REGIONAL STRATEGY FOR THE *EX SITU* CONSERVATION AND USE OF CROP GENETIC DIVERSITY IN THE PACIFIC ISLANDS REGION

The GLOBAL CROP DIVERSITY TRUST
A FOUNDATION FOR FOOD SECURITY

1. Strategy overview, background and development process

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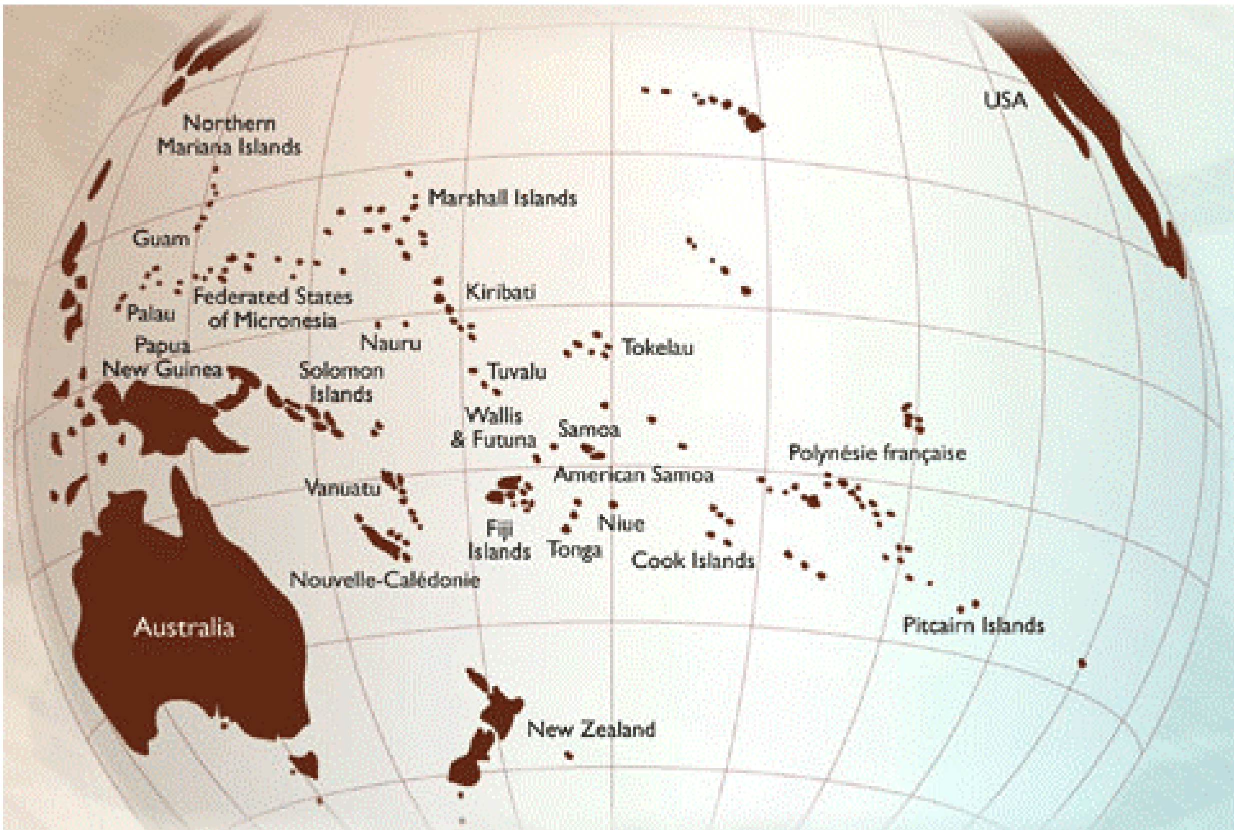
Countries	Pacific Island Countries and Territories (PICTs) American Samoa, Cook Islands, Federated States of Micronesia (FSM), Fiji Islands, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Commonwealth of the Northern Mariana Islands (CNMI), Palau, Papua New Guinea (PNG), Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis & Futuna.
Annex 1 crops	Aroids (taro and giant swamp taro), banana, breadfruit, coconut, sweet potato, yams



The 22 Pacific Islands Countries and Territories are made up of thousands of islands scattered over some 33 million sq km of ocean, a third of the Earth's surface. Only 2% of this area is land, of course, but this is home to about 8 million people, speaking 50% of the world's languages, over 800 in PNG alone. Most of these people live in rural areas and rely on agriculture, together with fishing and forest products, for their livelihoods. The Pacific is a centre of diversity and/or origin for a small cumber of crops, but in general, due to its history of human colonization, crop genetic diversity in the mostly vegetatively propagated crops of the region declines markedly from west to east.

This diversity – already limited in many cases – is under threat. As rural people move to cities and adopt modern lifestyles, they change their eating habits, forget their traditional foods and their crop varieties, no longer value them, and often abandon them. Outbreaks of new pests and diseases, made more likely by easier travel, and increasing drought and soil salinity, which are expected to increase in many places due to climate change, can wreak havoc with crops which do not include resistant varieties. A dramatic example of this is what happened with taro leaf blight in Samoa in the early 1990s. The introduction of modern crop varieties, and of new cash crops, often means that farmers are happy to get rid of traditional local ones – until, that is, they succumb to diseases, or prove too expensive or environmentally unsound to maintain. All these processes are causing the disappearance of local cultivars of traditional crops. And the loss of this biodiversity is leading to deteriorating health and nutrition, to a lessening of income generating opportunities and an inexorable narrowing of future options. All this in a region of mainly very small countries where human capacity in the field is limited.

Pacific Ministers of Agriculture therefore resolved at a meeting of the Secretariat of the Pacific Community (SPC) in 1996 to put in place, both in their countries and through regional cooperation, policies and programmes to conserve, protect and use their plant genetic resources effectively and efficiently for development. SPC is a regional technical advisory, training and research organization with a vision for a "prosperous Pacific Community whose people are healthy and manage their resources in an economically and environmentally sustainable way." Its Land Resources Division (LRD), based in Suva, Fiji, has the objectives to improve nutritional security and health, and incomes, through sustainable management of forestry and agriculture systems and improved biosecurity and trade facilitation.

The Regional Germplasm Centre (RGC) has been the key component of SPC's response to this recommendation since September 1998, though its origin can be traced back to the SPC Plant Protection Service's Tissue Culture Laboratory, which multiplied and distributed disease-free planting materials starting in the 1980s. Funding for the establishment of the RGC has come from the Australian government through the Australian Agency for International Development (AusAID) and the Australian Centre for International Agricultural Research (ACIAR), and from the European Union (EU) through the Pacific Regional Agricultural Programme (PRAP). IPGRI has provided technical support from the beginning.

The aim of the RGC is to assist Pacific Island Countries and Territories (PICTs) to conserve the region's genetic resources, and to provide access to the germplasm they need. The Centre is using *in vitro* techniques for conservation, and priority is given to taro, yam, sweet potato and banana, but other crops, such as cassava, kava, breadfruit, aibika (*Abelmoschus manihot*) and black pepper are also receiving attention. The RGC was a key partner in the Taro Genetic Resources Conservation & Utilization (TaroGen), the Taro Network for Southeast Asia and Oceania (TANSAO) and the South Pacific Yam Network (SPYN) projects, and currently collaborates with IPGRI's global crop networks, such as the International Network for Improvement of Banana and Plantain (INIBAP) and the Coconut Genetic Resources Network (COGENT). It is also collaborating with other international agricultural research centres (IARCs), in particular the Centro Internacional de Agricultural Tropical (CIAT), the International Potato Centre (CIP) and the International Institute of Tropical Agriculture (IITA), to make improved germplasm of their mandate crops (cassava ,sweet potato and yams, respectively) available in the Pacific.

The response of SPC to the 1996 ministerial decision has not stopped at the RGC. In October 2000, the PNG-NARI Principal Scientist for PGR, Rosa Kambuou, the senior agronomist of Fiji's MASLR, Aliki Turagakula, and the SPC's RGC Adviser, Dr Mary Taylor, proposed a *Framework for Plant Genetic Resources Conservation, Management and Use in the Pacific*. This document was presented to Directors of Agriculture in May 2001. The directors recommended that a Pacific Agricultural Plant Genetic Resource Network (PAPGREN) be established. PAPGREN was launched at a workshop in September 2001, organized by LRD in collaboration with IPGRI with funding from NZAID. This resulted in a regional PGR Action Plan. The overall objectives of PAPGREN are to strengthen national PGR programmes and collaboration among them, so as to use scarce resources – human, financial and genetic – more effectively to solve common problems. A PGR Adviser was recruited at SPC under a complementary IPGRI project supported by ACIAR funding, to work closely with the RGC. The Adviser started work in June 2002, with the task of getting the network off the ground. NZAID agreed to provide support for the initial three years of network activities.

The following activities have been carried out under the umbrella of PAPGREN, with technical backstopping from IPGRI:

- PGR stakeholder consultations have been held in several countries.
- A policy options paper for decision-makers and researchers has been published[1] and policy training workshops held.
- Existing germplasm collections have been documented in a regional genebank directory[2].
- Priority conservation activities have been identified and are being supported in various countries.
- Regional conservation strategies have been developed for breadfruit and taro, the latter during the TaroGen project and a major international event, the 3rd international Taro Symposium, and for PGR education and capacity building in the Pacific.
- Regular regional meetings of national PAPGREN focal points (and NGO representatives) have been held.
- Proposals have been developed for specific priority PGR conservation activities at both national and regional levels, and significant complementary resources are being mobilized to implement them.
- Countries have been kept informed on the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), and a session on the ITPGRFA was organized at the meetings of agriculture ministers and of heads of agriculture and forestry held by SPC in September 2004.
- A number of communication and awareness materials have been prepared (pamphlet, poster, website, weblog[3], email newsletter), and the network has been represented in various regional and international fora.

In 2002 SPC prepared the strategy paper *Plant Genetic Resources for Food and Agriculture in the Pacific: The Way Forward for SPC*, which then provided an input into the development of the new Strategic Plan for the Land Resources Division in 2004. The LRD Strategic Plan established a Genetic Resources Team within LRD and recognized that conservation and use of PGRFA provides the foundation for SPC's support of agricultural development in the Pacific[4].

Development of this Regional Strategy thus falls squarely within the mandates of PAPGREN and LRD. Note in particular past work on a regional genebank inventory and on the development of regional strategies for taro and breadfruit. Also, SPC staff have been

[1] http://www.spc.int/pgr/Documents/Intellectual%20PR/Policy%20Issues%20Relating%20to%20PGR%20in%20the%20Pacific.pdf
[2] http://www.spc.int/pgr/Documents/Databases/Germplasm%20Directory.pdf
[3] http://papgren.blogspot.com
[4] **Objective 1 of the LRD Strategic Plan is "Sustainable management of integrated forest and agricultural systems." One of three outputs under this objective is "Biodiversity and genetic resources conserved, developed and promoted."**

involved in supervising an MSc thesis at USP which developed a conservation/use strategy for the regionally important aroid, giant swamp taro (*Cyrtosperma*). The basic elements of this Regional Strategy were discussed and agreed at the annual meeting of PAPGREN in October 2004, in which IPGRI staff also participated and gave a briefing on the Global Crop Diversity Trust (hereinafter GCDT or "the Trust"). A first draft was then put together by the Genetic Resources Team of LRD (again with input from IPGRI) and submitted to the Trust.

In parallel to these technical developments, there has also been discussion at the decision- and policy-making level. In late 2004, LRD organized and hosted the first joint meeting of Ministers and Heads of Agriculture and Forestry Systems (HOAFS). The following is a relevant excerpt from the Ministerial communiqué:

> Ministers and Representatives Acknowledged that access to genetic resources (crop, tree and animal) is necessary to ensure food security in the long-term. Broadening the genetic base of crops, trees and livestock, genetic improvement and diversification are crucial in coping with rapid change. Regional initiatives such as NARI's PARCIP[5] should be supported. Access to and utilization of genetic resources will be enhanced through active participation in PGR networks, both at the regional level (PAPGREN) and at the international level (COGENT and BAPNET). To ensure continued access to genetic resources the countries of the region should consider endorsing the RGC MTA, ratifying the International Treaty, signing the Establishment Agreement for the Global Crop Diversity Trust.

Following up on this, the Heads made the following recommendation:

> HOAFS agreed that PICTs need sustained and ready access to plant genetic resources from both within the region and other parts of the world, and to actively use these PGR to broaden and improve the genetic base of their food production, and thus be in a position to react to the challenges facing their agriculture. The ITPGRFA can be instrumental in facilitating access to PGR for food and agriculture, and also in obtaining financial support for national and regional efforts in PGR sustainable conservation, management and use through the Global Crop Diversity Trust.
>
> The Pacific needs to have a voice on the Governing Body (which will meet in mid-2005), in order for its specific needs and requirements and concerns to be taken into account as the details of implementation are negotiated. This will require the early ratification of the ITGRFA. PICTs which still have questions and need clarification of specific issues relating to the ITPGRFA can contact SPC for further information. In particular, HOAFS recommends:
>
> 1. That SPC-LRD develop a two page briefing paper on the ITPGRFA.
> 2. That SPC-LRD, in collaboration with PICTs through PAPGREN, develop a regional strategy for sustainable conservation and use of PGR for submission to the Global Crop Diversity Trust.
> 3. That SPC-LRD ensure that the RGC is provided adequate funding to deliver an effective supply of pathogen-tested germplasm to the PICTs.

At the moment, the Cook Islands and Kiribati have ratified the ITPGRFA, the Marshall Islands have signed but have not yet ratified. Papua New Guinea, Samoa and Vanuatu are close to ratification. Both SPC-LRD and the FAO Regional Office in Samoa are following up on this process actively. Draft cabinet submissions prepared with Gerald Moore have been sent to all the Heads of Agriculture. SPC has participated in the SMTA discussions. Kiribati and Samoa have participated in the recent ITPGRFA meeting in Rome on financial mechanisms. Samoa has signed the Establishment Agreement of the Trust.

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[5] This is discussed further below and in the Appendix.

