in Central and South America were mostly unsuccessful. These are areas were further efforts are needed to determine if collections exist. However, estimates of taro (cocoyam) production in Central and South America on FAOSTAT[7] are very low, about 0.25 million hectares: by contrast production in Africa is put at more than 1.6 million hectares in 2004, and it is likely that numerous varieties exist in farmers' fields. A similar situation probably exists in Central and South America for *Xanthosoma*.

9. Strategies for conservation for taro collections

9.1 Introduction

Rao *et al.* (in press) provide a comprehensive study of approaches for the development of a global genetic resources conservation strategy. Of the *ex situ* methods discussed, seed is not possible for taro genotypes, though it is a suitable method for conservation of genes, and so they conclude that field genebanks are the easiest way of conserving genetic diversity for most programmes. They are best suited for maintaining working collections for breeding and evaluation of local cultivars, many of which may not be conserved in any regional or international core collection, such as those developed by TANSAO and TaroGen. *In vitro* methods are seen as an important complementary method that facilitates distribution, efficient in terms of space, and can lead to cryopreservation, which will reduce risks of

[7] http://faostat.fao.org/site/408/DesktopDefault.aspx?PageID=408

contamination, genetic change, and costs. However, is this study by Rao *et al*. (in press) a sound basis for a strategy?

9.2 Pacific and Southeast Asia genepools

9.2.1 Cultivated diploids

Based on the studies of TANSAO and TaroGen and subsequent research, there is now a good understanding of the genetic diversity of taro within Asia and Pacific countries, sufficient to provide a firm basis for a strategy for conservation and use. In the short-term, the Strategy should concentrate on the Pacific and Southeast Asia parts of the genepool, leaving aside the diversity that may be present in Africa and South America until collections and assessments have been made. The priority is clear: after all, the Asia/Pacific region contains the centre of origin, possibly between Myanmar and Bangladesh (Plucknett 1976) - although there is no evidence to prove it (Lebot 1999) - and domestication probably occurred in the Asia/Pacific region over a wide area from genetically diverse wild forms (Yen 1989; Matthews 1990; Lebot 1999).

As we have seen, there is substantial evidence for two separate genepools of cultivated taro, one in Asia and the other in the Pacific - with some overlap in Indonesia where there is high genetic diversity of diploid varieties - and these have been identified with isozymes (Lebot and Aradhya 1991) and confirmed with RAPD (Irwin *et al*. 1998) and AFLP (Kreike *et al.* 2004) markers. There is also similarity between the Indonesia and Malaysian taro. However, within the Asia genepool there are anomalies. First, the 146 diploid cultivars of the Philippines showed limited isozyme variation and are distinct from Indonesian cultivars, being more closely related to those of the Pacific, possibly derived from Papua New Guinea and Solomon Islands (Lebot and Aradhya 1991; Kreike *et al*. 2004). Second, the origin of diploid cultivars from Thailand “is certainly also Pacific”; and third, the same can be said for the (few) diploid accessions of Vietnam (Kreike *et al.* 2004), the rest being triploid. The core sample from the six TANSAO countries contained 168 accessions initially; however, it was subsequently reduced to 120. Papua New Guinea was omitted because of the risk of transferring accessions that had not been indexed for all known taro viruses. Instead, Vanuatu accessions were included as alomae and bobone diseases are absent from that country. The Pacific genepool has much narrower diversity, with many lines from Pacific Island countries being traced back to Papua New Guinea (Mace *et al*. 2006a,b).

The conclusion is that for most countries in Southeast Asia and the Pacific, diploids are sufficiently represented in the TANSAO and TaroGen collections, and there is a good understanding of the diversity present.

9.2.2 Triploids

Triploid taro was mostly found in the Vietnam collection, although there were some in Indonesia and Thailand (Lebot *et al.* 2004a). Two are represented in the TANSAO core. They have restricted value in plant improvement programmes, which require sexually functional parents.

9.2.3 Wild taro

In terms of the number of wild accessions in collections, Thailand has the most (17 accessions presently maintained), which may be because the country is near the centre of origin of the species (Kreike *et al.* 2004). In general, in the survey made by TANSAO, the genetic diversity of the wild taro within a country was higher than that of the cultivars, although differences between the two groups in Indonesia and Malaysia were much less (Kreike *et al.* 2004). Hay (1998a) visited several collections of taro in Southeast Asia to check the taxonomy of plants and considered that "taro collections generally under-represent wild (rather than merely feral) taro…" He recommended that collections be made in North Vietnam as a promising area for the discovery of wild *Colocasia* species, as several have recently come to light in Yunnan, China. Also, he suggested that visits to herbaria and botanic gardens in Thailand, Vietnam and China would give localities where living plants could be collected for addition to germplasm collections.

There is need to assess the genetic diversity in the wild population as it appears that there is considerable diversity present (Krieke *et al.* 2004), with particular potential for breeding programmes.

9.3 South and East Asia genepool

The collections of India and China have been described morphologically, so the task now is to stratify the collections using this data and agronomic information, followed by molecular analyses using, preferably, codominant SSR or ISSR markers (Mace and Godwin 2002; Okpul *et al*. 2005; Mace *et a*l. 2006a,b). Afterwards, national core collections need to be identified, comparisons made with the present TANSAO collection and selections pathogen-indexed, conserved and shared. This work is a priority. In order to ensure long-term conservation and utilization of the rationalized collections, the accessions need to be pathogen-indexed and duplicated.

With the results from India, China, Southeast Asia and the Pacific, scientists will be able to assess the genetic diversity within this large genepool. Already, Vanautu is finding considerable heterozygosity in accessions from Southeast Asia after raising 3000 hybrids from crosses between TANSAO and local cultivars. Accessions from India and China are likely to add to that (Vincent Lebot, CIRAD, pers. comm.).

9.4 Long-term conservation and distribution

Most countries will no doubt continue to maintain their collections as field genebanks, and for some of the 'major' ones international assistance can be provided, but for most, this method has serious limitations. It has failed many countries in the past, and there is no reason why it should not do so in the future. And even for those where international support is provided, it should be for 'working collections' only, those undergoing rationalization with the identification of duplicates, the development of representative cores for conservation *in vitro* and, importantly, for breeding and evaluation, the provision of planting material for local communities and, possibly, the generation of seed for sharing internationally.

The recurring losses from *ex situ* field genebanks will continue to be a problem, even where international support is provided, so duplication will be necessary. *In vitro* methods offer a practical solution. And for a global strategy to be successfull, there is a need to have an efficient and effective method of distributing germplasm that is rapid and respects international guidelines. These call for germplasm to be distributed as pathogen-indexed tissue cultures (Zettler *et al*. 1989). There are several institutions where expertise can be obtained, for instance LIPI, Indonesia; NBPGR, India and the CePaCT, Fiji. The last is presently conserving the TANSAO and TaroGen collections, other taro germplasm, and an array of other vegetatively propagated crops. It is also carrying out research into *in vitro* protocols and ways to facilitate international transfers. The CePaCT is working towards long-term conservation techniques so that "one could consider, under a global conservation strategy, to expand the mandate of CePaCT to conserve a global set using cryopreservation technique in the near future" (Rao *et al*. in press). Some of the reasons for this support include:

- Currently maintains 850 accessions, including the TANSAO and TaroGen cores, and is committed to conserve the germplasm of the Pacific and that from southeast Asia provided through TANSAO.
- Has effective links to government agencies, NGOs, farmers, etc. in order to distribute germplasm.
- Has staff with the necessary skills, including pathogen-indexing.
- Carries out research into technologies to enhance the capability of the facility.
- Has links to international agricultural research centres of the CGIAR system, and other specialist institutes and organizations, regionally and globally involved in the maintenance of vegetatively propagated crops (eg COGENT, IITA, CIP, CIAT, Bioversity International).
- Has developed effective cryopreservation protocols which have proved successful with a selection of cultivars from a representative sample of countries.
- It is supported by numerous donors on an on-going basis.
- It is a pivotal component of PAPGREN and assists counties with technical aspects of the ITPGRFA. Indeed, in 2009 the CePaCT collections were placed in the Multilateral System of access and benefit-sharing (MLS) of the Treaty.
- Provides training in PGR conservation in association with local universities.

CePaCT should be requested to play an increased international role, back-stopping the global strategy for edible aroids. It has taken the first step by inclusion of the collection in the MLS, in the same way as the CGIAR Centres, under Article 15.

9.5 Information database and characterisation

While morphological and molecular information for TANSAO and TaroGen has been documented, this is not so for agronomic evaluations. This needs to be added to the descriptor information and made available online. At present, it is difficult to select cultivars for particular qualities. Overall, there is more complete information available for the TANSAO collections than for those of TaroGen. This is because TANSAO and TaroGen approached the rationalization of the collections in different ways. TANSAO selected accessions in each country based on morpho-agronomic traits and, later, after the 2298 accessions had been reduced to 168, formal trials were

carried out on the elite cultivars for yield and eating quality. TaroGen took a different approach: the cultivars were chosen on phenotypic characterization and genotypic analysis to select a core that captured the genetic diversity of the entire 2190 accessions; this does not necessarily mean that those taro with the best agronomic characteristics were selected, although some were added later. Information on these are lacking for some of the selections. It should not be difficult to gather the information required.

10. Strategies for use of taro germplasm

10.1 Introduction

Rao *et al*. (in press) have shown how taro genetic resources have been used in breeding programmes for taro leaf blight resistance in Samoa, Solomon Islands and Papua New Guinea under TaroGen. Although the Pacific programmes recognised early that germplasm was required from Asia (India, in particular, because of reports of taro varieties with resistance to taro leaf blight), it was not until TANSAO showed the structure of the Asia/Pacific genepool that the reason became clear. It was seen that breeding within the Pacific genepool for taro leaf blight resistance would provide only limited success and broadening the base by inclusion of Asian cultivars (not wild types as used in Solomon Islands and Papua New Guinea) was needed (Kreike *et al.* 2004). This is now the strategy even where taro leaf blight resistance is not the sole aim, for instance in Vanuatu. Recently, both Papua New Guinea and India have expressed a need to incorporate material from the corresponding part of the genepool (Guaf and Komolong in press; Edison *et al*. 2004). Recently, part of the TANSAO collection has been sent to Samoa.