Following these developments, and in reaction to input from GCDT[6] and IPGRI staff, the draft Regional Strategy was again discussed and further refined at the PAPGREN meeting in late 2005, in particular with regard to crop priorities. The result is presented in this document. This meeting also served to update participants (largely technical people) on the SMTA negotiations.

What are the next steps? An update on the ITPGRFA and GCDT will be presented to policy- and decision-makers at the next HOAFS, in September 2006 (there will also be a position paper on coconut development in the Pacific which will include discussion of genetic resources issues in general and the Trust strategy in particular). In addition, there will be an opportunity to discuss these issues, including this Regional Strategy, in more depth at a workshop on PGR policy issues being organized by the Australian Department of Agriculture, Fisheries and Forestry (DAFF) and SPC-LRD in late May 2006. A proposal has been submitted to CTA for support of a workshop on breadfruit development which would include discussion of a global crop conservation/use strategy. SPC-LRD staff are involved with both INIBAP/BAPNET and COGENT in the development of global crops strategies for bananas and coconut respectively. SPC may also lead the development of crop strategies for taro and breadfruit in the future.

2. Objectives

1. To conserve existing diversity of priority regional crops *ex situ* safely and sustainably.
2. To make regional diversity available to farmers, development workers and scientists for direct use, enhancement and improvement.
3. To study genetic diversity in regional genepools.

3. Outputs expected

1	• Regional PGRFA conserved *ex situ* on a long-term, sustainable basis, with adequate safety duplication • Agreed genebank management standards in place at national and regional levels
2	• Germplasm distributed to farmers and other users quickly, safely and efficiently • Germplasm improved and made available to farmers and other users • Germplasm with desirable traits identified and made available to breeders and other users • Germplasm enhancement and improvement undertaken using both local and exotic germplasm
3	• DNA fingerprinting capacity within the region strengthened • Genetic diversity of national and regional collections quantified • “Core” collections identified and conserved for selected crops (sweet potato, breadfruit, yam, banana)

6 We would also like to acknowledge with thanks that the Trust also supported the participation of Dr Mary Taylor at a planning meeting in Rome in 2004 and a visit to PGR regional network meetings in Southern and Eastern Africa by Luigi Guarino in 2005. These experiences were all very useful in developing this Regional Strategy.

4. Crops of greatest importance

A prioritization exercise on the Annex 1[7] crops resulted in the following table (1=high priority; 2=medium priority; 3=low priority; 4=not a priority). The main criteria for priority, roughly in order of importance, were: role in food/nutritional security (especially if throughout the region or specifically 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).

Crop (in alphabetical order within priority classes)	**Overall regional priority**
Aroids	1
Banana / Plantain	1
Breadfruit	1
Coconut	1
Sweet potato	1
Yams	1
Cassava	2
Citrus	3
Cowpea	3
Eggplant	3
Rice[8]	3

Compare this with FAO data on area harvested (ha):

	Year	
	1981	**2001**
Coconut	506,575	573,848
Sweet potato	101,569	109,468
Banana	48,193	59,070
Taro	42,216	43,480
Yams	15,839	17,507
Cassava	15,023	15,374
Rice, Paddy	12,418	8,050
Plantain	1,650	305

[7] **Note on non-Annex 1 crops:** Although all the most important staple crops of the Pacific are included in Annex 1, the PAPGREN meeting in 2005 suggested that this Regional Strategy also mention for future reference, if only in passing, the following non-Annex 1 crops of regional importance: kava, aibika/bele (*Abelmoschus manihot*), pandanus, pitpit/duruka (*Saccharum edule*), sugarcane, various exotic but naturalized vegetables, sago palm, betel nut and *Barringtonia* and *Canarium* nuts.

[8] Rice was discussed at the 2005 PAPGREN meeting, but it was decided not to include it in the strategy in the end. On the one hand, it is an important staple in many Pacific countries. Although this is mostly as an imported foodstuff, rice is grown on a significant scale in a couple of countries in the region, and rice development projects are underway in others, often supported by China or Taiwan. NARI has a breeding programme in PNG. There are various wild relatives of the crop in the region, particularly in PNG. On the other hand, crop diversity is very limited and there is only one, small collection of any significance (in Fiji).

Breaking down the higher priority crops by country and species (where appropriate) gives the following table:

	Pohnpei	Tonga	Cook Is.	Fiji	Kiribati	New Cal.	Vanuatu	PNG	Samoa
Banana	1	1	1	3	1	1	1	1	2
Breadfruit	1	1	1	2	1	3	1	2	1
Cassava	2	2	1	2	3	2	1	1	2
Coconut	1	2	2	1	1	1	1	1	1
Sweet potato	1	2	1	2	2	1	1	1	3
Aroids									
Colocasia	1	1	1	1	4	1	1	1	1
Cyrtosperma	1	1	2		1			2	
Xanthosoma	2	1	2				2	2	
Alocasia	4	2	4				2	2	
Amorphophallus		1							
Yams									
Dioscorea	1	1	2	2	3	1	1	1	2
D. alata	1	1					1	1	
D. esculenta		1					1	1	
D. nummularia	1						1	1	
D. bulbifera									
D. pentaphylla									

In summary:

Crop	Countries	Importance factors
Taro	All countries	Food/nutritional security: High importance throughout region
		Diversity: Primary centre, unique diversity (separate genepool to SE Asia); being replaced in some countries by sweet potato, threatened also by taro leaf blight and viral disease (in Papua New Guinea, Solomon Islands)
		Income generation: Important cash crop in some places, export crop in some countries
		Cultural value: High
Giant swamp taro (*Cyrtosperma chamissionis*)	Atolls (Kiribati, Tuvalu, Tokelau, parts of other countries)	Food/nutritional security: High importance in atoll countries
		Diversity: Primary centre (Micronesia, atolls)
		Cultural value: High in Micronesia
Sweet potato *(Ipomoea batatas)*	PNG, Vanuatu, Solomon Islands, Tonga	Food/nutritional security: High importance, especially in Melanesian countries
		Diversity: Secondary centre (PNG)
		Income generation: Important cash crop in PNG
Yams (*Dioscorea* spp)	All countries	Food/nutritional security: Medium, some very important as famine foods and after disasters
		Diversity: Primary/secondary centres; at risk from introduction of African yams
		Cultural value: High, especially in Melanesia
Breadfruit	All countries	Food/nutritional security: High

(*Artocarpus* spp)		Diversity: Primary centre
		Cultural value: High
Coconut	All countries	Food/nutritional security: High importance throughout region
		Diversity: Primary centre; at risk from felling of senile plantations
		Income generation: Most important cash crop in many places; most important export crop in some countries; possible role in import substitution (e.g. biofuel)
		Cultural value: High
Banana	All countries	Food/nutritional security: High importance throughout region
		Diversity: Primary centre, origin in PNG; unique diversity elsewhere (e.g. fe'i types)
		Income generation: Important cash crop in some places, export crop in some countries
Alocasia	Some countries	Food/nutritional security: Disaster food in some countries
		Diversity: wild in PNG, cyclone proof, tolerant to taro leaf blight, few varieties
Cassava	All countries	Food/nutritional security: Medium to high importance throughout region
		Diversity: Some evidence of unique material (e.g. triploid in Vanuatu)
		Income generation: Important cash crop in some places, export crop in some countries

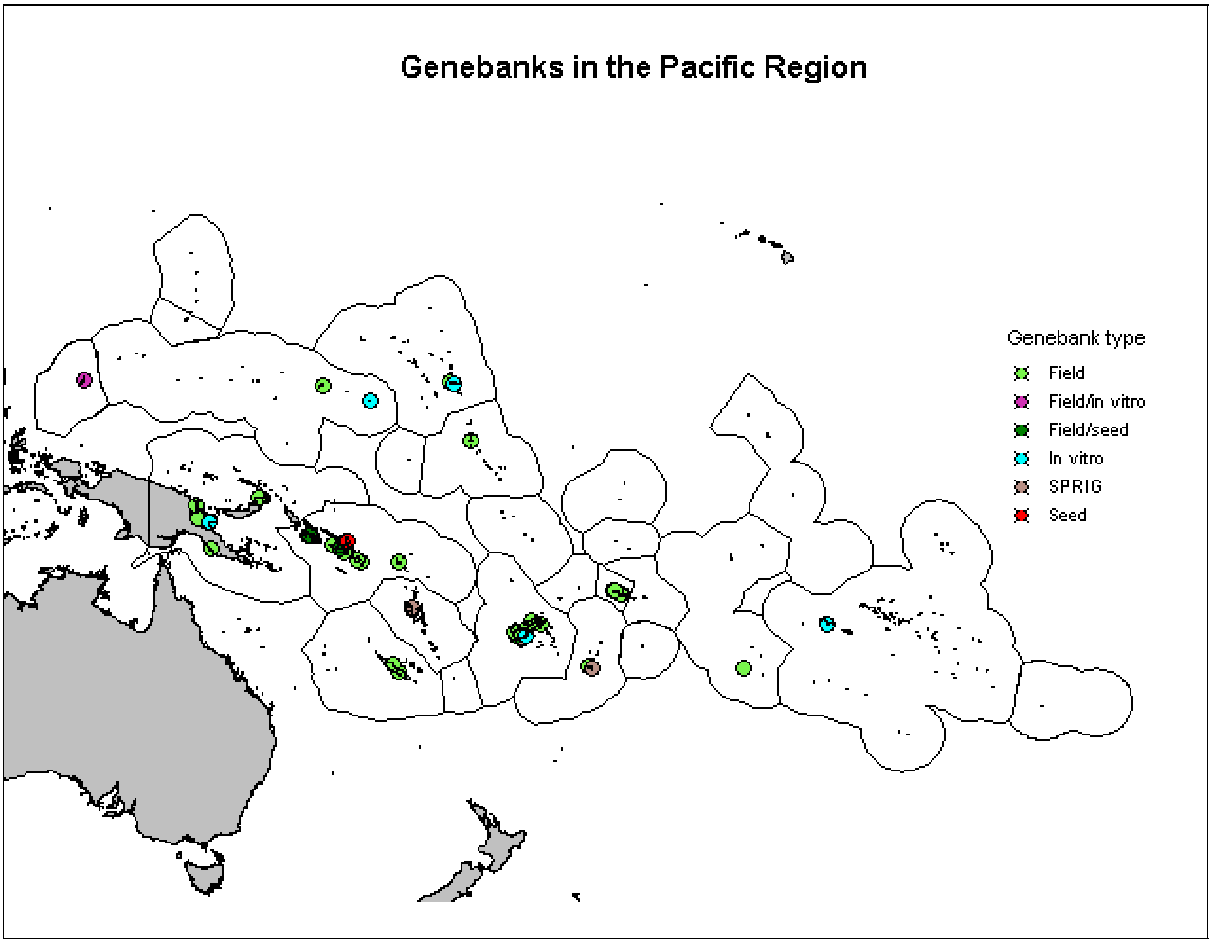
5. Collections of greatest importance and highest priority for support

The Directory of Plant Genetic Resources Collections in the Pacific Island Countries and Territories, put together by PAPGREN and published by SPC, provides the following information on collections of Annex 1 crops (key collections are highlighted; for more information on the location of genebanks, visit Pacific Mapper[9]):

			Bananas	Breadfruit	Cassava	Coconut	Cocoyam	Giant swamp taro	Sweet potato	Taro	Yams
Totokoitu Research Station	Cook Islands	Field	19		7	6	4			23	
Micronesia Plant Propagation Centre	FSM	*In vitro*	30							23	
Pohnlangas Pilot Farm	FSM	Field	38	6	8			20		11	10
College of Micronesia	FSM	*In vitro*	10								
Koronivia Research Station	Fiji	Field			27		2		30	112	128
Taveuni Coconut Centre	Fiji	Field				14					
Sigatoka Research Station	Fiji	Field		15							
Naduruloulou Research Station	Fiji	Field		5							
Wainigata Research Station	Fiji	Field				14					
Seaqaqa Research Station	Fiji	Field									128
Dobuilevu Research Station	Fiji	Field							30		128
Hiva Oa	French Polynesia	Field	16								
Central Nursery, Bikenibeu	Kiribati	Field		8		7					
Division of Agriculture HQ, Tanaea	Kiribati		8							4	
Arrak Agricultural Research Station	RMI	Field	10	6							
College of the Marshall Islands	RMI	*In vitro*	7						15	24	
Station de Recherches Fruitières de Pocquereux	New Caledonia	Field	71	5							
Centre des tubercules tropicaux	New Caledonia	Field			25				17	80	150
Palau Community College R&D Station	Palau	Field			50				22	98	
NARI-Aiyura	PNG	Field	26		34				1311		
NARI-Keravat	PNG	Field									
NARI-Laloki	PNG	Field	235		77				16	19	348
NARI-Bubia	PNG	Field	37		29				22	859	
UNITECH	PNG	Field							50		
CCI	PNG	Field				49					
CCI	PNG	*In vitro*				22					
Atele Research Station	Samoa	Field		13							
Nu'u Research Station	Samoa	Field	21							9	3
Nu'u Research Station	Samoa	*In vitro*	41				1			123	
Olomanu Research Station	Samoa	Field				13					
Fote Field Experiment Station	Solomon Islands	Field		16							
Dala Field Experiment Station	Solomon Islands	Field									300?
Tenaru Field Experiment Station	Solomon Islands	Field		13							
Newi Field Experiment Station	Solomon Islands	Field		13							
Russell Islands Plantation Estate	Solomon Islands	Field				17					
Kasdom Gaden Association, Burns Creek	Solomon Islands	Field	8								
PMN Vanga Seed Centre	Solomon Islands	Field							2		
PMN Seed Centre, Manivovo Rural Training Centre	Solomon Islands	Field	100								
Makira Highlands Banana Collection, Central Bauro	Solomon Islands	Field	30								
Vaini Research Division	Tonga	Field									
VARTC	Vanuatu	Field			26	60	8		52	260	300?
SPC-RGS, Suva, Fiji	Regional	*In vitro*	14		28	8			123	727	139

[9] http://www.diva-gis.org/gmaps/pacific.htm

USP, Alafua	Regional	*In vitro*								172	
USP, Alafua	Regional	Field								79	



Using the above as a starting point, the 2004 and 2005 PAPGREN meetings agreed the following list of priority collections:

Crop	Holder	Priority and reason	Accession-level passport data available?
Taro	Regional Germplasm Centre (RGC), Secretariat of the Pacific Community (SPC), Suva, Fiji	**1st priority** • One of the largest *in vitro* taro collections in the world (ca. 758 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	Yes (for most countries)

Crop	Holder	Priority and reason	Accession-level passport data available?
	National Agriculture Research Institute (NARI), Papua New Guinea (PNG)	• 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
Sweet potato	NARI, PNG	**2nd priority** • Two major collections: highlands (1311 accessions) and lowlands (108 accessions), both maintained in the field; most of the lowland accessions are also maintained in vitro by NARI (Keravat) and by RGC • PNG recognized as an important secondary centre of diversity • DNA fingerprinting carried out by CIP (on the small number of PNG varieties) shows marked differences between PNG and S. American germplasm • Size of collections affecting maintenance (some losses have occurred) • Collections require rationalization (and identification of core)	Partly
Yams	• NARI, PNG • Vanuatu Agricultural Research and Training Centre, Vanuatu	**3rd priority** • Largest (field) collections in region (PNG 348, Vanuatu ca. 300) • Melanesia considered major centre of yam diversity, origin • Collections at risk because of size and limited resources at national level • Collections require rationalization, safety duplication, identification of core	No
	RGC, Fiji	• Holds regional *D. alata* core identified on the basis of selected characteristics (98 accessions) • Holds threatened varieties (20) from Pohnpei (because at risk from anthracnose disease in Pohnpei)	Yes

Crop	Holder	Priority and reason	Accession-level passport data available?
Breadfruit	National Tropical Botanic Garden (NTBG), Maui, Hawaii	• Unique collection (field): largest and most extensive global collection of breadfruit (200 accessions of which 120 from the Pacific) • Some characterization and ethnobotanical research completed • Duplication (including *in vitro*) and utilization (by countries) of collection required • Selection of 20 elite varieties carried out	Yes
	VARTC, Vanuatu	• Well characterized national collection • Material lacking at NTBG	Yes
Giant swamp taro	Agriculture Pohnpei	• Only collection (23 accessions) • Duplication of collection required (*in vitro*)	Yes
Banana	• NARI, PNG • Crops Division, Ministry of Agriculture and Fisheries, Samoa • Kastom Gaden Association, Solomon Islands • Agriculture Pohnpei • Institut Agronomique néo-Calédonien, Station de Recherches Fruitières de Pocquereux, New Caledonia	• Largest collections in region (PNG 235, Samoa 21, Solomon Islands 138, Agriculture Pohnpei 38, New Caledonia 80) • Collections cover range of diversity in region, some of it unique to Pacific (fe'i types and Maia maoli and Popoulou sub-groups) • Require characterization and documentation, development of regional core • Some accessions show to be important nutritionally • Maintained on limited resources (losses occurring)	Partly
Coconut	• PNG Cocoa and Coconut Institute, Stewart Research Station, Madang, PNG • VARTC, Vanuatu • Ex Yandina Research Station, Solomon Islands	• PNG hosts the International Coconut Genebank – South Pacific • Vanuatu hosts an important regional collection and variety trials but exchange is currently not possible due to foliar disease • The status of the collection in the Solomon Islands is uncertain and needs to be verified	Yes

Crop	Holder	Priority and reason	Accession-level passport data available?
Cassava	NARI, PNG	• Largest collection in region (77) • Well characterized • Needs to be evaluated for nutritional and industrial characters	Yes
Alocasia	• VARTC, Vanuatu	• Only significant collection (10 accessions)	Yes

6. Collaboration for effective and efficient conservation in the region

a. Coordination of PGRFA activities.

Germplasm conservation and use activities in the Pacific are coordinated by PAPGREN – the Pacific Agricultural PGR Network. PAPGREN brought together representatives of Pacific national programmes in October 2004 to start developing this regional strategy and map out the process. PAPGREN has agreed that SPC will take the lead in developing the regional strategy. The PAPGREN coordinator is SPC's PGR Adviser, who is a member of the SPC Genetic Resources Team, which also includes the RGC Adviser. IPGRI provides technical backstopping to PAPGREN and channels financial support from ACIAR and NZAID.

b. Main partners in the Pacific able to play a regional role in PGRFA conservation/use

- The **SPC Regional Germplasm Centre** will be responsible for maintaining collections of taro, sweet potato, yam, banana, breadfruit, and cassava *in vitro*. These will be "core" collections under normal or slow growth storage and some non-core collections under cryopreservation, namely taro. The RGC will also be responsible for carrying out research on Pacific crops, within the limits of its capacity. Because of virus concerns, the RGC will have major responsibility for regional distribution (all distributed germplasm must be virus-indexed), facilitating evaluation, collating evaluation information and feeding back evaluation information to countries. The RGC will be the focal point for importing germplasm into the region.
- The **SPC Plant Health Team** provides expertise in plant pathology and virology. The SPC Virologist provides technical support, when necessary, to RGC staff in virus indexing. There is capacity to use ELISA within the SPC Plant Health section.
- The **Developing Sustainable Agriculture in the Pacific (DSAP)** project, funded by the EU and implemented by SPC-LRD, has staff based in the extension services of most PICTs and is undertaking PGR activities such as variety evaluation. DSAP provides an excellent mechanism for determining countries' germplasm needs through its national steering committees.
- **University of the South Pacific (USP)**, Suva, Fiji. SPC shares a facility with USP's **Institute of Applied Science (IAS)** where virus indexing of germplasm (using PCR) and some DNA fingerprinting can be carried out. There is as yet no capacity to develop technology, but the facility and recent training of staff in Fiji (mainly RGC staff) enables technologies to be transferred from institutes outside of the region and used on Pacific collections. IAS also has a worldwide reputation in carrying out chemical analyses, e.g. nutrient composition of foods.
- USP plays a role in the regional strategy in human resources development, e.g. the PGR and RGC Advisers contribute to a postgraduate course in "Biodiversity and Conservation" at the **School of Biology**. There are plans to develop PGR distance learning courses in collaboration with USP.
- The taro collection maintained at SPC RGC is duplicated at the USP **School of Agriculture**, Alafua, Samoa. Any crops held by the RGC and not duplicated elsewhere, such as in an IARC, will be duplicated at Alafua. This is also the location for the taro improvement programme (TIP), a participatory breeding programme which has released five generations of taro tolerant/resistant to taro leaf blight. Cycle 5 breeding lines are crosses between Pacific and Asian taro. Alafua also provides human resources development through their undergraduate courses.
- The **Secretariat of the Pacific Regional Environment Programme (SPREP)** is leading regional efforts in developing ABS regimes under the CBD.
- The **Pacific Island Forum Secretariat** has a regional mandate for developing policies on trade issues, including IPRs.
- **NARI, PNG.** PNG is the source of much genetic diversity for the region's major crops. It maintains large collections of taro, yams, sweet potato and banana. NARI implements an active breeding programme in taro and could also lead in evaluation through the availability of research stations in different ecologies. The potential

regional role of NARI in PGR research and training is highlighted by the proposal for a Pacific Regional Crop Improvement Programme (PARCIP)[10].

- The **University of Technology (Unitech**), Lae, PNG is developing a virus indexing and molecular marker lab. This will complement the conservation work being carried out by NARI, and also support similar work taking place at USP IAS Suva. Unitech also have a role to play in human resources development.
- The **University of Vudal**, PNG is developing expertise in seed storage work through its current research on taro seed storage. Vudal also is a significant provider of human resources development in agriculture in the region.
- The **University of New Caledonia** has research expertise in biotechnology, including tissue culture.
- The **Vanuatu Agricultural Research and Training Centre (VARTC)**, Vanuatu maintains important collections of crops, breadfruit and coconut. There is significant expertise within VARTC in breeding, mainly with taro, sweet potato, yams and coconut. VARTC could provide training in this area.
- The recently inaugurated **Vanuatu Agricultural College** has the potential for playing a significant regional role in human resources development.
- The **Island Food Community of Pohnpei**, NGO, has expertise in nutritional analyses of traditional foods, and documentation of traditional cultivars.
- Other NGOs, **Kasdom Gaden Association** and the **Melanesian Farmers First Network**, based in Solomon Islands, have considerable experience in sustainable agriculture, and have been involved in various PGR activities, including both *ex situ* and on-farm conservation.
- **PestNet** is a virtual community and network of people interested in plant protection in the Pacific. It could provide both advice on specific pest/disease problems and also a model for information exchange.

In summary:

Organization	Role in Regional Strategy
SPC Regional Germplasm Centre	• Conservation • Research • Germplasm exchange • Information
SPC Plant Health Team	• Virus indexing
Developing Sustainable Agriculture in the Pacific (DSAP)	• Germplasm exchange • Evaluation
USP Institute of Applied Science (IAS)	• DNA characterization • Virus indexing • Nutritional analysis
USP School of Biology	• Training
USP School of Agriculture	• Conservation • Research • Training
SPREP	• Policy
Pacific Island Forum Secretariat	• Policy
NARI, PNG	• Conservation • Research • Germplasm exchange
University of Technology (Unitech),	• Research • Training
University of Vudal,	• Research • Training
University of New Caledonia	• Research

[10] See Appendix 1.

	• Training
Vanuatu Agricultural Research and Training Centre (VARTC)	• Conservation • Training
Vanuatu Agricultural College	• Training
Island Food Community of Pohnpei,	• Characterization • Use
Kasdom Gaden Association, Melanesian Farmers First Network,	• Conservation • Characterization • Evaluation • Use
PestNet	• Information

c. Linkages outside the Pacific

Organization	Role in Regional Strategy
IPGRI	• Technical backstopping
COGENT	• Development of global strategy for coconut • Support of International Coconut Genebank • Access to information
BAPNET	• Development of global strategy for banana • Access to germplasm and information • Safety duplication
CIP/ANSWER	• Development of global strategy for sweet potato • Training (breeding) • Safety duplication
CIAT	• Access to cassava germplasm and related information • Safety duplication
IITA	• Access to yam germplasm and related information • Training • Safety duplication
AVRDC	• Training in seed storage
CTCRI, Kerala, India	• Access to germplasm and related information of yams and other root and tuber crops
US Land Grant system, ADAP, USDA	• Research • Training
CIRAD	• Research • Training (breeding, biotechnology)
Natural Resources Institute (NRI), UK	• Research and development of virus-indexing technology
University of Queensland (UQ), Australia	• Research and development of molecular markers • Training, advice
The Queensland University of Technology (QUT), Australia	• Research and development of virus-indexing technology • Training, advice
FAO	• Policy support • Supporting/facilitating germplasm exchange through FAO Food Security project
UNESCO	• Training programmes in biotechnology (mainly *in vitro*)
CTA	• Funding for workshops, documentation, information activities

d. User linkages

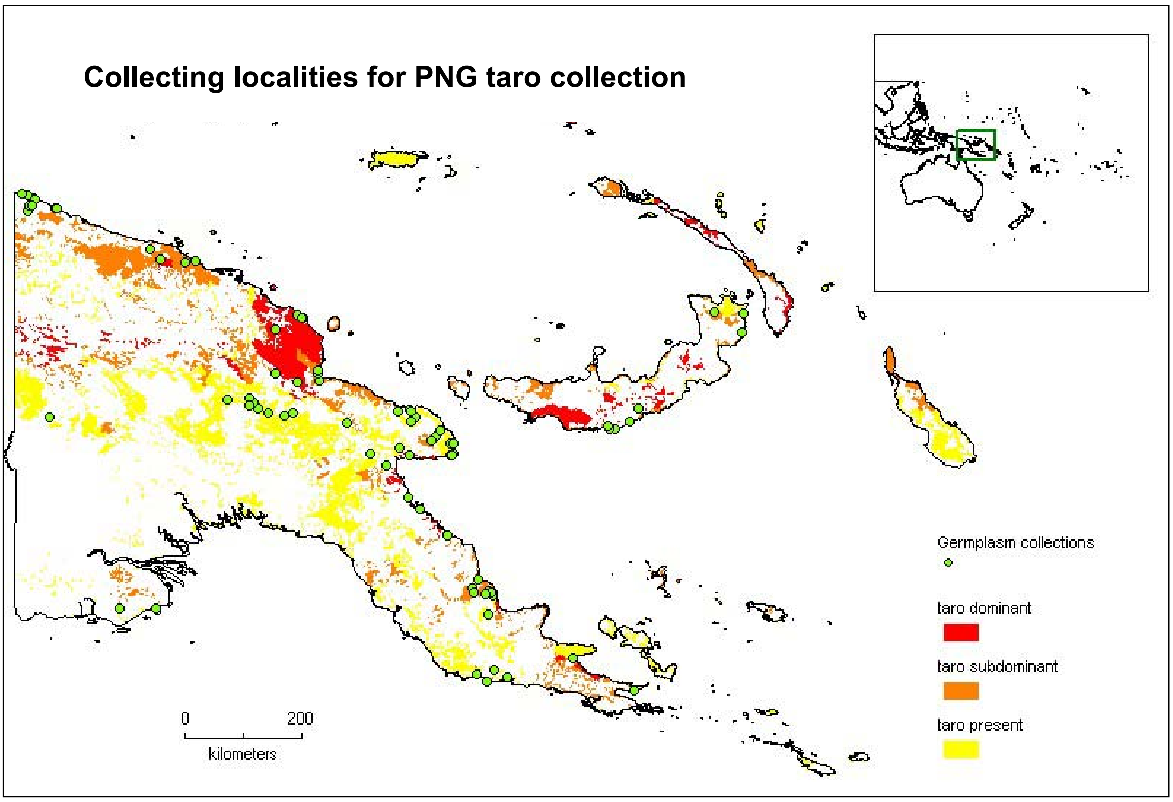
Because the Pacific region is made up of relatively isolated islands with serious quarantine concerns, in particular with regard to viruses, germplasm distribution must be conducted with caution. Germplasm must be virus tested and can then be distributed from the RGC to PICTs as virus-indexed material, either to national laboratories (if available), for further multiplication, or directly to the field for evaluation. This has been the mode of disseminating germplasm since the establishment of a regional genebank in the Pacific. Between-country germplasm distribution can take place but only after the risks are assessed. National systems for dissemination of germplasm to farmers need to be strengthened throughout the region. Two models are emerging as important models for this:

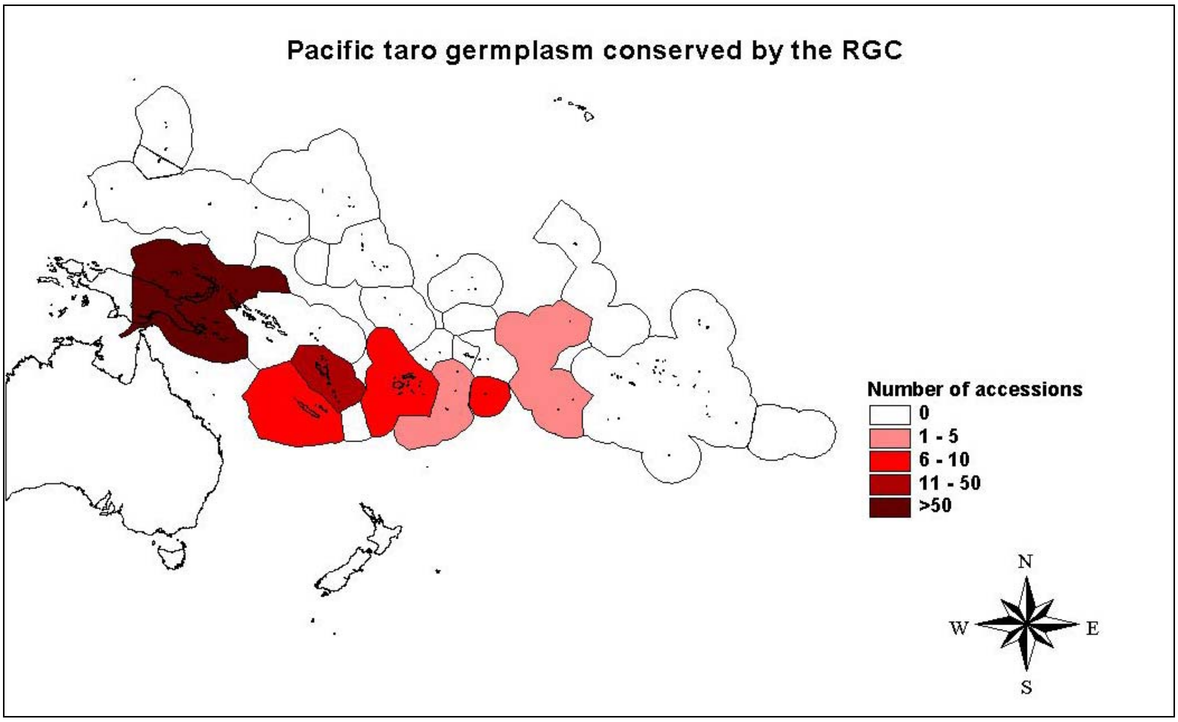
- Development of Sustainable Agriculture in the Pacific (DSAP) – DSAP has been responsible for the establishment of National Steering Committees in all PICTs. These, and the participatory workshops that they organize, provide a mechanism for PAPGREN and the RGC to respond to national needs.
- NGOs and Farmers' Groups – SPC is mandated to work through governments so in the past this has limited collaboration with NGOs. However recently the SPC-RGC has begun distributing germplasm in the Solomon Islands through the Planting Materials Network, and also in Samoa the distribution of taro germplasm is largely through a farmers' group (Taro Improvement Programme, TIP).

Other potential distribution channels to users that need to be evaluated include: rural training centres, correctional services, schools, church groups and diversity fairs.

7. Priority crop conservation/use activities

Taro





Objectives

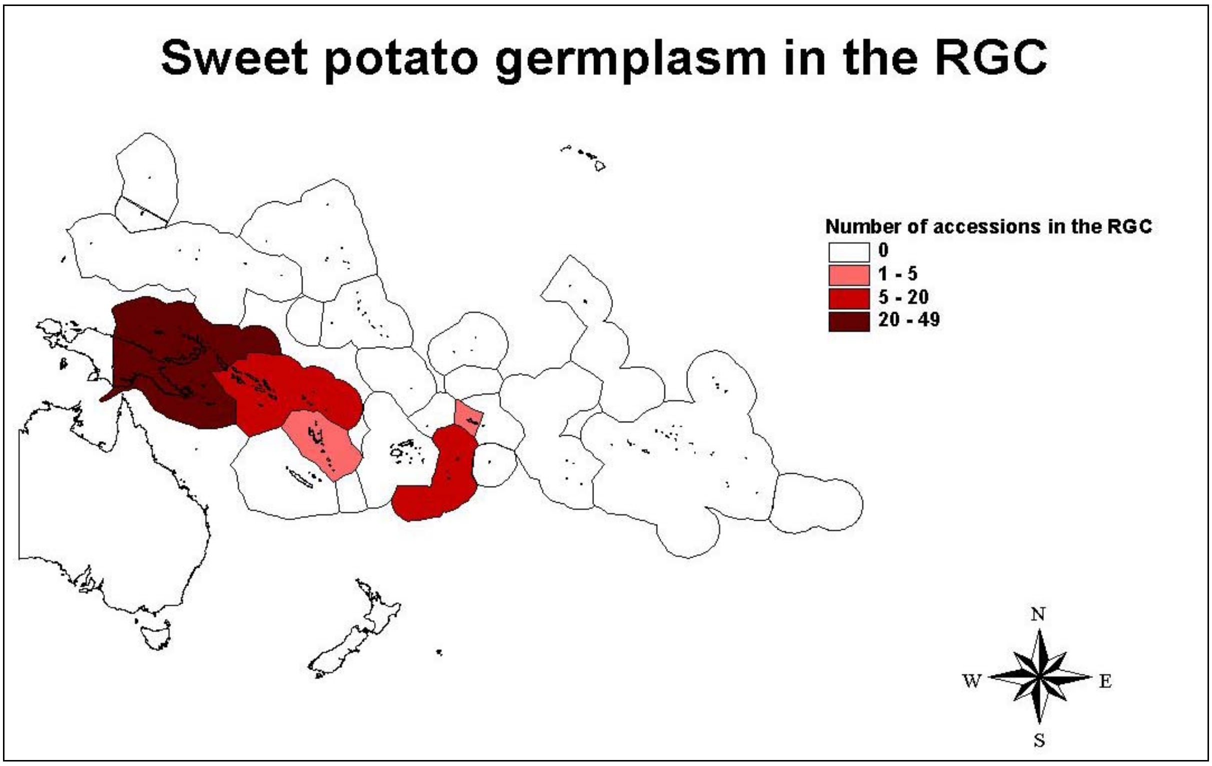
- To ensure the taro regional core collection at RGC is securely conserved
- To ensure that the national collection currently maintained by NARI, PNG is cryopreserved
- To ensure the continuation of taro improvement programmes in Samoa and PNG

Institute	Contact details	Responsibilities	User links
SPC-RGC	Valerie Tuia RGC Curator RGCcurator@spc.int ValerieT@spc.int	• Conservation (slow growth and cryopreservation) • Virus indexing (USP-IAS) • Distribution • Facilitating evaluation and ensuring information disseminated to countries • Research	• NARES • NGOs
NARI, PNG	Rosa Kambuou PGR Programme Leader rosa.kambuou@nari.org.pg	• Maintaining field collection until cryopreservation technology is implemented at SPC • Taro breeding programme • Evaluation of new breeding lines and of taro core collection.	NARI has good links to farmer groups etc. throughout the country. Links have also been established with the correctional services.
University of Technology (Unitech), Lae, PNG		• Virus indexing and molecular characterization to support taro in PNG • HRD	
USP, Alafua, Samoa	Anthony Palupe Manager Tissue Culture Unit Palupe_a@samoa.usp.ac.fj	• Safety duplication of RGC taro collection • Participatory breeding programme (TIP) • Evaluation • HRD	Farmer groups (TIP)
University of Vudal, PNG		• Seed storage research • HRD	

Annex. 3rd International Taro Symposium recommendations arranged by type of action (May 2003).

Area	Potential Partners
Carry out basic and applied research	
1. Carry out research to develop reliable cryopreservation protocol for taro	
2. Carry out seed conservation research, including induction of flowering	RGC, Unitech/NARI, IPGRI
3. CBDV epidemiological studies in PNG	Unitech, NARI, Vudal
4. Field trials and chemical analyses for taro beetle control	SPC TBM
5. Carry out research on macro-propagation and micro-propagation techniques (esp. GA-induced multiplication technique) with focus on multiplication rates achieved, costs and applicability	
6. Quantify losses due to virus diseases	
7. Marketing surveys in PICTs and Pacific Rim countries	
Support conservation	
8. Validate TaroGen, TANSAO cores and compare with other genepools using standardized molecular markers	
9. Molecular characterization of germplasm from India	
10. Seek long-term funding for RGC, e.g. through GCDT	
11. Ensure safety duplication of taro core collections	
12. Provide short-term support to national programmes for field genebank maintenance or *in vitro* conservation of base collections	
Evaluate germplasm	
13. Participatory evaluation and selection of germplasm currently available (TaroGen and TANSAO cores, breeding lines) to investigate relationships among chemotypes, genotypes and organoleptic properties	
14. Evaluate varieties for potential in organic production	
15. Analyze the chemotypes of commercial varieties so that the private sector can use this information to promote products	
16. Evaluate taro varieties for atoll requirements through distribution to these countries	RGC, atoll countries
17. Investigate the possibility of screening for salt tolerance *in vitro*	
Exchange genetic material	
18. Exchange clean material within region and outside	national programmes, RGC, CIRAD
19. Develop virus indexing capacity within region	SPC, USP, NARI
20. Obtain FQID approval to introduce plants for indexing	SPC
21. Convene meeting to update safe transfer guidelines	SPC, IPGRI
22. Monitor PT clones after field release	SPC
23. Explore innovative avenues for distributing planting material from NARS to NGOs	
Improve and use germplasm	
24. Marker-assisted selection	
25. Ensure sustainability of current breeding programmes in the Pacific	
26. Strengthen coordination among breeding programmes in the Pacific	
27. Focus on quality and taste, use geographical	

indicators to promote the product combining the name of the variety, the geographical area of production, the cultivation techniques etc for niche and high value new markets	
28. Recognize that there are two markets: fresh and processed products needing different plant material	
29. Further studies on product development	
Develop project proposals	
30. Develop pilot (shop window) project for *in situ* management of taro genetic resources	
31. Develop project document on interactive diagnostic tool for taro	UQ, SPC
32. Consultations on novel pest control methods	QUT, SPC, national programmes
Document information	
33. Compile information on the use of various farming practices to prevent decline in soil fertility	
34. Collate and review information on multiplication techniques (macro and micro)	
35. Prepare catalogue of main taro diversity in region	
36. Establish an international network on taro to facilitate exchange of information	
37. Collect data on costs of production	
Increase awareness	
38. PAPGREN to address the issue of the other edible aroids	
39. Carry out marketing and educational campaigns (needs a strong lobby)	
40. Explore the possibility that the image of taro within the global research community could be raised through participation in the CGIAR system	
Build capacity	
41. National capacity building and training in molecular techniques and implementing molecular technologies	
Increase international collaboration	
42. Development of regional MTAs and other ABS policy instruments	SPC, IPGRI, national programmes
43. Broaden international collaboration in taro research	



Objectives

- To describe and rationalize the PNG sweet potato collections
- To define a core collection of PNG sweet potato for conservation in PNG and at SPC-RGC
- To investigate yield decline in the PNG highlands
- To establish a participatory pre-improvement programme

Institute	Contact details	Responsibilities	User links
NARI, PNG	Rosa Kambuou PGR Programme Leader rosa.kambuou@nari.org.pg	• Conservation • Breeding • Evaluation	NARI has good links to farmer groups etc. throughout the country
University of Technology (Unitech), Lae, PNG		• Virus indexing and molecular marker work to support sweet programme in PNG	
SPC RGC	Valerie Tuia RGC Curator RGCcurator@spc.int ValerieT@spc.int	• Conserving the core collection • Virus indexing (USP IAS) • Distributing to other PICTs	• NARES • NGOs
CIP, Peru		• Support for virus indexing and molecular marker work • Safety duplication	

Annex. A discussion paper on sweet potato conservation and use in the Pacific presented at the PAPGREN annual meeting in 2003 by Dr G.V.H. Jackson is provided below (note that these suggestions were discussed but no regional consensus has yet been reached).

What's the problem?

I believe that our strategy on sweet potato improvement over the last 30 years or more has been wrong, and consequently our policy for conservation.

Why do I say this?

The strategy to date has to amass huge collections of germplasm: collect all the varieties, describe them using innumerable IPGRI descriptors, evaluate for agronomic criteria and palatability, select a few and distribute them. Collections in PNG have hundreds of accessions, or they did have, at Laloki, Keravat and Aiyura, and at Kuk before it was closed. The collection at Aiyura still contains over one thousand accessions. There were previously large collections in Solomon Islands, and smaller ones still in Vanuatu and New Caledonia.

But surely selection of varieties among the huge genepool of Melanesia and sharing selections among the farming communities is the right thing to do? It is done with so many other crops: farmers need access to better varieties to test; surely there can't be anything wrong with the strategy?

There is nothing wrong *per se*, but if it based on a false premise, then it is the wrong strategy.

So what's that premise?

It is that the varieties are stable and do not deteriorate or decline over time.

If they do there is no point in giving out new varieties, selected or bred, unless you know what they are likely to do, or you can quickly resupply with new varieties. Otherwise, it is a great waste of resources.

Where's the evidence?

Do varieties of sweet potato decline in yield over time in the Pacific?

I think they do.

My concern comes from talking to farmers in the lowlands of Melanesia, Solomon Islands in particular, from occasional observation in other countries and from recent literature. I do not have experience from the highlands of PNG and elsewhere.