Although it is becoming clear what needs to be done in terms of conserving genotypes in the Asia/Pacific genepool, and where further work is needed on the collections that have yet to be analysed, there is still much to be decided in practical terms about how the genetic resources can best be used by farmers. Collections can be made, rationalized to contain the elite cultivars and broad genetic diversity, exchanged and conserved, but much more needs to be done to assist countries where social and environmental conditions – climate and pests and diseases – are changing rapidly.

Rao *et al*. (in press) suggest that collections should be stratified into type of material, genetic diversity, type of use, and then the groups allocated to different methods of conservation, and different priorities assigned to each. Unfortunately, this model requires a great deal of information, not least passport, characterization, evaluation data, molecular markers to identify duplicates and to assess genetic diversity, etc. Where that information is available and where there taro improvement programmes exist, this is an ideal approach. In reality, there are few national programmes focusing on taro; either it is a minor crop and of low priority or, where it is a priority, funds are limited. Thus, any model has to take account of these realities if it is to be relevant to the ultimate beneficiaries and be sustainable (Vincent Lebot, CIRAD; pers comm.).

Strategies have focused primarily on collecting accessions and conserving them, rather than looking at farmers' needs and designing conservation and use strategies accordingly. As a result, taro breeding, where it has occurred, has mostly produced lines adapted locally without regard to GxE interactions. The improved genotypes that have been identified and distributed (after many years of slow multiplication) have often failed to meet farmers' expectations, or because of scant resources and the difficulty of distribution, have not even found their way to farmers' fields. In Papua New Guinea, for instance, the few selections released after several cycles of breeding were found to have far less potential than expected (Guaf and Komolong, in press). The Taro Improvement Programme (TIP) in Samoa has been possibly more successful in meeting farmers' needs by using a more participatory approach and involving farmers in the evaluation of new lines

Farmers are constrained by several factors: first, they do not have access to 'new' cultivars, but are keen to test any that are given them or they find by chance as self-grown seedlings; two, they do not have ways of avoiding pests and diseases or reinvigorating cultivars once infected by internally borne pathogens, viruses in particular, which accumulate over time and depress yields; and three, there is no possibility of using seed as a filter to remove infections, or only occasionally so. In some countries, for instance Solomon Islands and Vanuatu, farmers are finding seedlings in their gardens and are evaluating them. In Vanuatu, studies under TaroGen found a complex system of naming such happy finds. If farmers have already determined ways of crop improvement using seedling selections, then conservation and use strategies should assist them by making the process more efficient. They should not give them clones which have been selected in one environment without broad adaptation in others.

10.2 A strategy for use: putting farmers' first

The following scheme is offered based on studies by Lebot *et al*. (2005b) and is provided here as a novel way to overcome past constraints to conserve and use taro genetic resources. It is flexible and accommodates countries where there is considerable information on taro morphology and genetic diversity (for example, those within TANSAO and TaroGen) and those where little is known. Entry points will differ: some countries already have the core samples/collections of TANSAO and TaroGen, so they will concentrate on true seed (Lebot *et al*. 2004b); others will make introductions of pathogen-tested tissue cultures of genotypes to give to farmers directly and/or use them in breeding programmes. The scheme is being put to the test in Vanuatu, so it can be monitored to gauge its relevance there and to countries elsewhere. The sequence of the programme would be:

<u>Collection of a core sample</u>
In each country, select a core sample. This does not necessarily mean a collection of all the varieties, but a sample provided by farmers from a number of localities, widely separated and where taro is a popular crop. The core sample should be based on five criteria:

- origin (distinct geographical regions);
- diversity (highly distinctive traits);
- quality of corms;
- agronomic performance;

- functional sexuality of a majority, i.e. diploids, though some triploids for direct evaluation can be included.

Ideally, DNA markers should be used to measure genetic distances, but for most countries this is impractical and stratification of the collections should be done using the four (or five) criteria listed.

Again, the selections should be analysed for chemotype, because of its importance, but in most countries the analyses cannot be done as they are expensive; in these cases, the alternative is to make selections over as wide an areas as possible. Experience has shown that 50-60 carefully chosen cultivars can assemble significant allelic diversity (Lebot *et al*. 2005b).

Send for virus-indexing

- Send the varietal selections (core samples) to an international transit centre (e.g. CePaCT);
- Propagate *in vitro* and send the core samples to as many partners as possible. The core for distribution to any country should be selected based on genetic distances and geographic origin (ideally, and dependant on costs, they should be DNA fingerprinted).

Distribute to farmers

Partner countries will propagate the exotic varieties and *without testing* distribute to farmers – let farmers do the selecting as part of a programme of decentralized evaluation (PPS), to overcome limitations that would otherwise occur due to GxE interactions. Farmers will be keen to evaluate new taro varieties, and some will do well, but not all.

Intercross selected core genotypes

Alternatively, and/or concurrently with the direct distribution of core samples to farmers, intercross the accessions and distribute seedlings from either the C1 or C2 (selections of the first crosses as parents) generations. Some countries may wish to make preliminary selections, removing plants with unacceptable characteristics, such as high acridity, stolons, profuse suckering, susceptibility to taro leaf blight, etc. Farmers will be made aware that many of the seedlings will not be useful, but it is likely that some will be. On that understanding, and willingness to experiment, farmers would join the programme, and seedlings provided.

Develop a network

- Establish a farmers' network in each county, members of which can occasionally meet to share experiences, following the example of the TIP – the Taro Improvement Programme - in Samoa (Iosefa *et al.* 2004).
- Tap into the established variety sharing networks that farmers have used over many thousands of years.
- The farmers would be visited by scientists on a regular basis to monitor the evaluations.

Share the selections

- Selections that farmers have made would be shared within the network.

- They would also be shared internationally via the transit centre, which can conserve them if necessary.

Thus, there would be a dynamic movement of alleles through the system, constantly being refreshed as new crosses are made. In this way, the allelic diversity of farmers' germplasm will be broadened and maintained.

Share the seeds

There will be some countries that will not have the resources to make the crosses between local and exotic germplasm. They can share seed from countries that can, germinate them and distribute seedlings to farmers, i.e. one country takes the lead and generates seed for others. The only problem that might arise concerns the issue of seed borne viruses. One virus (*Taro badnavirus*) is considered seed borne (Macanawai *et al*. 2005) and another is possibly integrated into the genome (Yang *et al*. 2003), but whether it is able to reconstitute is not known. The fact that TaBV is widespread and that some seed has passed between countries without, seemingly, untoward consequences, suggests that seed transfers can be made with relative safety. They would have to originate from countries free from alomae and bobone diseases, such as from Vanuatu, for instance.

Assess the allelic diversity

This would be done at the transit centre as the genetoypes are moving through. The aim would be to monitor the extent of the diversity using SSR, ISSR or other markers to assess the extent that diversity is being preserved in the network. Here, the need is:

- To check whether the core sample contains duplicates, as it will have been selected mostly on agro-morphological criteria.
- To check that the national cores have contrasting genetic diversity so that countries receive useful material in terms of allelic diversity.

11. Other edible aroids species

11.1 *Alocasia macrorrhiza*

There is relatively little information on *Alocasia* compared to the other genera. The genus contains about 65 species occurring from Sri Lanka and India, through Indochina to China and southern Japan, the Malesian archpelago, Australia and Oceania (Hay 1999). The main centre of diversity of the genus is Borneo, where there are an estimated 23 species (Hay 1998b; 1999). It is not known where *Alocasia* was brought into domestication. Hay (1998b) considered *A. macrorrhizos* a cultigen, without wild forms, although it is possibly wild in Peninsular Malaysia (Hay and Wise 1991). There is speculation that *A macrorrhizos* has hybridsed with *A. portei* to give a form with slightly wavy leaf margins in the Philippines (Hay 1999).

In India, *A. macrorrhiza* (together with *Colocasia*) occurs mostly in the humid tropical habitats of the Western and Eastern Ghats and in the northeast (Arora 1991). The crop is important, too, in some Pacific islands, notably American Samoa, Samoa, Tonga and Wallis and Futuna The number of varieties is low and it is presumed that the species has a narrow genetic base (Lebot 1992). However, the crop has shown

potential in recent years: production of three varieties grown in Samoa increased substantially following the devastation of *Colocasia* by taro leaf blight in the early 1990s. Also, there is increased production in parts of Vanuatu (Vincent Lebot, CIRAD, pers. comm.). Tonga has four varieties.

There do not appear to be national collections of the edible forms of *Alocasia*, apart from India, which records seven (six farmers' and one wild) varieties of *A. macrorrhizos*; however, there are collections of a number of ornamental (presumed wild) species in botanic gardens and nurseries. The Hortus Botanicus Leiden, the Netherlands, holds 42 and the Belgium National Botanic Gardens, 17 accessions. Plants can be purchased at many nurseries; for instance, there are six species at Natural Selections Exotics[8] and another six at Plant Delight Nursery Inc.[9]

Hay (1998b) lists a number of species that are known from a very few collections and/or localities in West Malesia and Sulawesi. Some are highly ornamental and considered threatened by unscrupulous collectors. However, they are "open to *ex situ* conservation (in a broad sense) through the medium of ornamental horticulture sustained by tissue culture." Thus, this opens the possibility for commercial sales, easing the collecting pressure on limited wild populations;

Interestingly, a hybrid has been produced between *C. esculenta* var. *aquatilis* from Nepal and *A. brisbanensis* (Yoshino *et al.* 2000).

11.2 *Amorphophallus paeoniifolius*

Amorphophallus is a native of tropical Asia, commonly known as elephant foot yam. The distribution of the species is discussed by Hetterscheid and Ittenback (1996): West Africa is the westernmost limit, whereas the eastern limit is a line going from Japan, through Taiwan, the Philippines, and New Guinea to northeast Australia. There appears to be a high degree of endemism, with only *A. paeoniifolius*, *A. muelleri* and *A. abyssinicus* with a "fair geographic range"; this may indicate that the genus is actively speciating. There are more than 90 species described (Sastrapradia *et al*. 1984). Hay (1988b) puts the number at about 100, with centres of diversity in (Gondwanan) Africa and Laurasian Malesia west of Wallace's Line.

A. peaoniifolius occurs in the Pacific, having reached Australia and New Guinea without human intervention (Hay and Wise 1991). In Melanesia, it is still the practice to leave plants that are found when land is cleared for cultivation from forest, although they are not used. However, some cultivars are still retained (Jackson *et al.* 2007), others are introductions (Sivan 1984). But it is India where most diversity of the edible form exists and where it is relatively important among root crops. Within the network of the 10 research centres of the All India Coordinated Research Project on Tuber Crops, there are 195 accessions. Some selections have been made for different regions (Palaniswami and Anil 2006) and a hybrid released from a breeding programme (Abraham *et al*. 1998). In northeastern states, wild forms are used as vegetables as well as for medicine.