I'll list my observations:

- growers do not keep varieties of sweet potato for many years: it varies, it might be 3-4 years, some longer;
- asked why and you get a variety of answers: yields decline; peer pressure as new varieties come into circulation; want to try something new;
- there are no traditional names of sweet potato: their names reflect from where they came or who bought them;
- in Solomon's, out of the top twenty a majority came from a small province where growers selected 'new' varieties found in their gardens – I think they are selecting seedlings.

Perhaps the best evidence in our region is the work of Peter Beetham and Angela Mason when working on the sub-regional *ACIAR-IPS Sweet Potato Improvement Program* (1980s) and Paul Wijmeersch in PNG with the sweet potato component of the Pacific Agricultural Research Programme (1990s):

- The ACIAR-IPS found “that PT planting material in some accessions can increase storage root fresh-weight yields by 250%. [The result] also showed that PT material is quickly re-infected by viruses, but over two generations yields are still significantly higher in some accessions”.
- PRAP showed that a majority of PT (meristem cultured, pathogen-tested) sweet potatoes gave increased yields compared to the parent material in field evaluations.
- but yield decline also occurred in some of the selected first class varieties over a number of years of planting at LAES.

Because of this it was suggested by PRAP "that when planting material of selected varieties is distributed to farmers, only the pathogen tested material should be distributed, at least of those varieties for which a yield decline is observed"

However, this begs the question whether varieties that are known to exhibit yield decline should be distributed at all. (If varieties decline in yield at LAES, is it not to be expected that they will decline, too, in farmers' fields? If they do, what is their use to farmers?)

What’s the reason for the decline?

So, if it is true that sweet potatoes decline, what’s going on? Two obvious answers are that somatic mutations are accumulating that depress yield or it’s the accumulation of viruses, and/or other internally borne pathogens.

In September 2000, a meeting was held at Miyakonojo City, Japan: *International Workshop on Sweet potato Cultivar Decline Study*. The meeting acknowledged that “performance decline of sweet potato cultivars is a limiting factor to production”, so the aim of the meeting was to determine the primary factors in cultivar decline.

At the time of the meeting no genetic mechanism had been identified as leading to mutations in sweet potato. However, a number of types of mutations were thought possible as well as the effect of transposable elements (“jumping genes”).

Reasons for decline from the papers presented:

- There is evidence from the USA that for some selections of var. Beauregard, randomly selected from different farmers’ seed stocks, yields were still low even after meristem culture and indexing.

- We also know that there are there many viruses infecting sweet potato as well as viroids and phytoplasmas, so it would not be surprising to find that these are implicated in yield decline. South Africa for instance is convinced that the problem is due to viruses and a *SP Plant Improvement Scheme* have been giving out indexed propagating material for a number of years, and this has solved yield decline.

- CIP is investigating resistance to sweet potato, generating maps for important varieties.

What can we do about it?

First, we need to comes to terms with the decline problem:

- determine if it is real or not and if it is how extensive.
- talk to growers:
    - If varieties are turning over rapidly in farmers’ fields, evaluation projects are likely to be selecting varieties that farmers may have already rejected. They are yesterday’s varieties.

- On the other hand, they might be stable ones that will not decline further. They may be resistant to mutations or viruses.
- Selection programmes might be unwittingly distributing viruses to places where they did not exist before. We need to know what we are doing.

And there is no point in breeding new varieties until that information has been obtained. It makes nonsense of any breeding programme. But if yield decline is proved to be real, a breeding programme could be the solution.

How to do this have been provided by Raoul Robinson who visited PNG and Solomon Islands in 1986. The strategy appears in his book *Return to Resistance* (1996). He took yield decline as a given and to be caused by viruses, or virus-like pathogens.

Conceptually, the idea is simple: it involves a PPB participatory breeding programme. This he considered to be the most likely way to bring about major improvements in sweet potato over a vast region where different agro-ecological conditions are commonplace, and complicate breeding strategies. The programme would:

- determine the stable types of sweet potato (those in which yield decline is least – perhaps resistant to virus);
- use these in breeding blocks (polycross nurseries) to provide seed for testing by farmers for particular demands of taste and location.
- Challenge the seedlings with shoots from varieties that have declined
- Those that yield will be distributed to farmers for testing.
- Monitor the success in farmers' fields.

Thus a multidisciplinary programme is required, with agronomists, breeders and virologists working with NGOs and farmers. Obviously, and as start, surveys are required to understand more about farmers' practices and viruses.

Complementary Conservation Strategy?

If yield decline is a reality then it will have a bearing on conservation strategies as outlined for Asian collections (Eero et al. 1999). In the approach outlined in the paper genetic diversity structuring is combined with use-based structuring. Although yield is only one of many criteria evaluated it presumably is an important one from a plant breeder's perspective. Breeders might want to be satisfied that what they consider elite material is really worthy of conservation. They might wish to give greater weight to stability of yield over time as a more worthy character in lines that were used frequently (and given priority for conservation – use-based structuring).

And what of *in situ* or on-farm conservation? Would yield decline affect it? Sthapit et al. 2001 have given the general approach for on –farm conservation of sweet potatoes. However, its application seems premature, although Wiles has suggested such a programme for the highlands. But the surveys that have been done under PRAP (Kronen and Kanua1996) do not mention yield decline or how often new varieties are introduced and older ones are discarded. (It does, however, mention that at Tombil, South Waghi Valley and at Warakar, North Waghi Valley, a variety at each place was sourced from seed).

It is important to know if yield decline occurs in the highlands. If farmers are not retaining varieties, then on-farm conservation strategies might have little relevance. More important is to begin a dialogue with farming communities over as wide an area of Melanesia as possible to find out about people's experiences. Only then can conservation policies be considered.

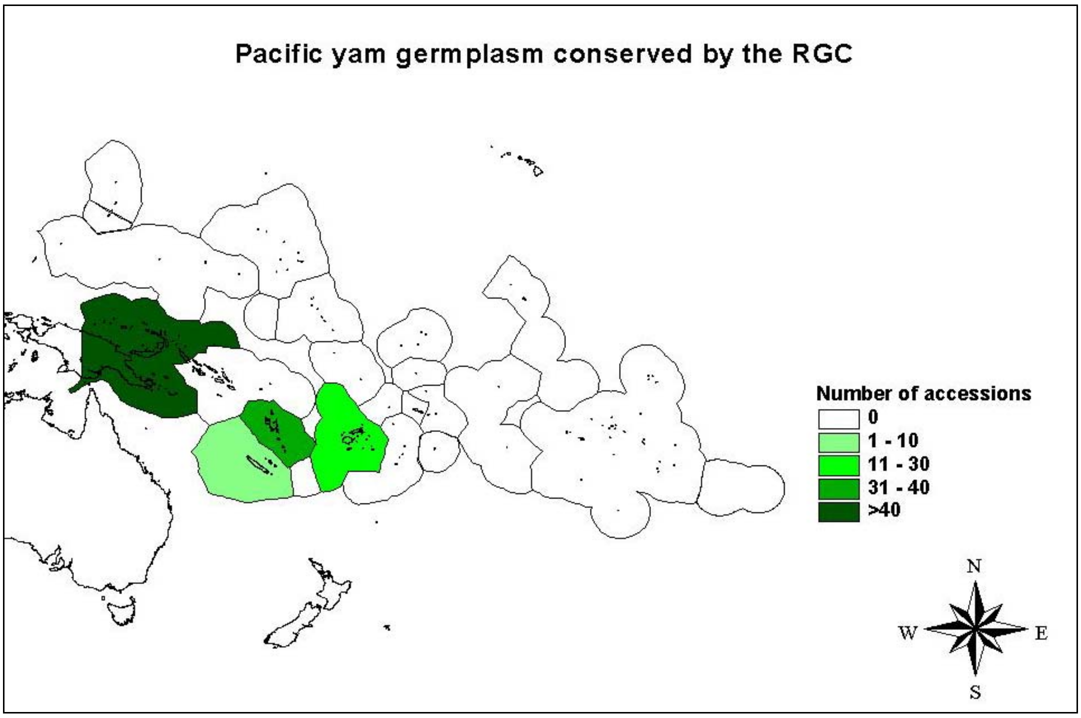
And are there any messages for *ex situ* conservation, especially for PNG, which is still maintaining large collections? These collections are now only in the highlands as those of the lowlands have been discarded – only 75 or so selected varieties are being maintained at Keravat (and some are known to decline in yield, so their usefulness may be limited). But in the highlands there are about 1000 varieties, and all have been described. Of these there are about 40 selections. It would certainly be wise to index these accessions for viruses before they are distributed. As for the rest, it may be still premature to make a decision on them.

So what's the strategy?

Initial elements of a work plan are:

1. virus index PNG selections and
2. investigate yield decline through surveys in selected areas
3. identify stable varieties
4. set up PPB programme

Yams



Objectives

- To characterize, document and rationalize the Melanesian yam collections[11]
- To clarify the taxonomy of Pacific yams
- To develop virus indexing technology to allow germplasm movement and sharing

Institute	Contact details	Responsibilities	User links
NARI, PNG	Rosa Kambuou PGR Programme Leader rosa.kambuou@nari.org.pg	• Conservation (non-elite/core accessions of specific interest to PNG) • Breeding • Evaluation	NARI has good links to farmer groups etc. throughout the country
VARTC, Vanuatu	Vincent Lebot lebot@vanuatu.com.vu	• Conservation (non-elite/core accessions of specific interest to Vanuatu) • Breeding • Evaluation • Training in breeding	Good linkages to farmers in selected localities through ongoing projects
Department of Agriculture and Livestock, Solomon Islands	**Jimi Saelea** **Director of Research** **j_saelea@yahoo.com**	• Conservation (non-elite/core accessions of specific interest to Solomon Islands) • Evaluation	Via DSAP partners and NGOs
University of	**Miok Komulong**	• Virus indexing	

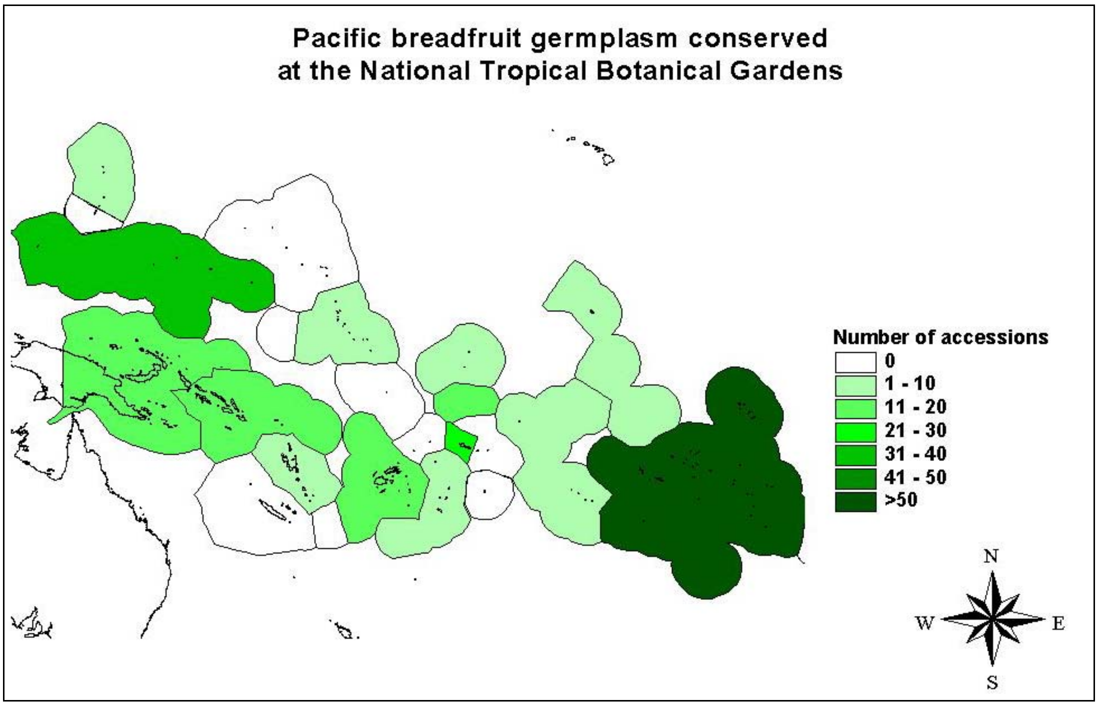
[11] The process would be similar to the model developed for the TaroGen project, in that collections would be described in country and then a regional core developed through comparison of the morphological descriptors and molecular markers. The core collection would be available for evaluation by PICTs.

Technology (Unitech), Lae, PNG	**Director** **Biotechnology Centre** **mkomolong@ag.unitech.ac.pg**	• Molecular characterization	
SPC RGC	Valerie Tuia RGC Curator RGCcurator@spc.int ValerieT@spc.int	• Conserving the core collection • Virus indexing (USP IAS) • Distribution to PICTs	• NARES • NGOs
Queensland University of Technology	**Rob Harding** **Associate Professor** **R.harding@qut.edu.au**	• Virus indexing • Possible development of detection systems for newly identified viruses.	
Natural Resources Institute, UK	**Lawrence Kenyon** **L.Kenyon@gre.ac.uk**	• Virus indexing • Possible development of detection systems for newly identified viruses	
University of Queensland (UQ)	**Ian Godwin** **Associate Professor** **i.godwin@mailbox.uq.edu.au**	• Molecular characterization	

Breadfruit

Objectives

- To support the long-term conservation of the field collection at the Breadfruit Institute, National Tropical Botanic Garden (NTBG), Maui, Hawaii[12]
- To duplicate the NTBG collection *in vitro*
- To establish an *in vitro* based protocol for safe movement of germplasm
- To distribute and evaluate the sub-sample of varieties providing all-year-round fruiting
- To provide training to PICT scientists in characterization, evaluation and documentation of breadfruit genetic resources
- To carry out seed conservation research



Institute	Contact details	Responsibilities	User links
NTBG, Maui, Hawaii	Diane Ragone ragone@ntbg.org	• Maintain field collection • Maintain data on collection • Provide training in the characterization, evaluation, and documentation of breadfruit genetic resources	Establishing linkages to potential users throughout the world
SPC-RGC	Valerie Tuia RGC Curator RGCcurator@spc.int ValerieT@spc.int	• Develop and implement *in vitro* methodology for breadfruit • Establish duplicate of NTBG collection • Carry out virus indexing, if necessary • Distribute elite sample to countries for evaluation.	• NARES • NGOs
Queensland University of	**Dr Rob Harding, Associate Professor**	• Assessment of virus status of NTBG	

12 See the Case Statement of the Breadfruit Institute in Appendix 2.

Technology	**R.harding@qut.edu.au**	collection • Development of virus indexing methodology, if required.	
VARTC, Vanuatu	**Frazer Bule** **faovan_nc@vanuatu.com.vu**	• Maintain field collection • Maintain data on collection	Good linkages to farmers in selected localities through ongoing projects

Annex. Priority action list agreed at PAPGREN Regional Workshop on Conservation and Sustainable Use of Breadfruit Genetic Resources in the Pacific, SPC, Suva, Fiji, 29 Nov. 2002

Activity	Partners
1. Distribute catalogue of NTBG collection to all countries, including in particular information on the "core" collection	NTBG
a. Translate and distribute Vanuatu breadfruit database and other French language information	
2. Develop a standardized methodology for the field assessment of breadfruit diversity, provide training and implement national surveys	NTBG, SPC, SPRIG, national programmes
a. Characterize traditional agroforestry systems	
b. Document traditional knowledge on cultivars and associated cultural practices	
c. Identify cultivars at risk of loss and develop appropriate conservation strategies	
d. Distribute information on appropriate husbandry practices	
3. Intensify investigation of tissue culture and stem cuttings as rapid propagation methods	NTBG, RGC
a. Test stem cutting methods in Kiribati	SPC
4. Distribute *ex situ* conserved material from NTBG and other countries to interested countries once safe, rapid propagation method is in place	NTBG, national programmes
a. Identify a sub-set of the collection of potential interest to atolls	NTBG, SPC, national programmes
b. Carry out pest risk assessment to facilitate safe movement	SPC
5. Screen wide array of material from the NTBG collection in the laboratory for salinity tolerance (possible thesis project)	NTBG
6. Promote breadfruit consumption for better nutrition	SPC, national programmes

Objectives

- To duplicate the Pohnpei collection *in vitro* in the RGC
- To develop a descriptor list
- To collect germplasm throughout the region
- To develop a safe transfer protocol
- To establish a collection of germplasm specifically for atoll countries

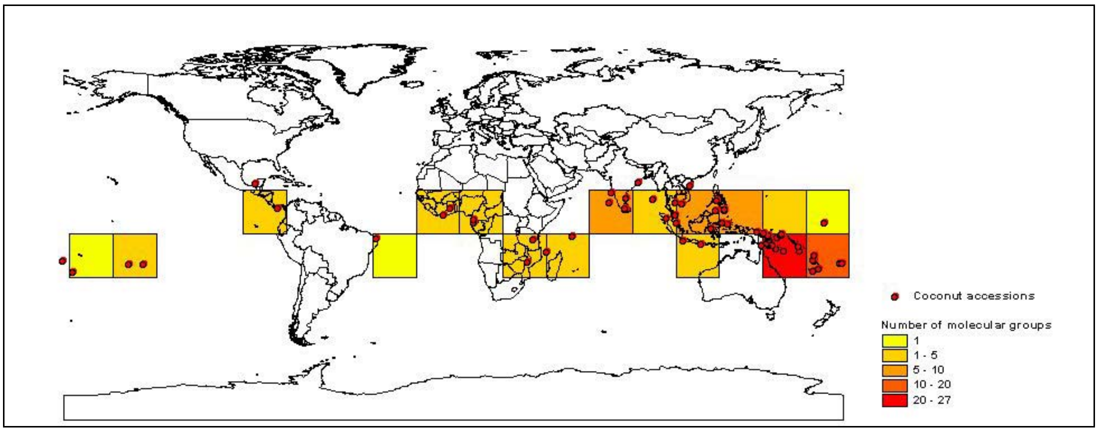
Institute	Contact details	Responsibilities	User links
• Department of Agriculture, Pohnpei • Island Food Community of Pohnpei	Adelino Lorens pniagriculture@mail.fm	• Conservation • Characterization • Evaluation	• To RGC for duplication and distribution • To other islands in FSM for evaluation
SPC-RGC	Valerie Tuia RGC Curator RGCcurator@spc.int ValerieT@spc.int	• Duplicate collection of swamp taro *in vitro*	• NARES • NGOs
Queensland University of Technology	**Dr Rob Harding, Associate Professor** **R.harding@qut.edu.au**	• Assess virus status of Pohnpei collection • Develop virus indexing technology if required	
NARI, PNG	Rosa Kambuou PGR Programme Leader rosa.kambuou@nari.org.pg	• Conservation as part of Atoll Project	NARI has good links to farmer groups etc. throughout the country

Banana: Pacific component of global strategy

Objectives

- To characterize and document the national collections in PNG, Samoa, Solomon Islands, New Caledonia and Pohnpei
- To establish a collection of Pacific bananas
- To provide duplication *in vitro* as required in RGC
- To Identify a sample of nutritionally valuable accessions and make available for distribution and evaluation

Coconut: Pacific component of global strategy



Objectives

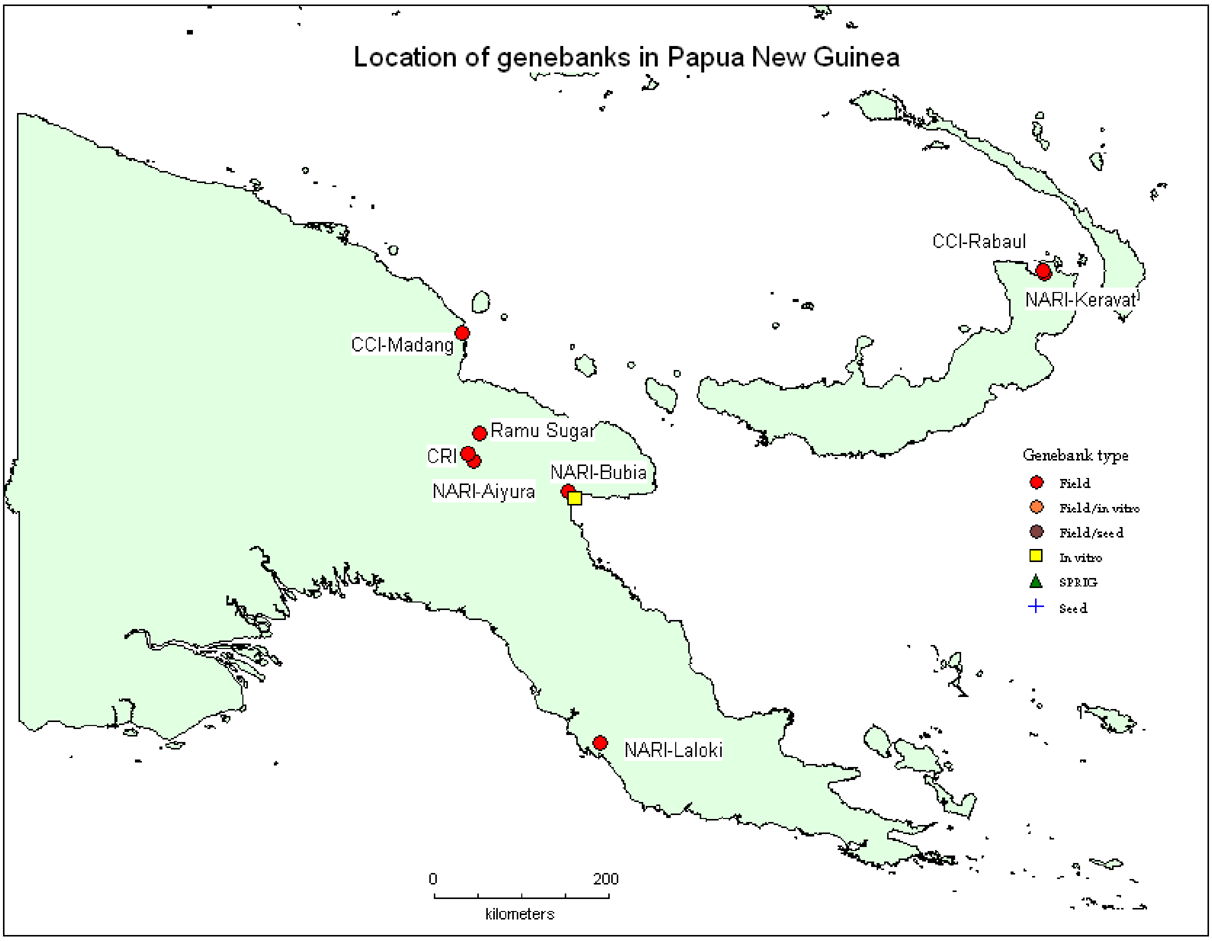
- To support for the establishment of the International Coconut Genebank for the South Pacific at CCI, PNG, with possible duplication *in vitro* at SPC-RGC (note in figure above the concentration of molecular groups in the Pacific, making this region a hotspot for genetic diversity)
- To support for the continued operation of the genebank and hybrid trials at VARTC
- To assess of the status of the Solomon Islands collection and carry out rescue activities as necessary

8. Upgrading, capacity building and research priorities

Given the above crop-based priorities, the following upgrading requirements have been identified as the main immediate priorities:

1. Strengthen and expand the SPC-RGC
2. Secure the PNG national network of collections managed by NARI

GCDT eligibility criterion	NARI, PNG	SPC-RGC
The recipient has effective links to users of plant genetic resources	NARI has one of the few breeding programmes in the region (taro) and NARI has strong links to farmers.	The RGC is very active in distribution of germplasm both to NARES and NGOs in the SPC 22 member countries..
The collection is important	PNG is a centre of diversity for many of the crops under consideration, the collections are large and have been amassed and maintained over many years at great expense. Where genetic studies have been done, the diversity in PNG usually encompasses that in other island states further East.	The RGC maintains a unique regional collection of taro and important collections of other crops.
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	These are national collections maintained by a reputable and duly constituted national agricultural research entity. PNG is ready to ratify the ITPGRFA.	The RGC has been using an MTA based on the one used by INIBAP. In the future, the SMTA developed by 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 there has been, and in fact has even offered to act as “breeders to the region” through the PARCIP idea.	The RGC 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	These definitely need strengthening, hence the suggestions in the Regional Strategy for capacity-building (see below).	
The facilities in which the collection is maintained are adequate to ensure long-term conservation	These definitely need strengthening and/or expansion, hence the high priority given to their upgrading in this Regional Strategy.	



In addition, the cross-cutting areas below have been identified as priorities for capacity-building at various times, but most recently and in most detail at a PAPGREN workshop in 2004 which developed a human capacity development strategy for the region. The lead agency for each initiative is indicated.

1. Management of collections of vegetatively propagated crops: NARI, PNG
2. PGR data management: SPC
3. Genetic resources use (especially breeding): VARTC/CIRAD

Though breeding programmes are few in the Pacific, in part because of the particular problems associated with vegetatively propagated crops, there is enough evidence from taro, for example, to show that they can be extremely effective in broadening the genetic base of crops. The variability required to suit the different agro-ecological conditions found in the region is only likely to be obtained from segregating progeny populations from parents of diverse origin. Using the region's well-characterized accessions, and combining these with the best from Asia, crosses can be made focusing on a few traits known to be important in each country. This model needs to be further investigated in the region, in particular in close collaboration with farmers in participatory plant breeding (PPB), as has been done by the TaroGen project.

How the proposed capacity building activities fit into the overall education strategy is summarized in the following table:

<table>
<tr><th>What is needed?</th><th>What is (or could be) on offer from Pacific educational institutions?</th></tr>
<tr><td>Farmers
▪ Ways to bring farmers together for mutual sharing etc. (field days, diversity fairs, competitions)
▪ Germplasm catalogues aimed at farmers
▪ Support to Farmer Field Schools and Rural training Centres
▪ Rural email to back-stop extension activities</td><td rowspan="3">▪ MSc course/projects (SPC, UPLB)
▪ Specialized training in participatory approaches (gender/age sensitivity)
▪ Short courses/workshops/seminars Teacher training
▪ Summer university courses
▪ College-level certificate in PGR
▪ Apprenticeships/attachments
▪ Supervision of student research projects (all levels)
▪ Distance courses and materials
▪ Resource materials for short courses
▪ Demonstration gardens (and help in setting them up)
▪ Organization of competitions
▪ Support to curriculum revision and development
▪ Technical backstopping by sharing of expertise</td></tr>
<tr><td>Schools
▪ Curriculum development (secondary)
▪ Use local examples and demonstrations for theoretical and practical instruction (primary)
▪ Competitions
▪ Training of science teachers and at vocational level</td></tr>
<tr><td>Professionals – skills upgrading in the following areas
▪ Policy and law
▪ Documentation of TK (participatory approaches)
▪ Public awareness
▪ Management of ex situ collections (field, in vitro)
▪ Use of collections (esp. breeding)</td></tr>
</table>

Finally, PAPGREN suggested that there should be a concerted initiative to evaluate the nutritional value of germplasm in collections of all crops across all countries in the Pacific. This could be part of a general effort to combat non-communicable diseases such as diabetes and Vitamin A deficiency, which are significant and worsening problems in the Pacific, and probably the main public health issues at the moment. This would perhaps be the most direct contribution that PGR use could make to development and sustainable livelihoods in the region.

Appendix 1: The Pacific Regional Crops Improvement Program (PARCIP)

Introduction

Food security is an increasingly important issue among Pacific Island countries as populations grow, climates change and eating habits alter. In response, governments are seeking to improve both agricultural productivity and nutrition by working at both the national and regional level. The commitment is to achieve sustainable food security within the framework set by the 1996 World Food Summit, reaffirmed at the WFS: *five years later* and expressed by the Millennium Development Goals.