[8] http://naturalselections.safeshopper.com/51/cat51.htm?444
[9] http://www.plantdelights.com/Catalog/Current/page5.html

Diversity studies have been done on parts of the collection in India using morphological descriptors and isozyme markers (Bhagavan *et al*. in press; Chattopadhyay *et al*. in press), and further work needs to be done with more sophisticated markers. Apart from India, studies are reported from Indonesia, with a collection of eight species (16 are known) reported from the Bogor Botanic Gardens, collected from Java, Sumatra and Kalimantan. There are two forms of *A. peaoniifolius* - one wild, the other cultivated (Sastrapradia *et al*. 1984). It is a useful subsistence crop in dry areas

Many species have entered the nursery trade and there are many companies[10] offering online sales of plants from Asian countries: Burma, Thailand, Vietnam, India, China, Japan. One company advertising aroids of Yunnan[11] has outlets worldwide. It would be a relatively simple exercise to compare the known species with those that are available commercially. It does appear, based upon a brief survey, that many of these fascinating plants are well conserved, with one caveat: that the genetic diversity retained by nurseries may not be representative of that in the natural populations. There are also collections at botanic gardens, for example: National Botanic Garden of Belgium (seven accessions); Royal Botanic Gardens, Kew (42 accessions); Royal Botanic Gardens Sydney (nine accessions of *A. paeoniifolius* and seven of *A. rivieri*); and Hortus Botanicus Leiden, the Netherlands (530 accessions).

Useful notes on the geography, ecology and conservation, but mostly relating to *A. titanium*, can be found on the International Aroid Society website, adapted from Hetterscheid and Ittenbach (1996)[12].

11.3 *Cyrtosperma merkusii*

Cyrtosperma contains a variable number of species (11 or 12) depending on the classification used (Hay 1990; Hetterscheid 2004), with *C. merkusii* (syn. *C. chamissonis*) the only edible form - known commonly as giant swamp taro. Most authorities accept an Indo-Malay centre of origin, with Plucknett (1976) suggesting Indonesia; however, Lebot (1999) considered “coastal New Guinea region” more likely, because of the variation in wild forms. Hay (1988a) says that the species is wild and little used in Peninsular Malaysia, Sumatra, Borneo and Java. It is present in the Philippines and also Solomon Islands. Hay (1988a) continues: “The occurrence of seemingly wild-type plants in the Solomon Islands makes it difficult to arrive at a single suggestion as to the origin of *C. merkusii* in Pacific cultivation”. The possibilities are: a) Solomon Islands or West Malesia (Malay Peninsula and the islands of Sumatra, Java, Bali and Borneo) or both independently; b) that the seemingly wild types (heavily armed with spines) of Solomon Islands are relics of introductions from the west.

Cyrtosperma is cultivated in most Pacific Island countries, more rarely today as a staple food but, nevertheless, still retained for its important cultural uses – ceremonies, weddings, funeral, competitions – and/or a reserve food (Iese 2006). Interestingly, parts of Solomon Islands have increased cultivation in recent years because of the failure of other food crop staples (Jackson *et al.* 2007).

[10] For example: http://www.plantdelights.com/Catalog/Current/page7.html
[11] http://natureproducts.net/forest_products/Aroids/Aroids.html
[12] http://www.aroid.org/genera/amorphophallus/amgec.html.

A recent study has been undertaken on cultivars in four Pacific island countries, and the number of accessions was: Federated States of Micronesia (48), Fiji (5), Kiribati (18) and Tuvalu (12) (Englberger *et al*. 2003; Iese 2006). Morphological and molecular comparisons were made, traditional knowledge collected and dendrograms of morphological characters drawn to show that some varieties were closely related between countries, while others were unique (Iese 2006). In three of the countries, the combined percentage of varieties considered very rare or threatened – cultivated by less than 25% and 10% of farmers respectively – was: Fiji, 60; FSM, Pohnpei, 86; and Tuvalu, 50. Preliminary DNA fingerprinting studies supported the view that some varieties were rare and in need of sharing between growers and/or conservation in other ways (Iese 2006).

With this in mind, some collecting has taken place in Kiribati by CePaCT in collaboration with the Ministry of Environment, Lands and Agricultural Development, pers. comm.). A similar development is planned in Pohnpei. Here, conservation is the aim as well as transfers to CePaCT, and thence to Solomon Islands, to reduce the vulnerability in parts of the country where only a single variety is grown (Jackson *et al*. 2007). At present, only Pohnpei has a collection – there are about 68 accessions (Adelino Lorens, Pohnpei State Department of Agriculture, pers. comm.). Once the varieties are at the CePaCT, DNA fingerprinting of the accessions from the different countries can be completed, a core sample based on agronomic and genetic criteria defined and, with suitable plant health certification, sharing commenced.

Although seed set occurs in this species, the sharing of germplasm as true seed is unlikely. Unlike *Colocasia*, there is no breeding program for this crop; it was tried previously to obtain salt tolerant plants, but this was unsuccessful. Seedlings were raised in Samoa for evaluation in Kiribati (Wilson and Cable 1984).

In conclusion, the priorities for *Cyrtosperma* are collecting in some countries, 'gap filling' in others, establishing core samples and establishing *in vitro* collections.

11.4 *Xanthosoma sagittifolium*

As with the edible species of *Colocasia*, those of *Xanthosoma* are also pan-tropical; however, the origin of the genus is tropical America, possibly in northern South America (Clement 1994; Giacometti and León 1994) where some species were domesticated, probably from different wild forms (Hernández Bermejo and León 1994). *Xanthosoma* was introduced to West Africa, Oceania and Asia in the 19th century (Coursey 1968; Wilson 1984), although Brown (2000) considers *Xanthosoma* reached West Africa earlier, between the 16th and 17th centuries. Today, it is ranked sixth in cultivation and production (Onwueme and Charles 1994), and an important food for some 400 million people (Onokpise *et al*. 1999). It has overtaken *Colocasia* as the main edible aroid in many tropical areas (Matthews 2002b).

Taxonomists have described a number of edible species based on leaf shape, pigmentation and other vegetative characteristics. Wilson (1984) lists *X. violaceum*, *X. atrovirens*, *X. caracu*, *X. jacquini*, *X. maffafa*, *X. belophyllum* and *X. brasiliense*.

According to Brown (2000) there are two main species, *X. sagittifolium* and *X. violaceum.* Castro (2006) refers to Giacometti and Léon (1994) and states: "The taxonomic position of the cultivated *Xanthosoma* species is unclear, and in recent years the tendency has been to give the name of *X. sagittifolium* to all cultivated *Xanthosoma*". But this distinction is based on morphological features - colour of the corm, cormels and leaves and on the shape of the cormels - that seem unconvincing as a basis to separate the species. Brown (2000) now recognizes *X. mafaffa* as the species of Nigeria, having replaced *X. sagittifolium*. The phylogeny of *Xanthosoma* is being studied at the Universidade Católica de Brasília, Brazil as well as the cytogenetics of the more than 30 wild and cultivated species, maintained in order to obtain data for a taxonomic revision (Eduardo G Gonçalves, Coordenador do Horto-botânico da UCB, pers. comm.).

There have been past attempts to collect and characterize the edible species. Crop improvement work has been done in Cameroon to hybridise different genotypes (Goenaga and Hepperly, 1990; Onokpise *et al.* 1999), some attempts have been made to produce new forms through *in vitro* culture (Tambong *et al*. 1998) and breeding continues in the Caribbean (Angel Bosques Vega, pers. comm.). Other work has been done on the characterisation of collections, such as that in Cuba where four species (*X. violaceum*, *X. atrovirens*, *X. caracu* and *X. sagittifolium*) have been described (Milián *et al*. 2001), and in Sri Lanka (KPM de Silva, Department of Agriculture, pers. comm.). The studies in Cuba concluded that classification "based on one or a few morphologic characters does not show the true genetic variability within the genus", and that DNA markers are needed (Milián *et al*. 2001). In this regard, analyses of *X. sagittifolium* in the cocoyam collection in Florida showed very little genetic variation (Schnell *et al.* 1999).

Characterisation would indeed seem a priority, but so too is filling in the gaps in *Xanthosoma* collections. Major collections of *X. sagittifolium* from Cameroon, Equatorial Guinea, Gabon, Ghana, Puerto Rico, Togo and Central and South America were made between 1986 and 1991 (Onokpise *et al*. 1993; Tambong *et al*. 1997), and maintained at the Institute of Agricultural Research, Ekona, Cameroon. The collections were evaluated for petiole length, yield and incidence of *Pythium* infection (Onokpise *et al*. 1999). Over 300 accessions were assembled; many of them were considered landraces of previous introductions, especially by the Portuguese. Hybridization resulted in the production of more than 10,000 seeds from "white" x "white and "white" x "red" crosses, but few viable seeds from "white" x "yellow" or "red" x "yellow" crosses, perhaps due to ploidy differences (Onokpise *et al*. 1999). Unfortunately, funding for the maintenance of the collection ended in 1994, and by 1997 there were substantial losses (Tambong *et al.* 1997). A collection in Miami, USA, held by the USDA National Plant Germplasm System was lost in a 1992 hurricane (Wilhelmina Wasik, Biological Science Technician, GRIN Database, pers. comm.).

More recently, a collection of 70 *X. sagittifolium* accessions at the University of Ghana showed that the diversity present was of potential interest to plant breeders and those concerned with conservation (Offei *et al*. 2004). Collections are also being made in Central America, and for a similar reason: to have germplasm to use in root disease control programmes. Nicaragua is using conventional approaches and tissue culture to induce variation (Guillermo Castro, University of Nicaragua, pers.

comm.), and in a collaborative project involving universities in Nicaragua, Costa Rica and Sweden, it had been hoped to analyse them using morphological and molecular techniques; however, funding has been difficult (Marie Nyman, Swedish University of Agriculture Science, pers.comm.). Root disease is also a problem in Brazil; however, a few species of the *X. maximilianii-X. hyleae* complex have resistance (Eduardo G Gonçalves, Coordenador do Horto-botânico da UCB, pers. comm.). Conventional breeding is also being done in Cuba where there is a collection of 78 accessions has been described using morphological descriptors and partly by molecular markers (Marilys Diley Milián Jiménez, Curator, INIVIT, pers. comm.). The results from a recent survey of collections worldwide are summeraised in Table 14.