For the most part, the emphasis is on policy matters, diversification of smallholder commercial crop production to promote trade, and developing participatory approaches for identifying and adapting existing agricultural technologies. However, throughout the region there is little agriculture research and development, even into the major food crops. And where it occurs it is not shared among countries.

This lack of R&D investment into food crops could have serious long-term implications. In Pacific Island countries, subsistence or semi-subsistence agriculture remains a significant activity, sustaining the livelihoods of around 75 percent of the population. If improvements to yield are not achieved and post-harvest problems reduced, it is unlikely that people will have sufficient time for economic enterprises, such as processing and value addition of presently grown crops or diversification into new ones. In which case, unemployment will continue to grow, with concomitant increase in migration to urban centres. The challenge faced by most Pacific Island countries is how to carry out the R&D that is needed when capabilities to undertake research of any kind is so limited.

Realizing that this problem is real and pressing, NARI, the National Agricultural Research Institute of Papua New Guinea, has put forward a proposal for regional collaboration on the genetic improvement of staples. This is PARCIP, the Pacific Regional Crop Improvement Program. The aim is for countries of the region and regional organizations to work together to exploit the food crop genetic resources that exist to the benefit of all. The Program maintains that there is considerable potential for staple food crop yield increases through breeding as well as the elimination of pests and diseases.

The importance of PARCIP to long-term food security was acknowledged by the Ministers of Agriculture and Forestry at the First Regional Conference, Fiji, 9-10 September 2004. Their communiqué supports the conservation of genetic resources, diversity of foods and the genetic improvement of the staple foods of the region as measures for coping with rapid change. Ways of bringing about these aims are described in this concept note.

Principles of PARCIP

In May 2003, at a meeting of the Pacific Agricultural Plant Genetic Resources Network, the NARI Chief Scientist outlined the concept of PARCIP, which focuses on genetic improvement of crops for increased productivity. Papua New Guinea is endowed with abundant genetic resources, has a diversity of environments, representative of those in other Pacific Island countries, and has well-established agricultural research institutes. To assist the region, NARI could conduct R&D in Papua New Guinea, or collaborate in research done elsewhere. Where new varieties were the outcome, these would be shared via the SPC Regional Germplasm Centre, Fiji.

A meeting of Pacific Island representatives in Papua New Guinea was suggested to take the concept further. This was held on 6-7 December 2004 at NARI Head Office, Kana Aburu Haus, Sir Alkan Tololo Research Station, Lae. NARI staff and representatives from Fiji, Tonga, the Federated States of Micronesia, the Food and Agriculture Organization of he United Nations and the Secretariat of the Pacific Community drew up the principles of PARCIP, the crops of focus and priority activities. Further details can be found in Annex 1.

Representatives at the Lae meeting agreed on three guiding principles of PARCIP:

- Build on past regional collaboration, and strengthen present PGR networks;
- Ensure access of food crop genetic resources and equitable sharing of benefits; and
- Utilize participatory and consultative approaches.

How these principles may be applied to the PARCIP framework is addressed below.

Build on past regional collaboration, and strengthen present PGR crop networks

In recent years, the most successful research projects have been those where countries have collaborated. Not only does collaboration allow wide access to the genetic resources of particular crops, and avoids duplication of efforts, but by outsourcing research activities to specialist organizations, countries can obtain the benefits at more reasonable costs than if they were to try to establish separate capabilities. Collaboration can also have a synergistic effect, improving the quality and timeliness of research outcomes. Where countries have worked independently or where regional programs have tried to give equal opportunity to all, regardless of capacity, success has been limited. Examples of regional research projects where significant achievements were gained are:

- TaroGen (1998-2003), Taro Genetic Resources: Conservation and Utilization. Developed in response to the outbreak of taro leaf blight in Samoa in 1993, the project helped countries collect, describe, conserve and transfer traditional taro varieties between countries, as well as breeding new varieties resistant to taro leaf blight. The project ceased at the end of 2003, but breeding has continued in Samoa, with SPC support, and at NARI. TaroGen worked with complementary ACIAR projects on virus indexing (QUT) and DNA fingerprinting (UQ).

- SPYN (1998-2002), South Pacific Yam Network. A four-year project to enhance the competitive position of yam in traditional cropping systems of five Pacific Island countries: Fiji, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu. Cultivars were selected for desired agronomic characteristics, to be exchanged and evaluated in diverse agro-ecological environments. The project was assisted by specialists in yam pathology (University of Reading and the Natural Resources Institute, UK); germplasm conservation (SPC); and molecular taxonomy (CIRAD).

These projects had a number of factors in common which contributed to their success (Lebot *et al*, 1999[13]):

- use of modern biotechnologies to solve crop improvement problems, linking countries, regional institutions and universities with centres of excellence outside the region that specialize in DNA fingerprinting, virus indexing, cryopreservation, etc;
- a regional genebank, i.e. the RGC SPC; this is seen as crucial when dealing with vegetatively propagated crops. Conservation of 'core' collections to backstop national holdings is required as well as a facility to take charge of the multiplication and dissemination of germplasm;
- participation of international technical assistance agencies (ACIAR, CIRAD, FAO, IPGRI, SPC) in the network. Not only does this ensure technical competence, but also it improves the chances of long term funding;
- effective and efficient project coordination, ensuring interaction among national programs, other partners and funding agencies. Two approaches have been used: first, coordination from within a national program (SPYN); and second, by a regional organization with a mandate for agriculture (SPC);

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[13] Wells KF & KG Eldridge (eds) 2001. Plant genetic resources in the Pacific: towards cooperation in conservation and management. ACIAR Monograph 76.

- regular meetings of participating countries to assist network implementation and to ensure good governance, to set work plans, monitor implementation and review results; and
- common policies on plant quarantine, access to germplasm and intellectual property rights so that germplasm can be safely and easily moved among partners.

Following on from these projects, and their emphasis on the use of PGR for agriculture, SPC, in collaboration with IPGRI, launched PAPGREN – the Pacific Agricultural Plant Genetic Resource Network – to strengthen national and regional capacity in the conservation and use of plant genetic resources for food and agriculture. The RGC is part of the Network.

Ensure equitable access and sharing of food crop genetic resources

The PARCIP concept is unique; it is a realization that although countries differ in plant genetic resources, none is self-sufficient, and the benefits of working together and sharing far outweigh those to be gained by working independently. It is a statement that countries with agricultural research capabilities wish to help those that do not have them. And it is also a conviction that, by bringing together agriculture researchers into regional networks, it will foster scientific excellence and facilitate rapid advances in food crop improvement. The objectives of PARCIP will be achieved by exploiting the region's wealth of plant genetic resources and, where necessary, germplasm from outside the region, particularly the international agricultural research centres.

Under PARCIP, countries agree to share their PGR, and the products from selection and breeding programs. Most of the crops of interest to PARCIP are within the Multilateral System for exchange of germplasm under the International Treaty on Plant Genetic Resources for Food and Agriculture. As such, and depending on the wishes of the partners, they will be exchanged using the Standard Material Transfer Agreement being developed by the ITPGRFA's Governing Body. Pacific Island countries are giving serious consideration to ratifying the ITPGRFA, following a recommendation by the First Regional Conference of the Heads of Agriculture and Forestry Services (HOAFS) in late 2004.

Utilize participatory and consultative approaches

PARCIP will bring together representatives of the research and development institutions of the Pacific, including those of national agencies, universities and regional and international organizations. Importantly, it will develop close relationships with the non-government sector, including community development organizations, farmers' networks, lead farmers, schools and religious institutions, to ensure representation of all stakeholders in the development of crop improvement strategies, and in the implementation of agreed activities. Specifically, it will build farmer participation in the identification of priorities, germplasm evaluation and improvement (including participatory plant breeding where appropriate), and develop effective linkages between genebanks and the farming community, building on regional expertise and experiences.

The crops

The Lae meeting reviewed the staple food crops of the region and placed them into two groups. The first includes the major staples (banana, sweet potato, taro and yams, including *D. alata*, *D. esculenta*, *D. nummularia* and the exotic *D. rotundata/cayenensis*), grown throughout the region. The second group contains those crops that are grown widely, but are only locally important (breadfruit, cassava, giant swamp taro (*Cyrtosperma merkusii*), giant taro (*Alocasia macrorrhizos*) and *Xanthosoma sagittifolium*).

The first group will be the main thrust of PARCIP, and will require strategies for crop improvement that depends on selection and plant breeding – where flowering and seed formation is a possibility. Strategies of individual crops are discussed more fully in position papers attached to this concept note.

The second group is of interest to PARCIP, but the program considers that it lacks the resources to work on them. The most appropriate strategy for these crops is to collect (or further collect) the varieties, transfer them to the SPC RGC, Suva, establish them *in vitro*, index for viruses, studying their genetic diversity (including the identification of core collections, as appropriate) and make them available for evaluation. Breadfruit is the exception: accessions will be added to the collection of Breadfruit Institute, National Tropical Botanical Gardens, Hawaii, and the most promising varieties identified by the Institute will be distributed for evaluation via the RGC.

Some crops are considered outside the scope of PARCIP: coconuts, sago and Pandanus being three prominent examples. Coconut improvement programs have been established for some years in the region with support from COGENT, and a sub-regional collection is being established in Papua New Guinea. Sago, though important to Papua New Guinea, does not have the regional significance for inclusion in PARCIP, nor does Pandanus, which is mainly of interest to atoll countries and the highlands of Papua New Guinea.

The framework

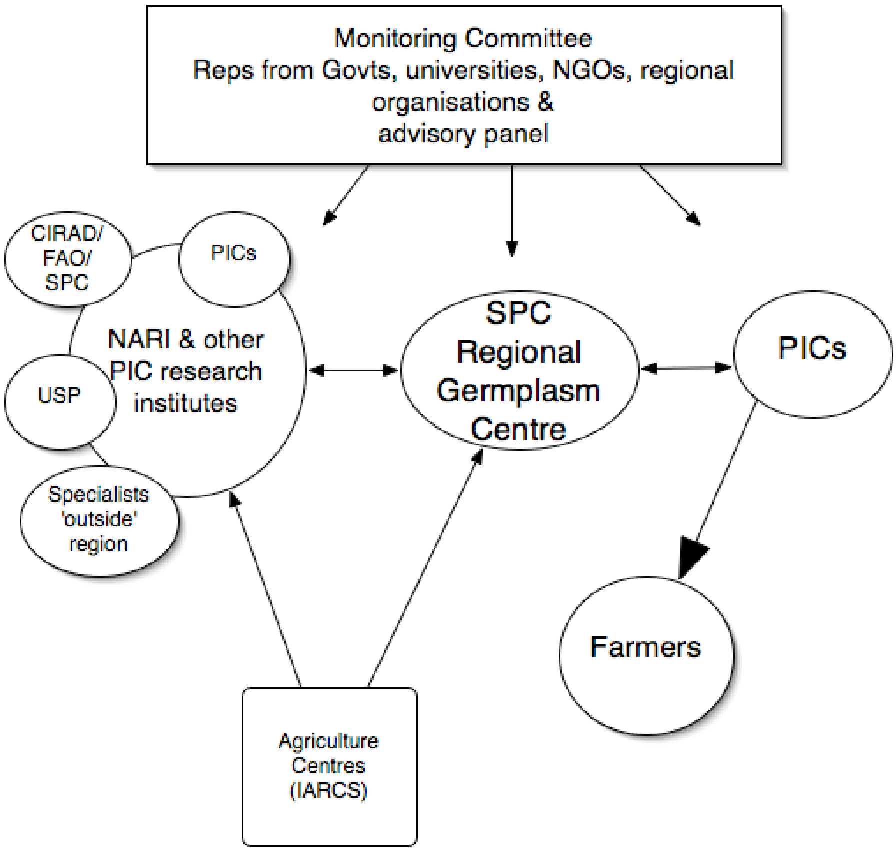
The short and long-term research requirements have been agreed or each of the crops of priority to PARCIP and these are summarized (Tables 1 and 2). Detailed needs for some of the priority crops are provided in the position papers attached to this proposal. Each provides background, a literature review of the work that has been done, the justification and objectives of further research, and the methodologies that will be used.

Crucial to the operation of PARCIP is the monitoring committee of representatives from the region, composed of government personnel, regional organizations, university staff, NGOs and farmers' networks. The Committee will be strengthened by at least three persons outside of these organizations who have had a long association with the food crops of the region, are familiar with the problems, and are willing to provide independent advice. They would be expected to have corporate knowledge of what has been done, contribute to needs analyses, identify gaps in knowledge, and provide critiques of ongoing work. They would also provide assistance in preparing research proposals.

This committee would meet annually, at which time it would review the position papers for funding. An important criterion for these papers is the degree to which the work is considered to be of a regional nature; that is, it should be important to more than one country, preferably several. All agencies, organizations and institutes will be eligible to put forward position papers to the committee and, if agreed, asked to develop a proposal. These would be put to members for comment via email, changes made, finalized and submitted for donor funding.

Preference would be given to projects that bring together research establishments in the region, drawing on the strengths that exist. They might require exchanges of scientists between institutions, or for scientists to be trained outside the region. It is particularly important that projects develop stronger links between universities and government research institutions, and that better networks be established for the exchange of technical information within the region and outside. Sharing of agriculture information, taking advantage of the systems among research institutions of Papua New Guinea, is likely to be a priority for PARCIP in addition to the needs of the crops already identified (Tables 1 and 2).

Fig. 1 Framework of PARCIP: the relationship between its components



In some instances, the research may be outsourced to specialist institutions if it is appropriate to do so. However, wherever possible, expertise in the use of relevant technologies, including biotechnologies, will be developed within the region. The development of biotechnologies, such as tissue culture and molecular techniques to accelerate conventional crop breeding, are essential if crop research is to provide the dividends expected. The development of these technologies may be at national centres or within regional organizations, such as SPC. SPC also has a key role to play, transferring germplasm between countries, and from outside the region, in a form that is free from quarantine concerns.