Table 14. Collections of *Xanthsoma*: species and varieties located from the present, 2006-07, survey

Country	No. of species				No. of varieties			
	Wild	Farmers	Breeders' vars	Breeder s' lines	Wild	Farmers	Breeders' vars	Breeder s' lines
National collections								
Brazil, Universidade Católica de Brasília	30 (wild and cultivated)							
Costa Rica, Centro Investigaciones Agronómicas, Universidad Costa Rica	2	±6	-	-	26	38	5	-
Cuba, Instituto Nacional de Investigaciones de Viandas Tropicales	-	4	-	-	-	78	-	-
Ghana, University of Ghana	-	1	-	-	-	70	-	-
Ghana, Plant Genetic Resources Research, Bunso	-	1	-	-	-	2	-	-
India, CTCRI	1	2	1	0	1	71	1	0
Nicaragua, Universidad Nacional Agraria	-	±6	-	-	-	56	-	-
Nigeria, National Root Crops Research Institute	-	1	-	-	-	3	-	-
Puerto Rico, Estación Experimental Agricola de Isabela	1	1	-	-	4	21	1	86
Sri Lanka, Horticultural Crops Research & Development Institute	-	1	-	-	-	6	-	-
Tonga, Ministry of Agriculture & Food	-	1	-	-	-	4	-	-
Botanic gardens								
*Belgium (NBG)	1	5	-	-	2	No info	-	-
†Kew (RBG)	2	2	-	-	-	No info	-	-

*The wild material is given as *Xanthosma* sp.; the cultivated species are: *X atrovirens*; *X mafaffa*; *X robustum*; *X sagittifolium*; *X violacearum*; † *X sagittifolium* & *X violaceum* (also *X cubense* and *X helleborifolium*); ± *X. sagittifolium*, *X wendlandii*, *X atrovirens*, *X violaceum*, *X mexicanum* & *X robustum*

Hernández and León (1994) argue that there is an urgent need to establish live and *in vitro* collections globally to enable genetic potential to be evaluated to meet present needs and problems. This means "…collecting the known cultivars, both in

the New World and in Africa, and exploring the northern part of South America in search of possible wild forms and primitive cultivars as well as related species (such as *X. jacquinii). In vitro* cultivation now enables healthy and easily transportable propagation material to be obtained". This might be considered premature, considering the recent past, but there is interest in the crop in several countries, to meet increasing demand of the corms in the USA. However, there are production problems, those of root rot disease in particular. Thus, meeting the needs of these targeted improvement programmes would seem a priority.

If access to collections of diverse species is required for genetic studies, in addition to those in West Africa, Central and South America, several botanic gardens hold putative species (Table 14). Whatever the decision, SSR (Mace *et al*. 2006a,b) and ISSR markers (Okpul *et al*. 2005) are now available, developed for *Colocasia*, that can provide greater insights into the genetic relationships within and between species (Mace *et al*. 2006a,b). As Offei *et al.* 2004) state: "In Ghana, genetic improvement in cocoyam has been slow due to lack of knowledge on genetic diversity in the crop". This could be said about most edible aroids.

12. Conclusions

It is important to look back over the last 50 years or more at the history of conserving taro and related aroids as *ex situ* field collections. The results have not been good. Collections, big and small, have come and gone, and for many, this has happened several times. Even in the immediate past, the picture has been the same: many of the collections assembled in the field under TANSAO and TaroGen no longer exist or have been severely depleted, and in 2007 Typhoon Milenyo inflicted heavy losses on the Los Banos taro collection in the Philippines. Only collections made in Papua New Guinea, Thailand and Vietnam remain intact.

The Papua New Guinea collection is important as it represents the taro of the Pacific genepool. However, greatest diversity exists in Indonesia, where the Southeast Asia and Pacific genepools overlap, but the collection is no longer representative of the diversity of the country. Even with international funding, field collections are never going to be secure; they will always be vulnerable to constraints and threats of one kind or another. They cannot be used as a basis for a global conservation and use strategy. It is probably time to say: "Enough!"

That is not to say that field collections are not useful. They are, *for the short time that it takes to characterize collections adequately*. But for long-term conservation, well-duplicated, pathogen-indexed core samples/collections maintained *in vitro* – as plants in tissue culture and cryopreserved shoot tips – provide a better answer. The technologies are available and should be used.

Collections were made in many countries within the genepools of Southeast Asia and the Pacific and from these core samples/collections were identified based on morphological and molecular methods. These are now conserved in CePaCT, Fiji in tissue culture and duplicated at USP, Samoa. This work gave countries the chance to reduce their national collections, and some took that opportunity. The TANSAO and TaroGen cores have been well distributed in Southeast Asia and the Pacific, but

still a number of other issues remain to be discussed on the future conservation of these collections:

- Check the cores for completeness;
- Add information for each accession;
- Consider cryopreservation as a complementary method;
- Ensure sufficient duplication;
- Distribute to other regions;
- Determine if wild forms are sufficiently represented.

For both the TANSAO and TaroGen cores, the numbers held by CePaCT are less than originally selected. This is not due to losses in tissue culture, but because some were not deposited at CePaCT in the first place. For instance, the original core sample of TANSAO was 168 (134 diploids and 34 triploids), but CePaCT has only 120. There is a need to go through the list, identify those that are missing and determine if they are required. There is also a need to develop a database, which includes as much agronomic information on each of the accessions as is available. This will mean searching through much unpublished information. A decision will be needed on how many duplicates of each accession should be maintained, and whether cryopreservation can now be used as a reliable complementary method. There is also the question of the duplication necessary. At present, the collection is duplicated, but is this sufficient? It might be advisable to have another set of each collection in Southeast Asia or East Asia. And, finally, attention should be paid to wild forms, which are a highly diverse group and "comprise important material for long-term breeding purposes" (Kreike *et al*. 2004). Some gap filling seems to be required.

For the genepools of Southeast Asia and the Pacific, the way ahead is clear, and the activities described above can be undertaken with relatively ease. It is recommended that the CePaCT be asked to take the lead.

More difficult, time consuming and costly, are the needs of other parts of the global genepool, East Asia in particular, where, it is speculated, separate genepools may exist. There are large collections in China, India and Japan. These need to be analysed as a matter of priority: descriptor work completed, molecular studies carried out and comparisons made with the results from Southeast Asia. Based on these results, a core sample for the region needs to be defined, pathogen-indexed, duplicated and stored *in vitro* in that region and also at the CePaCT. A decision will be required on which county is to take the lead, as well as on the methodologies for DNA fingerprinting and pathogen-indexing. Fortunately, this work can rely on the pioneering work of TANSAO and TaroGen. Only after this has been done should gap filling be considered. The organization of this work should be left to collaboration between CTCRI, India, Wuhan Vegetable Research Institute, China and SPC. Japan should be asked to join, too, and it is recommended that staff at the VARTC, Vanuatu be asked to collaborate, having successfully led the TANSAO project previously.

More difficult still is the conservation of taro in Africa and South America. Here, there are few collections, confusion over what is meant by "cocoyam", and few curators from whom information can be obtained. If FAO figures are reliable, cocoyam production is relatively high, possibly indicative of substantial diversity, which should

be conserved. For *Xanthosoma*, at least, this is supported by the collections assembled in the Cameroon in the 1980s. For this crop, the way forward is to link conservation activities with plant improvement programmes, such as those in Brazil, Costa Rica, Nicaragua and Puerto Rico, where efforts are once again being made to improve the crop by breeding for tolerance to *Pythium* root rot. If gap filling is required, it should be done in association with these programmes. Field collections alone will not be sufficient to conserve the germplasm and, as with *Colocasia*, conservation of *Xanthosoma* should be *in vitro*.

As for the other aroids, edible *Alocasia* species can be easily conserved *in vitro*, as there are few of them. There are already plans by PAPGREN to support the *in vitro* conservation of the *Cyrtopserma* collection in Pohnpei, FSM, at CePaCT. Some collecting has already occurred in Kiribati, with the aim of *in vitro* conservation. Once done, a comparison can be made between Pohnpei and Kiribati accessions using molecular methods. There is also a need to look at *Cyrtosperma* in Papua New Guinea and to check the diversity represented there.

Amorphophallus presents a somewhat different challenge. Crop improvement work has been done in India, and a large number of accessions are in collections there, and a lesser number in Indonesia. There is also considerable diversity in the wild, with numerous forms in Yunnan, China. The genus is popular in the ornamental flower trade and many are for sale. Similarly, numerous species are maintained at botanic gardens around the world. For *Amorphophallus*, there is a need to take stock of the collections at these commercial nurseries and institutions. Commercialization is likely to be a useful method of conservation.

In order to promote the use of taro genetic resources, a model is proposed for *Colocasia* that puts farmers first. In each country, a core sample would be developed, based on five criteria and shared between countries through a transit centre where they would be virus-indexed and, if possible, DNA fingerprinted. In the recipient countries, the selections chosen on the basis of wide genetic distances would be multiplied and given to farmers directly or crossed and given as seedlings; either way, farmers will evaluate them to meet their particular needs. The approach aims to preserve useful genotypes while exploiting their genetic potential. The strategy incorporates concepts developed in TANSAO Phase II which should be re-evaluated, revised and presented to donors for funding.

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Annex 1. A Survey to Build a Global Conservation Strategy for Edible Aroids

Background

The Global Crop Diversity Trust (the Trust) is helping to develop strategies for the conservation of crop diversity. The Trust has commissioned the Secretariat of the Pacific Community (SPC) to coordinate the development of a global conservation strategy for edible aroids. This questionnaire is for people caring for major edible aroid collections to help develop that strategy. The Trust will base its support for the conservation of edible aroid genetic resources on this strategy, once developed and adopted. As a key curator of an edible aroid collection(s), please complete the questionnaire. SPC is keen to ensure your active participation in the development of the global edible aroid conservation strategy and will keep you informed of progress and consult you until it is completed.

1. General:

Please state what species of aroid you are reporting on. (**If you maintain more than one edible aroid species, please use a SEPARATE form for each**):

Alocasia macrorrhizos	yes
Amorphophallus paeoniifolius	2 yes
Colocasia esculenta	2 yes
Cyrtosperma chamissonis (merkusii)	2 yes
Xanthosoma sagittifolium	2 yes
Others (please specify)	2 yes

Name and address of organisation holding/maintaining edible aroid collections	
Address:	
City:	
Postal Code:	
Country:	
Web site:	
Curator in charge of the edible aroid collection:	
Name:	
Address:	
City:	
Telephone:	
Fax:	
Email:	
Name of respondent to this questionnaire if different then above	
Contact details:	
Date of response:	

Is the organisation holding the aroid collection:

2 A - an independent organisation

2 B - part of a larger organisation

In the case of (B) please provide the name and address of the larger organisation:

_____

Is the organisation holding the collection part of a government agency?

2 yes 2 no

If no, what type of organisation is it?

_____

Who is financing the conservation of the collection, and to what extent (%age)?

2 Government _____%

2 Private sector _____%

2 International or regional organisation/agency_____%

2 Other funding agencies (specify):_____%

Is the institution in charge of the collection the legal owner of the collection?

2 yes 2 no

If no, who is the owner (state if no owner is recognised)?

2. Details on the collection

Year the collection was established: _____

Present size of the collection:

Type of germplasm	Number of species	Number varieties	Freely available for distribution or not?
Related wild species			
Farmers' varieties			
Breeders' varieties			
Other (eg breeders lines)			
Total			

What is the maximum capacity of the collection in terms of existing infrastructure?

In the field: number of plants: _____
In the lab: number of plantlets: _____

What are the average annual costs for maintaining the collection?
Staff: _____
General maintenance of infrastructure: _____
Inputs (field and lab costs): _____
Other: _____

Origin of the collection. Please state how many countries are represented in the collection:
Geographic coverage of the collection (quantify %age of collection from different countries):
Home country: _____%
Neighbouring countries:_____%
Countries in other regions: _____%
Unknown _____%

Is passport data (collecting information) available for the collection?
2 yes 2 Partially 2 no

If yes or partially how many accessions have full/partial passport data?
- Related wild species: _____(%)
- Farmers' varieties: _____(%)
- Breeders' varieties: _____(%)
- Breeders' lines: _____(%)
- Others _____(%)

3. PGR management of the collection

3.1 Acquisition

Has the collection been enlarged during the **last 5 years** with new germplasm?
2 yes 2 no

If yes, how many new accessions have been included of the following:
- Related wild species: _____
- Farmers' varieties: _____
- Breeders' varieties: _____
- Breeders' lines: _____
- Others _____

How was the newly obtained germplasm acquired?
- Collecting in own country
- Collecting in other countries
- Introduction from other collections, institutes or private organisations in country
- Introduction from other countries
- Other sources, please specify: _____

Are there important gaps in the collection?
2 yes 2 no

- If so, what are they:

Do you plan to fill these gaps in the next 5 years? 2 yes 2 partly 2 no

- If yes or partly, how:
- If no, what are the main reasons why not:

Do you plan new collecting missions in the next 5 years?
2 yes 2 no

3.2 Storage and maintenance (seed, *in vitro*, field)

Please indicate how germplasm is maintained for long- and medium-term storage (give number of **accessions**).

Type of germplasm	**Stored as seed**	**Maintained in field**	**Maintained in pots etc in screen house**	**In vitro: *slow growth***	**In vitro: *Cryo conservation***
Related wild species					
Farmers' varieties					
Breeders' varieties					
Other, eg research material					

*more than one option for the same type of material is possible

What are the storage facilities and conditions of the genebank?

	Type of facility	**Describe the conditions**		
		Temp	**RH**	**Lighting**
Botanical seed				
Short-term storage of cormels				
***In vitro:* slow growth**				
***In vitro*: Cryo conservation**				

How are the plants maintained in the field and screen house?

Type of germplasm	**No. of plants per accession**	**Distance between rows**	**Distance between plants**
Related wild species			
Farmers' varieties			
Breeders' varieties			
Other, eg research material			

Numbers of plants of the different types maintained in the lab?

Type of germplasm	**Number of plants per accession**
Related wild species:	_____
Farmers' varieties:	_____
Breeders' varieties:	_____
Other, eg research material:	_____

Do you apply tests to control the quality of stored germplasm?

2 yes 2 no

What tests?
If yes, do you check whether the *in vitro* plantlets are true-to-type 2 yes 2 no

Please explain how these tests are done:

3.3 How is the collection replanted or recultured

How often do you replant or reculture at least part of the collection?

Type of germplasm	As seed	Vegetatively	In vitro
Related wild species			
Farmers' varieties			
Breeders' varieties			
Other, eg research material			

More than one option for the same type of material is possible

How much of the collection do you replant or reculture each time?

Type of germplasm	As seed	Vegetatively	In vitro
Related wild species			
Farmers' varieties			
Breeders' varieties			
Other, eg research material			

More than one option for the same type of material is possible

3.4 Identification (classification) and characterization (described)

Is the collection taxonomically **identified**?

2 yes 2 partially 2 no

If partially, please state the percentage **NOT** identified: ……. %

Do you have assistance of a taxonomist to identify the germplasm?

2 yes (fulltime) 2 occasionally 2 no

Please indicate how the collection is being **characterised**.

Type of germplasm	Descriptor list available & used	% of the collection characterised	
		Morphologically	Molecular
Related wild species	Yes / no		
Farmers' varieties	Yes / no		
Breeders' varieties	Yes / no		
Other, eg research material	Yes / no		

For molecular characterization, specify the system used, number of markers used and the %age characterised using each system.

For morphological characterization, specify the number of descriptors used.

Which type of descriptor list is used for characterisation?

2 Standard IPGRI descriptor list
2 Your own independently developed list
2 List developed by another organisation, please specify:

3.5 Documentation and access to information about the collection

Do you use a computerized information system for the management of the collection? 2 yes 2 no

If yes, what software do you use for documentation?

What data have been computerised? Please circle the appropriate answer.

Type of germplasm	Passport data	Characterisation/ evaluation data	Management data*
Related wild species	Yes / partly / no	Yes / partly / no	Yes / partly / no
Farmers' varieties	Yes / partly / no	Yes / partly / no	Yes / partly / no
Breeders' varieties	Yes / partly / no	Yes / partly / no	Yes / partly / no
Other, eg research material	Yes / partly / no	Yes / partly / no	Yes / partly / no

* data related to storage, regeneration, distribution, etc.

In case the collection is not computerised, are there plans to do so in the future?

2 No plans
2 Computerisation planned within next 1 year

Is information on the aroid collection accessible through the Internet?

2 yes 2 partly 2 no

If yes/partly, please provide URL: _____

Are data of the collection included in other databases?

- National 2 yes 2 partly 2 no
- Regional 2 yes 2 partly 2 no
- International 2 yes 2 partly 2 no

If yes/partly, specify the database:

_____

3.6 Health of germplasm

Is the collection affected by diseases that can restrict the distribution of the germplasm?
2 yes 2 no
If yes, which types of diseases are causing this restriction?
2 Seed-borne diseases
2 Infection of corms and/or suckers/cormels

If *in vitro* samples are distributed **within the country** are they virus indexed?
2 yes 2 some 2 no
If *in vitro* samples are distributed **outside the country** are they virus indexed?
2 yes 2 some 2 no
Is knowledge available at your institution and are there facilities for eradication of these diseases?
2 yes 2 limited 2 no
Do you need assistance to improve the health status of the collection?
2 yes 2 limited 2 no
If yes, what type of assistance is required?
1) _____
2) _____
3) _____

3.7 Distribution

Do you distribute material outside your institute?
2 yes 2 occasionally, special conditions 2 no

How many accessions have you distributed **within** the country in the past 3 years to the following users (specify whether material sent as seed, corms/cormels or *in vitro*):

	0-10	**10-50**	**50-200**	**>200**
Farmers				
Breeders				
Researchers/students				
NGOs				
Gene banks				
Extensionists				
Others, and specify				

What is the average number of samples sent per accession per shipment?

	1-5	**5-10**	**10-50**	**>50**
In vitro plantlets				
Suckers/cormels				

Do you distribute germplasm outside the country?

2 yes 2 no

How many accessions have you distributed outside the country in the past 3 years to the following users (specify whether material sent as seed, corms/cormels or in vitro):

	0-10	10-50	50-200	>200
Farmers				
Breeders				
Researchers				
NGOs				
Gene banks				
Extensionists				
Others, and specify				

What is the average number of samples sent per accession per shipment?

	1-5	5-10	10-50	>50
In vitro plantlets				
Suckers/cormels				

Are you distributing more material now than 5 years ago?

2 more 2 the same 2 less

Do you expect to distribute more material in 5 years' time than now?

2 more than now 2 the same 2 less than now

Do you keep records of the distribution? 2 yes 2 no

What information is included in these records:

Do you request and get any feed back from the recipients?

2 yes 2 no

If yes, what use is made of the information received

How are the services of the collection publicized to users and how effective are these methods in terms of increased use of the collection?

	High impact	Medium impact	Low impact	Don't know
Scientific publications				
Institutional reports				
Extension Leaflets				
Oral presentations				
Group visits to the collection				
Other				

Have any requests for material been refused? If yes, specify

How do the users of the germplasm influence the management of the collection?

	Through feedback on the material?	Through formal consultations	Through participation in the governing body of the genebank	Other (specify)
Farmers				

Breeders				
Researchers				
NGOs				
Gene banks				
Extensionists				
Others, and specify				

3.8 Safety duplication

Are the accessions of the collection safety-duplicated in another genebank?
2 yes, fully 2 partly 2 no

If yes/partly, please specify where the germplasm is safety-duplicated, what part (%) of the collection and under what storage conditions

_____

Is there any germplasm of other collections safety-duplicated at your facilities?
2 yes 2 no

If yes, can you specify the name of the holder of the aroid collection safety-duplicated at your genebank, including the number of accessions duplicated?

_____

3.9 General management

How many staff are working on the collection (full-time staff equivalents)?

	<1	**1**	**2**	**3-5**	**>5**
In the field					
scientists					
technical assistants					
field workers					
students					
In the lab					
scientists					
technicians					
students					

Have you established a quality management system or written procedures and protocols for:

2 Acquisition (including collecting, introduction and exchange)
2 Regeneration/Replanting and/or sub-culturing
2 Characterisation
2 Storage and maintenance
2 Documentation
2 Health of germplasm
2 Distribution
2 Safety duplication

In case you have written procedures and protocols, can you provide the Trust with this information or include a copy of it? 2 yes 2 no

Does the existing capacity in numbers and skills of staff meet the needs of the collection in the long term?