Appendix 2. Case Statement for the Breadfruit Institute

Summary

The Breadfruit Institute is committed to helping meet the nutritional and conservation needs of tropical regions by rapidly expanding plantings of exceptional breadfruit varieties in all areas where the trees can thrive. For 20 years, the Institute (part of the National Tropical Botanical Garden, Hawaii) has engaged in collecting, documenting, conserving, and evaluating breadfruit varieties. We now seek partners to help distribute the trees, set up local tissue culture labs, deliver agronomy support, and develop food products.

Breadfruit has been an important staple food crop in the Pacific for more than 3,000 years. Through the heroic efforts of Captain Bligh, a few Polynesian varieties were introduced into the Caribbean and other tropical countries where they are much used and much loved. Breadfruit trees require little attention, do well under a wide range of ecological conditions, begin bearing relatively quickly (in three to five years) and are productive for many decades. This 'tree of bread' has the potential to play a significant role in alleviating hunger in the tropics by providing nutritious food and trees for agroforestry and homegardens. More than 120 varieties from throughout the Pacific region have been conserved in the world's largest collection of breadfruit at NTBG. Simple and effective methods have been developed to propagate and distribute thousands of breadfruit plants. This project will disseminate breadfruit varieties to develop more sustainable agriculture, increase crop diversity, and enhance food security in the tropics.

World Hunger

The statistics are sobering:

- Every 4 seconds, someone dies of hunger.
- More than 80% of the world's hungry live in tropical and subtropical regions.
- 180 million people (1/3rd of the population) in Sub-Saharan Africa are hungry.
- In Latin American and the Caribbean, 53 million people suffer from hunger.

A long-term, sustainable approach to solving these problems in the tropics is both urgently needed and essential. One promising idea is to promote and make practical the widespread cultivation and use of the breadfruit tree.

Imagine a 'tree of bread' so prolific that Sir Joseph Banks, the first director of the Royal Botanic Gardens at Kew and the founder of the Royal Society of Britain, had this to say in 1769:

> *"Regarding food, if a man plant ten [breadfruit] trees in his life, which he can do in about an hour, he would completely fulfill his duty to his own as well as future generations."*

Thomas Jefferson, the third President of the United States and a passionate agrarian, wrote this in his autobiography, in thanks upon receiving some breadfruit seeds:

> *"One service of this kind rendered to a nation, is worth more to them than all the victories of the most splendid pages of their history."*

Why Breadfruit? – a brief history

For more than 3000 years, humans explored and settled the vast Pacific. Long before the era of European 'discovery,' innumerable islands were colonized—from rugged volcanic archipelagos with lush soils and abundant rainfall, to tiny, remote, widely scattered, flat coral atolls. The islanders were superb horticulturists who carefully tended and multiplied their prized food plants. One of these plants, breadfruit, became central to their lives, shaping the landscape and defining their culture.

Over the centuries, hundreds of varieties of breadfruit were derived from those first few trees—each specifically adapted to the ecological conditions of the different islands—as well as to the individual tastes and preferences of the islanders. Breadfruit trees were planted in and around the villages; extensive parcels of land were devoted to their cultivation. Entire hillsides were eventually blanketed with lush, productive forests of breadfruit.

When Europeans began exploring the Pacific in the 1500s, returning voyagers spread word of a remarkable discovery. A wondrous, bountiful tree produced a delicious starchy fruit which resembled a loaf of bread when baked—and remember how central bread was to the European culture these mariners had left behind.

Sir Joseph Banks, who sailed on *HMS Endeavour* with Captain Cook to Tahiti in 1769, recognized the potential of breadfruit as a food crop for other tropical areas of the empire. He proposed to King George III that a special expedition be commissioned to transport breadfruit plants from Tahiti to the Caribbean. This set the stage for one of the grandest and most notorious sailing adventures of all time.

The ill-fated journey of *HMS Bounty* in 1787, under the command of Captain William Bligh, is an amazing, legend-spawning tale of mutiny, loyalty, deceit, survival, desperation, courage, and navigational skill. Unfortunately, in one frenzied moment riotous mutineers tossed overboard hundreds of breadfruit plants meticulously gathered by Bligh's gardeners and crew over many months of painstaking effort. Despite his legendary ordeals, and arguably to give answer to them, Bligh made a second attempt aboard the *HMS Providence* and successfully introduced 600 plants of several Tahitian varieties to St. Vincent and Jamaica in 1793. The majority of breadfruit trees still growing in the Caribbean and elsewhere around the tropics originated from those very plants.

These may or may not have been the best varieties of breadfruit, merely those that were readily available or provided by the Tahitians at the time of Bligh's landfall. The French also collected a few varieties in Tonga that were taken to their own tropical colonies. Over the next two centuries, a few Polynesian varieties spread through the Caribbean, Central and South America, Africa, India, Southeast Asia, Indonesia, Sri Lanka, as well as Madagascar, the Seychelles, Maldives, and Mauritius. Breadfruit is now grown in close to 90 countries with a total population of 1.6 billion people. Another 26 countries, population 520 million, have the ecological conditions suitable for cultivation of breadfruit.

Breadfruit is underutilized in most tropical areas simply because it does not produce a consistent enough supply of good-quality fruits due to the somewhat capricious and historically-limited distribution of varieties. This lack of diversity also hampers efforts to develop new food products using fresh and processed breadfruit. While the harvest season is several months long for any given tree, fresh fruits are perishable and have a short shelf-life once they are picked. Pacific islanders developed innovative techniques to utilize large harvests and store fruits for future use, thus ensuring a supply of food during 'lean' periods. The most widespread practice involves fermenting starchy, uncooked fruits into a soft, doughy paste that can be stored for a year or more.

Post-harvest research on storage methods and product development is essential to expanding and diversifying the use of breadfruit. Most important is identifying varieties that will extend the season and making these available to farmers in the tropics and subtropics. In the Pacific region, breadfruit typically produces one or two crops per year, but there are varieties that produce fruits year round. In areas with a diverse array of varieties, early- and late-bearing types make it possible to harvest mature fruits for 8-10 months, or even the whole year.

A Most Useful Plant

Breadfruit is a versatile food. Fruits can be prepared and eaten at all stages of development, from small and immature, when it is comparable to a green vegetable, to starchy mature, to ripe, soft and sweet fruits for desserts. At the mature stage, fruits are similar to potatoes and can be roasted, baked, boiled, or fried. Breadfruit is used to prepare delicious appetizers, salads, soups, stews, casseroles, main dishes, breads, desserts, and more. It can also be readily processed for long-term storage by canning, pickling, drying, or fermenting. Dried as a cereal, or mashed as a puree, breadfruit is a nourishing food for infants and young children.

Nutritionally, breadfruit compares favorably to other starchy staple crops—taro, plantains, cassava, sweet potato, and white rice—commonly eaten in the tropics. Carbohydrates are the main source of energy. It is a good source of dietary fiber. Depending on the variety, breadfruit has two to three times the amount of fiber as plantains, cassava, and sweet potatoes, and more than 16 times the fiber content of white rice. Breadfruit is a comparable or better source of calcium, magnesium, potassium, and thiamin (see Appendix 2 for specifics). White rice, for example, contains just one-tenth the amount of potassium as breadfruit. Breadfruit is a slightly better source of iron and niacin. It is a fair source of Vitamin C and yellow-fleshed breadfruit varieties are a good source of Vitamin A and other carotenoids. Vitamin A deficiency is a serious and a widespread problem in the tropics.

A seeded form known as 'breadnut' is grown for its nutritious seeds. Immature fruits are sliced and cooked as a vegetable. Seeds are similar in flavor and texture to chestnuts and can be boiled, roasted, or ground into meal or flour. The seeds contain 13-20% protein, 6-29% fat, and are a good source of potassium, calcium, and niacin.

These multipurpose trees provide food, timber, fiber, and medicine for their growers. The ripe fruits, seeds, and leaves are used to feed pigs and other animals. The male flowers are dried and burned to repel mosquitoes and other flying insects. The sticky sap is used as caulk or glue. Various parts of the tree have traditional medicinal uses, including treating skin ailments, fungus diseases, stomach aches, diarrhea, dysentery, headaches, ear infections, reducing high blood pressure, and controlling diabetes.

From an ecological and human perspective, breadfruit is an ideal crop. The trees require little attention or care, producing an abundance of fruit with minimal input of labor or materials. Farmers do not have to engage in hard labor associated with planting, tending, and harvesting a field crop. The only effort associated with growing and tending a breadfruit tree is the initial soil preparation (digging a hole), planting, mulching with leaves and other organic material, and protecting the young tree from foraging animals. Once the tree is mature and producing fruits, occasional pruning and shaping are needed to optimize tree structure and to keep it low, making harvesting easier.

Because the land need not be plowed to grow breadfruit, there is not a problem with erosion or loss of topsoil. More important, breadfruit trees create forest cover. The trees grow well on hillsides, providing erosion control and protecting watersheds. This is especially significant since so many tropical areas have been denuded. Throughout its range, breadfruit is grown in home gardens and small subsistence farms interplanted with myriad subsistence and cash crops and other useful plants. The trees form a protective overstory providing shade, mulch, and a beneficial microclimate. Cultivating breadfruit trees replaces slash-and-burn agriculture and field cropping with a permanent tree cover.

Compared to bananas, plantains, and tropical root and tuber crops, breadfruit is relatively free of diseases and pests. Mealy bugs, and root and fruit rots caused by fungal organisms, can be a problem locally. Viruses and bacterial disease—a severe constraint to production of bananas, plantains, cassava, taro, sweet potato, and yams—have not been reported for breadfruit. For example, viruses and bacteria can reduce banana yields by 40-60%. A recent study to determine the virus status of breadfruit indicated that there were no viruses present in any of the samples.

From a perspective of yields, breadfruit is superior to other starchy staples due, in part, to the verticality of production. An average-sized breadfruit tree with a canopy cover of 25m^2 will conservatively produce 100 fruits per crop, and yields of 400-600 fruits per tree have been recorded for larger trees. Depending on the variety, individual fruits can have an average weight of up to 3 kg. A similar-sized plot of land planted in plantains or root and tuber crops will produce less food with greater inputs.

Conserving breadfruit

In the mid-1970s the National Tropical Botanical Garden, a non-profit NGO based in Hawaii and Florida, dedicated to the conservation and study of tropical plants, decided to bring together “a definitive collection of the varieties of breadfruit and breadnuts.” The goals of this project were to collect breadfruit varieties, document their uses, and create a permanent conservation collection. The breadfruit collection in Hawaii contains more than 120 varieties from 18 Pacific nations, Indonesia, the Philippines, and the Seychelles. This is the largest and most extensive collection of breadfruit species and varieties in the world. It preserves varieties that may no longer exist on their native islands. The breadfruit collection is being systematically studied to utilize and share this important plant genetic resource. This work has been underway for a decade and includes molecular and morphological studies to assess genetic diversity and taxonomic relationships. Characterization and description of accessions include fruit weights, fruit and leaf descriptors, yield estimates, and seasonality data.

A long-term study to document bearing season has shown that year-round production of breadfruit is a reality. A set of 20 varieties that produce year-round has been selected for more intensive evaluation including fruit quality, consumer preference, and nutritional composition. It includes varieties that are highly regarded in their islands of origin, popular varieties that are widely distributed in the Pacific, and ones with commercial potential.

NTBG’s incomparable breadfruit genebank represents a global resource in the effort to develop more sustainable agriculture, increase crop diversity, and enhance food security. To focus on these unique opportunities, the National Tropical Botanical Garden established the Breadfruit Institute in 2002. The Institute’s founder and director is Diane Ragone, Ph.D. The Breadfruit Institute’s purpose is to conserve breadfruit diversity and traditional knowledge and promote its use for nutrition, income, and environmental protection.

Distributing the Breadfruit Tree Worldwide

The National Tropical Botanical Garden has received requests from throughout the world for germplasm and planting material from its unique breadfruit collection. It has not been possible to provide the planting material needed, however, because breadfruit is typically propagated vegetatively. The traditional method is to clonally propagate breadfruit using root shoots or root cuttings. This method is labor-intensive, inefficient, and slow. These are some of the very same obstacles and constraints faced back in Captain Bligh’s time.

To overcome these constraints and to provide sufficient quantities of breadfruit planting materials, *in vitro* (tissue culture) protocols are needed to successfully and economically mass-propagate breadfruit plants. Tissue culture is a proven method to vegetatively propagate and distribute plant materials that meets international plant quarantine requirements. The process is fairly simple—buds or other small vegetative parts of the plant are placed into sterile media in a test tube and provided with the necessary growth hormones and nutrients to grow into a plant identical to the original source plant. Plantains, taro, sweet potatoes, yams, and many other crops are widely produced using tissue culture. Farmers throughout the tropics and subtropics rely upon this technology for disease-free planting material—plants free of viruses, bacteria, and fungi.

A research initiative is underway to develop efficient tissue culture protocols for breadfruit. Thus far, one popular Polynesian variety has been taken through all stages of tissue culture: shoot initiation, rooting, regeneration, and acclimatization. We are now refining and testing the methodology on other superior varieties in the NTBG collection. By 2007 it will be possible to mass-produce breadfruit plants of selected varieties for worldwide distribution. Thousands of healthy, disease-free plants can then be easily shipped in their own small containers, ready for planting into a field nursery. It will be possible to provide breadfruit varieties to farmers and gardeners throughout tropical and subtropical regions easily, cheaply, and quickly. This makes breadfruit-based agriculture, agroforestry, homegardening, and reforestation viable in ways previously beyond reach.

The Bounty of Breadfruit

Breadfruit varieties will be made available to establish in-country plantings where the selected varieties can be grown and tested under local conditions. A printed resource guide accompanying each shipment will contain simple, illustrated information on how to handle, transplant, and establish tissue-cultured plants. This information will also be available on the Breadfruit Institute's website (www.breadfruit.org) and other media. In this way, resource materials will be available for any level of technological capability and in several languages.

The key to success is developing partnerships with researchers and with international, national, regional, and local organizations in Africa and Madagascar, Latin America, the Caribbean, Indonesia, Pacific, and other tropical areas. Our goal is to put into place a network that will distribute breadfruit varieties and provide the technical support and training needed to grow and use breadfruit.

The Breadfruit Institute seeks partners to help provide this nutritious, easy-to-grow food to residents of hunger-affected tropical nations.

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