If no, please describe what is needed?

4. Utilisation of the collection

For what purposes is the collection used?

2 Research activities (e.g. taxonomical studies, diversity studies, evolution studies, etc.)
2 Characterisation
2 Evaluation for important agronomic traits (production and quality)
2 Screening for biotic and abiotic stress resistances
2 Conventional plant breeding
2 Participatory plant breeding
2 Biotechnology (e.g. gene isolation, molecular studies, functional genomics, etc)
2 Distribution to farmers
2 Return of germplasm to country of origin

Do you have a systematic program to evaluate the collection for agronomic and other traits?

2 yes 2 planned 2 no

If yes, can you list the most important traits the collection is evaluated for?

1) _____
2) _____
3) _____
4) _____
5) _____

Do you have collaboration with an *in situ* conservation programme

2 yes 2 planned 2 no

If yes/planned, give details: _____

5. Networks of edible aroid genetic resources

Do you collaborate (or have you collaborated in the past 5 years) in (a) plant genetic resources network(s) as a collection holder (specify if collaboration is ongoing)?

2 yes 2 no

If yes, please indicate what kind of network:

	National level	**Regional level**	**Global**	**None**
Exchange of germplasm				
Exchange of information				
Training				
Other, please specify				

Please specify if the activity is regular or occasional and/or whether it was in the past only or on-going

Please list the main benefits of the collaboration as you see them, if any

1) _____
2) _____
3) _____
4) _____
5) _____

What are the major activities of the network(s) in which you participate or have participated in the past 5 years?

2 Joint conservation of aroid germplasm
2 Evaluation or characterisation of aroid germplasm
2 Establishment of central database
2 Rationalisation of the collections
2 Safety duplication of aroid germplasm
2 Others
Note: more than one option is possible

Do you consider a worldwide network for edible aroid genetic resources important and would you consider participating in such network?

2 yes 2 no

What will be your major interest for participation in an edible aroid PGR network?
1) _____
2) _____
3) _____

6. Policies with regard to access of the collection

What is your policy regarding distribution of germplasm?

Geographic coverage
2 Distribution only to users in your country
2 Distribution only to users in certain countries
2 Distribution to users in all countries

Conditions of distribution
2 Distribution to any user, without further conditions
2 Distribution to any after signing of an MTA (Material Transfer Agreement)
2 Distribution only on a mutually agreed exchange basis
2 Other conditions, please specify: _____

Cost for distribution of germplasm
2 No cost, distribution gratis to all users
2 No cost, but reciprocal exchange of material required
2 Costs charged to some users (e.g. private sector) or some countries only
2 Request to contribute for processing and shipping; specify amount: _____
2 Request to pay for each requested accession; specify amount: _____
2 Other, please specify: _____

Please attach examples of your organisation's long-term commitment to long term conservation of aroid collection, for instance:
2 Legal statues
2 Institutional constitution
2 Mandates
2 Published strategic plans
2 National conservation strategy
2 Actions plans
2 Other: _____

7. Future developments regarding the aroid collection

Will the collection be enlarged with new material or rationalized in the next 5 years?
2 collection will remain approximately the same size
2 collection will be expanded to a limited extent (5-10 %)
2 collection will be substantially increased (> 20%)

2 collection will be reduced due to duplication with other collections and internal rationalisation
2 collection will be reduced as a result of lack of funding or facilities

Are there any constraints for the maintenance of the collection?
2 yes 2 no

If yes, what type of constraints do you face?
2 Insufficiently trained staff
2 Capacity to replant/maintain the collection in field and/or in vitro limited
2 Facilities for optimal maintenance of the collection not satisfactory
2 Others, please state:
_____

Will some of the above constraints result in a loss of germplasm?

2 yes 2 only incidentally 2 no

If yes, what is the most important constraint, which may contribute to genetic erosion within the collection?
_____

8. Further remarks

Do you have any further remarks or suggestions?
_____
_____

Many thanks! Please return the completed questionnaire, no later than 31 December 2006 to:

GVH Jackson
24 Alt Street, Queens Park, NSW, 2022, Australia
Fax: +61 2 9387 8004, Email: grahame@pestnet.org

Annex 2. People contacted for the global survey

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Costa Rica	Dr. Francisco Saborio	Professor, Universidad de Costa Rica	San José	saboriop@cariari.ucr.ac.cr
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Cuba	Leonor Castiñeiras	Director of the National Genetic Resources Programme at the Instituto de Investigaciones Fundamentales en Agriculturea Tropical (INIFAT)		lcastineiras@inifat.co.cu
Cuba	Dr. Sergio Rodríguez Morales	Director, Instituto Nacional de Investigaciones de Viandas Tropicales (INIVIT), Finca Tres Carolinas, Apartado 6	Santo Domingo	sergio@inivit.co.cu

Country	Full Name	Institute's name	City	Email - main
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Nigeria	Dr Ada Mbanaso	Curator, National Root Crops Research Institute	Umudike, Umuahia	embanaso@yahoo.com
Nigeria	Mr Sarumi	Director, NACGRB		nacgrab@skannet.com
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Puerto Rico	Alberto Beale	University of Puerto Rico		a_beale@upr.edu
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Annex 3. Pathogen tested clones conserved at the SPC CePACT (Note, Testing is on-going and the CePaCT should be requested for information on the PT-status of any accession)

A) TaroGen core collection

CePaCT ACC NO	COUNTRY ACC NO.	VARIETY	ORIGIN	Source
TR/CK/05	CIRA 06	Old Niue	Cooks	MAF,Cooks
TR/CK/07	CIRA 09	Puarenga	Cooks	MAF,Cooks
TR/CK/13	CIPUK 03	Mawolawola	Cooks	MAF,Cooks
TR/FJ11	KRS28	Dalo ni Jaina	Fiji	KRS,Fiji
TR/FJ18	KRS12	Qere (4)	Fiji	KRS,Fiji
TR/FJ28	KRS18	Cavuisa (Unbr)	Fiji	KRS,Fiji
TR/FJ30	KRS23	Tausala Dina	Fiji	KRS,Fiji
TR/FJ33	KRS70	Tausala	Fiji	KRS,Fiji
TR/FJ44	KRS34	Sikavi Loa	Fiji	KRS,Fiji
TR/FJ58	KRS35	Qawe ni Urau	Fiji	KRS,Fiji
TR/FJ63	KRS48	Uro ni Vonu	Fiji	KRS,Fiji
FSM/03	N/A	Toantal	FSM	USP,Samoa
TR/NC03	NC 12	N/A	N. Caledonia	MAF,NC
TR/NC06	NC 29	N/A	N. Caledonia	MAF,NC
TR/NC09	NC 49	N/A	N. Caledonia	MAF,NC
TR/NC11	NC 56	N/A	N. Caledonia	MAF,NC
TR/NC12	NC 102	N/A	N. Caledonia	MAF,NC
TR/NC15	NC 116	N/A	N. Caledonia	MAF,NC
TR/NC16	NC 117	N/A	N. Caledonia	MAF,NC
TR/NC17	NC 74	N/A	N. Caledonia	MAF,NC
TR/NC19	NC 99	N/A	N. Caledonia	MAF,NC
TR/NU/01	N/1	Fa Megemege	Niue	MAF.Niue
TR/NU/05	N/6	Maga Fa Tea	Niue	MAF.Niue
TR/NU/08	N/10	Toga Fa Tea	Niue	MAF.Niue
TR/NU/11	N/14	Maga Faikai Lanu	Niue	MAF.Niue
TR/NU/14	N/17	Poetu	Niue	MAF.Niue
TR/NU/23	N/30	Paku Lau Mame	Niue	MAF.Niue
PAL/04	P4	Homestead	Palau	USP,Samoa
PAL/06	P6	Kerdeu	Palau	USP,Samoa
PAL/19	P19	Ngetmadei	Palau	USP,Samoa
PAL/20	P20	Dirratengadik	Palau	USP,Samoa
TR/PNG/05	289	N/A	PNG	NARI-PNG
TR/PNG/07	297	N/A	PNG	NARI-PNG
TR/PNG/09	305	N/A	PNG	NARI-PNG
TR/PNG/12	309/7	N/A	PNG	NARI-PNG
TR/PNG/14	318/37	N/A	PNG	NARI-PNG
TR/PNG/15	319/41	N/A	PNG	NARI-PNG
TR/PNG/18	AA 05	N/A	PNG	NARI-PNG
TR/PNG/20	AA 07	N/A	PNG	NARI-PNG
TR/PNG/22	APOK 14	N/A	PNG	NARI-PNG
TR/PNG/23	BC 668	N/A	PNG	NARI-PNG
TR/PNG/26	BC 804	N/A	PNG	NARI-PNG
TR/PNG/27	BC 805	N/A	PNG	NARI-PNG
TR/PNG/29	GO 029	N/A	PNG	NARI-PNG
TR/PNG/30	KPOKP 22	N/A	PNG	NARI-PNG
TR/PNG/32	LN 002	N/A	PNG	NARI-PNG
TR/PNG/34	RG 02	N/A	PNG	NARI-PNG
TR/PNG/38	UP 03	N/A	PNG	NARI-PNG
TR/PNG/40	UP 09	N/A	PNG	NARI-PNG
TR/PNG/41	UP 10	N/A	PNG	NARI-PNG

TR/PNG/42	UP 11	N/A	PNG	NARI-PNG
TR/PNG/43	WJW 002	N/A	PNG	NARI-PNG
TR/PNG/44	WOKO	N/A	PNG	NARI-PNG
TR/PNG/46	284	N/A	PNG	NARI-PNG
TR/PNG/48	293	N/A	PNG	NARI-PNG
TR/PNG/50	304	N/A	PNG	NARI-PNG
TR/PNG/51	307	N/A	PNG	NARI-PNG
TR/PNG/52	308/1	N/A	PNG	NARI-PNG
TR/PNG/55	311/15	N/A	PNG	NARI-PNG
TR/PNG/59	316/26	N/A	PNG	NARI-PNG
TR/PNG/60	317/29	N/A	PNG	NARI-PNG
TR/PNG/61	317/32	N/A	PNG	NARI-PNG
TR/PNG/63	3I9/43 (1)	N/A	PNG	NARI-PNG
TR/PNG/67	APOK 02	N/A	PNG	NARI-PNG
TR/PNG/68	APOK 03	N/A	PNG	NARI-PNG
TR/PNG/70	APOK 06	N/A	PNG	NARI-PNG
TR/PNG/71	APOK 08	N/A	PNG	NARI-PNG
TR/PNG/73	APOK 15	N/A	PNG	NARI-PNG
TR/PNG/74	APOK 16	N/A	PNG	NARI-PNG
TR/PNG/75	APOK 18	N/A	PNG	NARI-PNG
TR/PNG/76	ARANGAO	N/A	PNG	NARI-PNG
TR/PNG/77	BC 653	N/A	PNG	NARI-PNG
TR/PNG/80	BC 661	N/A	PNG	NARI-PNG
TR/PNG/83	BC 701	N/A	PNG	NARI-PNG
TR/PNG/85	BC 719	N/A	PNG	NARI-PNG
TR/PNG/87	BC 728	N/A	PNG	NARI-PNG
TR/PNG/90	BC 797	N/A	PNG	NARI-PNG
TR/PNG/91	BC 806	N/A	PNG	NARI-PNG
TR/PNG/92	BC 814	N/A	PNG	NARI-PNG
TR/PNG/93	BC 819	N/A	PNG	NARI-PNG
TR/PNG/96	BC 843	N/A	PNG	NARI-PNG
TR/PNG/99	BC 866	N/A	PNG	NARI-PNG
TR/PNG/100	BC 871	N/A	PNG	NARI-PNG
TR/PNG/103	BC 896	N/A	PNG	NARI-PNG
TR/PNG/105	DPOK 06	N/A	PNG	NARI-PNG
TR/PNG/107	GGG 073	N/A	PNG	NARI-PNG
TR/PNG/109	GO 002	N/A	PNG	NARI-PNG
TR/PNG/111	GO 043	N/A	PNG	NARI-PNG
TR/PNG/113	KENDUNG	N/A	PNG	NARI-PNG
TR/PNG/114	KPO 07	N/A	PNG	NARI-PNG
TR/PNG/115	KPO 15	N/A	PNG	NARI-PNG
TR/PNG/116	KPO 22	N/A	PNG	NARI-PNG
TR/PNG/119	KPOKP 49	N/A	PNG	NARI-PNG
TR/PNG/121	MANANENG (1)	N/A	PNG	NARI-PNG
TR/PNG/123	MB 12	N/A	PNG	NARI-PNG
TR/PNG/125	MG 02	N/A	PNG	NARI-PNG
TR/PNG/128	ML 06	N/A	PNG	NARI-PNG
TR/PNG/130	MT 04	N/A	PNG	NARI-PNG
TR/PNG/133	OGG 006	N/A	PNG	NARI-PNG
TR/PNG/135	OGG 018	N/A	PNG	NARI-PNG
TR/PNG/137	OGG 033	N/A	PNG	NARI-PNG
TR/PNG/138	OGG 038	N/A	PNG	NARI-PNG
TR/PNG/139	OGG 042	N/A	PNG	NARI-PNG
TR/PNG/146	RK 09	N/A	PNG	NARI-PNG
TR/PNG/148	RS 05	N/A	PNG	NARI-PNG
TR/PNG/149	SIPILAWI	N/A	PNG	NARI-PNG
TR/PNG/150	SSYK 012	N/A	PNG	NARI-PNG

TR/PNG/151	SSYK 013	N/A	PNG	NARI-PNG
TR/PNG/152	SSYK 014	N/A	PNG	NARI-PNG
TR/PNG/153	SSYK 016	N/A	PNG	NARI-PNG
TR/PNG/158	WBD 010	N/A	PNG	NARI-PNG
TR/PNG/159	WEKU	N/A	PNG	NARI-PNG
TR/PNG/161	WJW 002 (11)	N/A	PNG	NARI-PNG
TR/PNG/163	WJW 005 (111)	N/A	PNG	NARI-PNG
TR/PNG/165	ZIKI (1)	N/A	PNG	NARI-PNG
S2	CHY 203/F20	N/A	S Islands	MAF,S Islands
S4	CHY 41/D18	N/A	S Islands	MAF,S Islands
S18	CHY 233/E40	N/A	S Islands	MAF,S Islands
S19	CHY 90/A20	N/A	S Islands	MAF,S Islands
S20	CHY 60/D37	N/A	S Islands	MAF,S Islands
S21	CHY 85/A15	N/A	S Islands	MAF,S Islands
S26	CHY 119/B25	N/A	S Islands	MAF,S Islands
S27	CHY 21	N/A	S Islands	MAF,S Islands
S30	CHY 183/C42	N/A	S Islands	MAF,S Islands
S35	CHY 127/B33	N/A	S Islands	MAF,S Islands
S38	CHY 212/E3	N/A	S Islands	MAF,S Islands
S43	CHY 193/F10	N/A	S Islands	MAF,S Islands
S44	CHY 22	N/A	S Islands	MAF,S Islands
S48	CHY 134/B40	N/A	S Islands	MAF,S Islands
S49	CHY 69/D46	N/A	S Islands	MAF,S Islands
S52	CHY 108/B15	N/A	S Islands	MAF,S Islands
S60	N/A	Tovla	S Islands	MAF,S Islands
S68	N/A	Naonan	S Islands	MAF,S Islands
S72	CHY 117/B23	N/A	S Islands	MAF,S Islands
S74	N/A	Malalta	S Islands	MAF,S Islands
S79	N/A	Menerlu	S Islands	MAF,S Islands
S83	N/A	Nepnau	S Islands	MAF,S Islands
S87	N/A	Morteula	S Islands	MAF,S Islands
S91	N/A	Niamatangi (white)	S Islands	MAF,S Islands
S93	N/A	Na'atapu (red)	S Islands	MAF,S Islands
S94	N/A	Namopla	S Islands	MAF,S Islands
S96	N/A	Lirpalirmtangi	S Islands	MAF,S Islands
S102	M123	Isikkome	S Islands	MAF,S Islands
S106	M140	Lahe Kabu	S Islands	MAF,S Islands
S112	M057	Asirini	S Islands	MAF,S Islands
S113	M075	Barakaiso	S Islands	MAF,S Islands
S120	M092	Alokini	S Islands	MAF,S Islands
S121	M050	Fui 2	S Islands	MAF,S Islands
S124	M055	Akomamale bulu (fem)	S Islands	MAF,S Islands
S125	M033	Lausina goa	S Islands	MAF,S Islands
S126	M076	Toto Abu	S Islands	MAF,S Islands
S132	M115	Kwakwao	S Islands	MAF,S Islands
S134	M066	Nge'e	S Islands	MAF,S Islands
S135	M043	Miditini	S Islands	MAF,S Islands
S136	M106	Fikakwana	S Islands	MAF,S Islands
S139	M060	Aiihu	S Islands	MAF,S Islands
S140	M054	Loosila	S Islands	MAF,S Islands
S142	M085	Iduano	S Islands	MAF,S Islands
S149	M001	Taliniu	S Islands	MAF,S Islands
TR/SAM/03	N/A	Magasiva	Samoa	USP,Samoa
TR/SAM/04	N/A	Manua	Samoa	USP,Samoa
TR/SAM/05	N/A	Niue	Samoa	USP,Samoa
TR/SAM/12	N/A	Sasauli	Samoa	USP,Samoa
TR/TN/01	TE 01	Lau'ila	Tonga	MAF.Tonga

TR/TN/03	TE 03	Manua	Tonga	MAF.Tonga
TR/TN/05	TE 05	Talo Kula	Tonga	MAF.Tonga
TR/VAN/01	VAN 021	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/03	VAN 025	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/04	VAN 032	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/06	VAN 055	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/07	VAN 057	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/08	VAN 089	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/16	VAN 180	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/19	VAN 225	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/22	VAN 240	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/23	VAN 244	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/24	VAN 250	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/25	VAN 254	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/26	VAN 257	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/27	VAN 268	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/28	VAN 275	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/32	VAN 307	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/34	VAN 330	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/38	VAN 365	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/39	VAN 376	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/43	VAN 433	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/45	VAN 471	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/49	VAN 42	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/50	VAN 44	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/60	VAN 113	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/63	VAN 142	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/68	VAN 202	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/71	VAN 210	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/73	VAN 218	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/76	VAN 276	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/77	VAN 285	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/79	VAN 309	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/81	VAN 322	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/85	VAN 375	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/87	VAN 391	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/88	VAN 395	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/91	VAN 459	N/A	Vanuatu	MAF.Vanuatu
TR/VAN/92	VAN 465	N/A	Vanuatu	MAF.Vanuatu

B) TANSAO core sample

CePaCT ACC NO	COUNTRY ACC. NO	VARIETY	ORIGIN	Source
TAN/IND/01	IND 010	N/A	Indonesia	RCB/IIS
TAN/IND/02	IND 054	N/A	Indonesia	Research Centre of Biotechnology(RCB)/Indonesia Institute of Science(IIS)
TAN/IND/03	IND 081	N/A	Indonesia	RCB/IIS
TAN/IND/04	IND 083	N/A	Indonesia	RCB/IIS
TAN/IND/05	IND 101	N/A	Indonesia	RCB/IIS
TAN/IND/06	IND 155	N/A	Indonesia	RCB/IIS
TAN/IND/07	IND 167	N/A	Indonesia	RCB/IIS
TAN/IND/08	IND 178	N/A	Indonesia	RCB/IIS
TAN/IND/09	IND 218	N/A	Indonesia	RCB/IIS
TAN/IND/10	IND 225	N/A	Indonesia	RCB/IIS
TAN/IND/11	IND 233	N/A	Indonesia	RCB/IIS
TAN/IND/12	IND 237	N/A	Indonesia	RCB/IIS

TAN/IND/13	IND 245	N/A	Indonesia	RCB/IIS
TAN/IND/14	IND 311	N/A	Indonesia	RCB/IIS
TAN/IND/15	IND 320	N/A	Indonesia	RCB/IIS
TAN/IND/16	IND 366	N/A	Indonesia	RCB/IIS
TAN/IND/17	IND 383	N/A	Indonesia	RCB/IIS
TAN/IND/18	IND 392	N/A	Indonesia	RCB/IIS
TAN/IND/19	IND 399	N/A	Indonesia	RCB/IIS
TAN/IND/20	IND 400	N/A	Indonesia	RCB/IIS
TAN/IND/21	IND 409	N/A	Indonesia	RCB/IIS
TAN/IND/22	IND 453	N/A	Indonesia	RCB/IIS
TAN/IND/23	IND 472	N/A	Indonesia	RCB/IIS
TAN/IND/24	IND 512	N/A	Indonesia	RCB/IIS
TAN/IND/25	IND 521	N/A	Indonesia	RCB/IIS
TAN/IND/26	IND 526	N/A	Indonesia	RCB/IIS
TAN/IND/27	IND 552	N/A	Indonesia	RCB/IIS
TAN/IND/28	IND 555	N/A	Indonesia	RCB/IIS
TAN/IND/29	IND 561	N/A	Indonesia	RCB/IIS
TAN/IND/30	IND 562	N/A	Indonesia	RCB/IIS
TAN/IND/31	IND 8M	N/A	Indonesia	RCB/IIS
TAN/IND/32	IND 231	N/A	Indonesia	NARI-PNG
TAN/IND/33	IND 257	N/A	Indonesia	NARI-PNG
TAN/IND/34	IND 270	N/A	Indonesia	NARI-PNG
TAN/IND/35	IND 328	N/A	Indonesia	NARI-PNG
TAN/IND/36	IND 452	N/A	Indonesia	NARI-PNG
TAN/IND/37	IND 497	N/A	Indonesia	NARI-PNG
TAN/IND/38	IND 518	N/A	Indonesia	NARI-PNG
TAN/IND/39	IND 562	N/A	Indonesia	USP Samoa rplmt
TAN/MAL/02	MAL 030	N/A	Malaysia	RCB/IIS
TAN/MAL/03	MAL 035	N/A	Malaysia	RCB/IIS
TAN/MAL/05	MAL 056	N/A	Malaysia	RCB/IIS
TAN/MAL/06	MAL 131	N/A	Malaysia	RCB/IIS
TAN/MAL/07	MAL 136	N/A	Malaysia	RCB/IIS
TAN/MAL/08	MAL 141	N/A	Malaysia	RCB/IIS
TAN/MAL/09	MAL 142	N/A	Malaysia	RCB/IIS
TAN/MAL/10	MAL 144	N/A	Malaysia	RCB/IIS
TAN/MAL/11	MAL 146	N/A	Malaysia	RCB/IIS
TAN/MAL/12	MAL 148	N/A	Malaysia	RCB/IIS
TAN/MAL/13	MAL 149	N/A	Malaysia	RCB/IIS
TAN/MAL/14	MAL 164	N/A	Malaysia	RCB/IIS
TAN/PHL/01	PH 023	N/A	Philippines	RCB/IIS
TAN/PHL/02	PH 038	N/A	Philippines	RCB/IIS
TAN/PHL/03	PH 039	N/A	Philippines	RCB/IIS
TAN/PHL/04	PH 049	N/A	Philippines	RCB/IIS
TAN/PHL/05	PH 055	N/A	Philippines	RCB/IIS
TAN/PHL/06	PH 057	N/A	Philippines	RCB/IIS
TAN/PHL/07	PH 063	N/A	Philippines	RCB/IIS
TAN/PHL/08	PH 067	N/A	Philippines	RCB/IIS
TAN/PHL/09	PH 070	N/A	Philippines	RCB/IIS
TAN/PHL/10	PH 074	N/A	Philippines	RCB/IIS
TAN/PHL/11	PH 103	N/A	Philippines	RCB/IIS
TAN/PHL/12	PH 121	N/A	Philippines	RCB/IIS
TAN/PHL/13	PH 123	N/A	Philippines	RCB/IIS
TAN/PHL/14	PH 157	N/A	Philippines	RCB/IIS
TAN/PHL/15	PH 164	N/A	Philippines	RCB/IIS
TAN/PHL/16	PH 14	N/A	Philippines	NARI-PNG
TAN/PHL/17	PH 86	N/A	Philippines	NARI-PNG
TAN/PNG/01	BC 790	N/A	PNG	NARI-PNG

TAN/PNG/02	BC 794	N/A	PNG	NARI-PNG
TAN/PNG/03	BC 818	N/A	PNG	NARI-PNG
TAN/PNG/04	BC 864	N/A	PNG	NARI-PNG
TAN/PNG/05	BC 843	N/A	PNG	NARI-PNG
TAN/PNG/06	BC 741	N/A	PNG	NARI-PNG
TAN/PNG/07	BC 792	N/A	PNG	NARI-PNG
TAN/PNG/08	BC 908	N/A	PNG	NARI-PNG
TAN/PNG/09	BC 791	N/A	PNG	NARI-PNG
TAN/PNG/10	BC 786	N/A	PNG	NARI-PNG
TAN/PNG/11	BC 776	N/A	PNG	NARI-PNG
TAN/PNG/12	BC 859	N/A	PNG	NARI-PNG
TAN/PNG/13	BC 802	N/A	PNG	NARI-PNG
TAN/PNG/14	BC 654	N/A	PNG	NARI-PNG
TAN/PNG/15	BC 772	N/A	PNG	NARI-PNG
TAN/PNG/16	BC 805	N/A	PNG	NARI-PNG
TAN/PNG/17	BC 781	N/A	PNG	NARI-PNG
TAN/PNG/18	BC 803	N/A	PNG	NARI-PNG
TAN/PNG/19	BC 804	N/A	PNG	NARI-PNG
TAN/PNG/20	BC 869	N/A	PNG	NARI-PNG
TAN/PNG/21	BC 826	N/A	PNG	NARI-PNG
TAN/PNG/22	BC 880	N/A	PNG	NARI-PNG
TAN/PNG/23	BC 880	N/A	PNG	USP Samoa rplmt
TAN/THA/01	THA 003	N/A	Thailand	RCB/IIS
TAN/THA/02	THA 004	N/A	Thailand	RCB/IIS
TAN/THA/03	THA 005	N/A	Thailand	RCB/IIS
TAN/THA/04	THA 008	N/A	Thailand	RCB/IIS
TAN/THA/05	THA 010	N/A	Thailand	RCB/IIS
TAN/THA/06	THA 012	N/A	Thailand	RCB/IIS
TAN/THA/07	THA 022	N/A	Thailand	RCB/IIS
TAN/THA/08	THA 030	N/A	Thailand	RCB/IIS
TAN/THA/09	THA 031	N/A	Thailand	RCB/IIS
TAN/THA/10	THA 032	N/A	Thailand	RCB/IIS
TAN/THA/11	THA 036	N/A	Thailand	RCB/IIS
TAN/THA/12	THA 039	N/A	Thailand	RCB/IIS
TAN/THA/13	THA 041	N/A	Thailand	RCB/IIS
TAN/THA/14	THA 047	N/A	Thailand	RCB/IIS
TAN/THA/15	THA 048	N/A	Thailand	RCB/IIS
TAN/THA/16	THA 055	N/A	Thailand	RCB/IIS
TAN/THA/17	THA 071	N/A	Thailand	RCB/IIS
TAN/THA/18	THA 091	N/A	Thailand	RCB/IIS
TAN/THA/19	THA 092	N/A	Thailand	RCB/IIS
TAN/THA/20	THA 101	N/A	Thailand	RCB/IIS
TAN/THA/21	THA 138	N/A	Thailand	RCB/IIS
TAN/THA/22	THA 144	N/A	Thailand	RCB/IIS
TAN/THA/24	THA 148	N/A	Thailand	RCB/IIS
TAN/THA/25	THA 156	N/A	Thailand	RCB/IIS
TAN/THA/26	THA 158	N/A	Thailand	RCB/IIS
TAN/THA/27	THA 160	N/A	Thailand	RCB/IIS
TAN/THA/28	THA 15	N/A	Thailand	NARI-PNG
TAN/THA/29	THA 98	N/A	Thailand	NARI-PNG
TAN/THA/30	THA108	N/A	Thailand	NARI-PNG
TAN/VEN/01	VN 044	N/A	Vietnam	RCB/IIS
TAN/VEN/02	VN 045	N/A	Vietnam	RCB/IIS

Annex 4. Abbreviations

ACIAR	Australian Centre for International Agriculture Research
AFLP	Amplified Fragment Length Polymorphism
AQIS	Australian Quarantine Inspection Service
AusAID	Australian Agency for International Development
BAPNET	Banana Asia Pacific network
Bioversity	Bioveristy International – previously the International Plant Genetic Resources Institute
BP	Before present
CGIAR	Consultative Group on International Agricultural Research
CIP	International Potato Center
CIRAD	Centre de cooperation internationale en recherche agronomique pour le développement
COGENT	International Coconut Genetic Resources Network
CePaCT	Centre for Pacific Crops and Trees, formely Regional Germplasm Centre (RGC)
CTCRI	Central Tuber Crops Research Institute
DNA	Deoxyribonucleic acid
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Database
FSM	Federated States of Micronesia
GRIN	Germplasm Resources Information Network
GxE	Genotype x environment
ICAR	Indian Council for Agriculture Research
IITA	International Institute of Tropical Agriculture
INGER	International Network for Genetic Evaluation of Rice
INIBAP	International Network for Improvement of Banana and Plantain
INIVIT	Instituto Nacional de Investigaciones de Viandas Tropicales
ISSR	Intersimple sequence repeat
ITPGRFA	International Treaty for Plant Genetic Resources for Food and Agriculture
LIPI	Indonesian Institute of Sciences
MTA	Material transfer agreement
NARES	National agriculture research and extension service
NARI	National Agriculture Research Institute
NBPGR	National Bureau of Plant Genetic Resources
NGO	Non-government organisation
NPGRL	National Plant Genetic Resources Laboratory
PAPGREN	Pacific Plant Genetic Resources Network
PGR	Plant Genetic Resources
PGRC	Plant Genetic Resources Centre
PNG	Papua New Guinea
PPS	Participatory plant selection
PR China	People's Republic of China
QLT	Quantitative trait loci
QUT	Queensland University of Technology
RAPD	Random Amplification of Polymorphic DNA
RECSEA	Regional Co-operation in Southeast Asia for Plant Genetic Resources
RGC	Regional Germplasm Centre
SANPGR	South Asia Network on Plant Genetic Resources
SINGER	System-wide Information Network for Genetic Resources
SMTA	Standard Material Transfer Agreement
SPC	Secretariat of the Pacific Community
SSEEA	South, SouthEast and East Asia
SSR	Simple sequence repeat
TANSAO	Taro Network for Southeast Asia and Oceania
TaroGEN	Taro Genetic Resources Network
Trust	Global Crop Diversity Trust
USA	United States of America
USDA	United States Department of Agriculture
USP	University of the South Pacific
VARTC	Vanuatu Agricultural Research and Technical Center
WIEWS	World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture