SECRETARIAT OF THE PACIFIC COMMUNITY

AusAID/SPC TARO GENETIC RESOURCES: CONSERVATION AND UTILISATION

TARO COLLECTING STRATEGY FOR PACIFIC ISLANDS WORKSHOP

(Lae, Papua New Guinea, 7–11 December 1998)

REPORT

Suva, Fiji
1999

Original text: English

Secretariat of the Pacific Community Cataloguing-in-publication data

AusAID/SPC taro genetic resources: conservation and utilisation. Taro collecting strategy for Pacific Islands workshop (1998 : Lae, Papua New Guinea)

Report.

(Report of Meeting (Technical) / Secretariat of the Pacific Community)

1. Taro-Genetics-Oceania-Congresses 2. Plant conservation-Oceania-Congresses
I. Title II. Secretariat of the Pacific Community III. Series

633.68 AACR2

Agdex 171

ISSN 0377-452X
ISBN 982-203-698-1

Published with financial assistance from Australian Government

Prepared for publication at the Secretariat of the Pacific Community
Suva, Fiji and at SPC Headquarters, Noumea, New Caledonia.
Printed at SPC, Suva, Fiji, 1999

CONTENTS

I. INTRODUCTION

This report summarises papers and discussions at a workshop entitled *Taro Collecting Strategy for Pacific Islands* . Workshop discussions were held at NARI, with practicals at BARC and UNITECH, Lae, Papua New Guinea, from 7 to 11 December 1998.

The workshop was organised by the regional project, *Taro Genetic Resources: Conservation and Utilization* (TaroGen). This project commenced in July 1998 in response to Pacific Island countries' concern over the continued loss of taro plant genetic resources, the difficulties and high costs of maintaining *ex situ* collections and the continued spread of serious diseases. The project is funded by AusAID and executed by SPC in partnership with IPGRI and USP.

TaroGen involves the collection and conservation of germplasm, and crop improvement through plant breeding. Complementary projects on virus-indexing and DNA fingerprinting are financed by ACIAR, and expertise in plant pathology is being supported by NZODA.

A regional approach is being taken in the collection and conservation of germplasm as no one country is self-sufficient in taro genetic resources, and there are considerable benefits to be gained by collaboration. A large part of the crop gene pool can be sampled at one time, and common methods can be used for collecting, describing and documenting germplasm, which in turn may lead to rationalisation of national collections and the identification of a core sample for conservation in a regional germplasm centre. As a first priority, a collection strategy was required incorporating all Pacific Island countries.

The specific objectives of the workshop were to:

- take stock of taro genetic resources presently maintained within the region, and in collections elsewhere, and to evaluate current plans to re-assemble taro collections;
- develop an agreed collecting strategy, including determining the priority areas for collecting, the methods to employ and where to store the germplasm while it is being documented;
- agree on the descriptors to capture morphological and molecular variation, as well as the type of database required to store the information obtained; and
- train country curators in the use of descriptors and the management of the database.

The workshop was attended by members of agriculture departments from Fiji, Papua New Guinea (NARI and DAL), Solomon Islands; representatives from ADAP, AusAID, HortResearch, IPGRI, QUT, TANSAO, UNITECH, UQ; and TaroGen project staff.

II. AGENDA

Monday 7 December

1. Official opening by TaroGen Team Leader and the Director of Research, NARI

2. Reports from taro development projects
- TaroGen: operation and activities (Param Sivan)
- Virus indexing and DNA finger printing (Rob Harding/Ian Godwin)
- Taro leaf blight screening for resistance (Bob Fullerton)

3. Statements by countries, organisations and institutions
- Fiji (Aliki Turagakula)
- Papua New Guinea (Rosa Kambuou)
- Solomon Islands (James Samu/Jimi Saelea)
- Vanuatu (Vincent Lebot)
- Polynesia (Mary Taylor)
- ADAP (Diana Greenough)
- TANSAO (Vincent Lebot)

Tuesday 8 December

4. Collecting taro genetic diversity (Ramanatha Rao, Luigi Guarino, Grahame Jackson)

5. Discussion (Chaired by Param Sivan/Ramanatha Rao)
- Agreement on a strategy
- Where to collect in Papua New Guinea, Solomon Islands, Vanuatu
- How and what to collect
- Where to hold collections
- Costs and who pays

Wednesday 9 December

6. Taro descriptors for the Pacific Islands (Ramanatha Rao)

7. Discussion (Chaired by Ramanatha Rao/Param Sivan)
- Agreement on a descriptors list
- Materials/equipment required for descriptive work.

8. Practical on use of descriptors at BARC (NARI/IPGRI)

Thursday 10 December

9. Introduction to genetic resources databases with practicals at UNITECH (Paul Quek)

Friday 11 December

10. Training on use of database at UNITECH continued (Paul Quek)

11. Workshop report

12. Closing

II. SUMMARY OF PAPERS AND DISCUSSIONS

1. OPENING CEREMONY

Param Sivan, TaroGen Team Leader, welcomed country participants and collaborators. He mentioned specifically the important role of a number of organisations and institutions that are partners with TaroGen in advancing taro conservation and use in the region. IPGRI is helping with germplasm collecting, describing and database management, and helped organise this workshop. QUT, UNITECH and UQ, with ACIAR support, are developing virus indexing and DNA fingerprinting techniques to assist the characterisation and international transfer of germplasm. HortResearch, with NZODA assistance, is taking the lead in developing screening methods for taro leaf blight resistance. TANSAO is providing input through its involvement with genetic resources of taro in Asia. USP is assisting TaroGen in its work in Samoa, and ADAP is collaborating with the Micronesian countries to ensure results from the project reach the entire region. All these organisations and NARI were thanked for supporting TaroGen and for coming to the workshop.

The main objectives of TaroGen are collecting, conservation and breeding. This workshop is concerned with the collecting and conservation components of the project. It will take stock of taro collections in the region and the germplasm that has been collected and stored elsewhere. Based on this survey, the project hopes to assist countries re-assemble the collections that have been lost, and provide better mechanisms for conservation. The workshop will discuss strategies, in particular, the priority areas for collection, how to collect, where to store germplasm during characterisation, and what descriptors to use. It is important that all countries use the same descriptors and methods of data management. The workshop will provide training on these aspects.

The Director of Research for NARI, Mark Johnston, welcomed all workshop participants. He commented that the project was an important one for Pacific Island countries. It had started in July this year, and already there had been two workshops, one on taro breeding, the other on project planning, and so the project had got off to a good start. This workshop was very useful for Papua New Guinea in particular, as it was difficult to decide what taro to collect, what to keep and what indigenous knowledge was required. There were conflicting opinions concerning the aim of collecting, whether all taro should be collected or whether other strategies should prevail depending on diversity and end use. The size of the proposed collection affects resources, and so perhaps it is preferable to establish a ‘core’ collection that captures as much diversity as possible. It is hoped that the workshop will help to resolve such questions.

2. REPORTS FROM TARO DEVELOPMENT PROJECTS

TaroGen (AusAID/SPC)

The project will enable the collection and conservation of taro germplasm in Pacific Island countries, and the use of those resources in plant improvement programmes. It is working with national programmes to develop regional strategies in each of these areas.

The status of taro collections varies between countries. Some, for instance, Fiji and New Caledonia, still retain collections and these have been documented using IBPGR descriptors. In other countries,

the collections have been lost due to disease, cost of maintenance and other factors, or the identification of accessions is in doubt. While assembling the collections and describing them in Polynesian countries is a relatively simple task, because genetic diversity is low, this is not the case in Melanesia. Substantial resources will be required. In Papua New Guinea, the task has already started with assistance from TANSAO; and in Vanuatu, germplasm collecting is being done by VARTC with assistance from CIRAD. The task ahead is to ensure that collecting strategies are soundly based, that methods of characterisation and data management are compatible and that there are sufficient resources for the work.

Virus indexing and DNA finger printing (ACIAR)

The virus-indexing will be carried out at QUT, and the DNA fingerprinting at UQ in association with MAFF&M, Samoa, NARI, UNITECH and USP. The research is financed by ACIAR.

The virus project developed as a result of the 1994 outbreaks of taro leaf blight in Samoa and American Samoa and the need to introduce resistant germplasm. Varieties were available, but in countries where virus diseases occur, and methods for detection were inadequate to provide the safeguards required to ensure safe movement. This led to the development of a project to characterise taro viruses, develop sensitive and specific diagnostic techniques, and establish a diagnostic capability for taro viruses in Papua New Guinea.

Virus characterisation will focus primarily on the particles associated with alomae and bobone. Two viruses have been found in plants with these diseases: dasheen (or taro) badnavirus and *Colocasia* bobone disease rhabdovirus. The badnavirus is widely distributed, but work needs to be carried out on transmission, and also to determine whether or not the virus is seed transmitted. The rhabdovirus has limited distribution, and is transmitted by *Tarophagus proserpina*. Dasheen mosaic virus is often found either alone or together with these viruses, but it is well characterised, although there is no information on the number of strains that exist.

It is anticipated that the virus diagnostic methods developed by the project will be easy to use and primarily serological, though it is possible that some DNA-based techniques will be required for the badnavirus. A scientist from Papua New Guinea will spend two years at QUT, and by the end of the project a diagnostic facility will be established at UNITECH.

DNA fingerprinting studies will be carried out at UQ. The work will facilitate identification and management of taro germplasm for the rationalisation of genetic resources, and in the process introduce Pacific Island countries to these new biotechnologies. The project will apply RFLP, SSR and ISSR markers to taro germplasm to develop cultivar and genotype fingerprints, use DNA marker information for genetic analysis of taro, establish a computer database incorporating DNA fingerprint information, train two Pacific scientists in DNA fingerprinting and database skills and hold a workshop so that scientists from other countries develop a familiarity with the work of the project.

The outcome of the study will be the development of techniques which have a number of applications to germplasm collections: the identification of duplicate accessions; solving problems concerned with rationalisation; and germplasm protection. The methods developed could also be

used for phylogenetic analysis, genetic diversity analysis, analysis of parentage and analysis of genetic integrity of plants maintained in tissue culture.

Similar, but complementary, work is being carried out by TANSAO working with countries of Asia. It was agreed that there is need for collaboration between UQ and Wageningen University, The Netherlands, the institute carrying out this work for TANSAO.

Taro leaf blight screening for resistance (NZODA)

Delays in finalising the contract between NZODA and HortResearch have delayed the start of the New Zealand inputs. It is expected that the details will be finalised in the near future.

A start has been made on collecting isolates of the fungus from a wide geographical area. Cooperation and exchange of cultures with TANSAO have been arranged for this purpose. Because diseased leaves decompose rapidly, collection of the fungus from remote areas presents problems. A technique is being developed which may allow the collection of pure cultures directly from the leaf surface. Plant pathology staff in Solomon Islands and Papua New Guinea will be testing the method in the near future.
Key elements of the proposed programme are:

- Development of a technique for assessing disease reactions of individual plants in breeding nurseries. The methods to be investigated include disease reaction type, and the use of field inoculations involving standardised inoculum load and specific target leaf;
- Determination of mating type of the fungus throughout the Pacific region; and
- Observations on the diversity of pathogenicity and other epidemiologically relevant characteristics amongst possible different strains of the fungus.

3. STATEMENTS ON BEHALF OF COUNTRIES AND REGIONS

Fiji

A collection of 72 taro accessions, with some duplication, exists at Koronivia Research Station. There are no plans for further collecting. The collection has been described, but there is need for further characterisation using the new set of IPGRI descriptors, and for the information to be transferred to a computerised database.

It was noted that the commercial importance of taro in Fiji sets the country apart from Papua New Guinea and Solomon Islands where the crop is mainly used for subsistence needs. In this context, one of the most pressing needs in Fiji at present is to find a solution to the storage decay caused by *Pythium*.

The discussion which followed the presentation highlighted the importance of TaroGen to Fiji and to other countries of the region, for instance, Cook Islands, French Polynesia, Niue and Vanuatu which do not yet have taro leaf blight. The intervention of the project offers them security and the reduction in vulnerability to a devastating disease which if introduced would annihilate taro production, as it has done in Samoa.

New Caledonia

There is a collection of 82 varieties, fully characterised and well maintained. Some of these are in tissue culture in the regional laboratories and have been distributed to other Pacific Island countries.

Papua New Guinea

The national taro collection is based at BARC. In 1986, it contained more than 600 accessions, mostly cultivars, and was fairly representative of the germplasm of the country, although taro from a few important areas were not present. The collection now contains only 301 accessions, with losses due to inadequate supervision and funding. In recent months, with TANSAO assistance, a further 311 accessions have been collected, but these have not been fully characterised. This needs to be done, further collections made, and the information obtained securely stored, using a system which is common to all countries of the region so that comparisons can be made.

The need to collect is becoming more urgent as the number of varieties maintained by growers decreases. In the Morobe province, for example, the variety Numkowec is commonly planted and farmers are not maintaining others for which there is no demand on local markets. Another indication that germplasm is being lost is the increasing number of requests from growers for planting material from national collections to replace varieties lost due to drought and other natural phenomena due to the impact of climate changes.

One major concern is funding. It has been estimated by the ACIAR project *The Economics of Preserving Genetic Diversity in Papua New Guinea's Indigenous Food Crops in the Context of World Agriculture* that the annual cost of maintaining 313 accessions in the field is K4,120, and K4,200 for the breeding programme. Papua New Guinea is willing to share germplasm, but there is a need to address the issue of maintaining a collection which is also of value to other countries.

A collecting strategy has been devised. It is felt that every effort should be made to recapture the entire genetic diversity of Papua New Guinea. Collecting should be carried out in major taro areas, especially in areas that are geographically isolated. Some areas, such as Bougainville, the Rabaraba area of Milne Bay Province, West New Britain Province and Oro Province were not visited by previous collecting expeditions. Collections should be made from sea level to 1,700m. Five priority areas have been selected for collecting, and the costs are estimated to be K27,000.

There was concern that as Papua New Guinea is involved in two taro projects, there might be overlap. However, the two projects are collaborating to develop the national collection, and because of this a greater number of priority areas can be included in the collecting strategy.

The relationship between the Papua New Guinea national taro collection of 301 accessions and those recently collected under TANSAO auspices drew considerable comment following the presentation. Although all germplasm should be considered part of the national collection, these two are being maintained separately because passport data and accession numbers of the national

collection are no longer reliable. This situation arose when the collection was moved to a new site. Whether or not it will be possible to identify the accessions is not yet clear, but it is thought unlikely. The collection contains useful diversity, so the best solution may be to describe it once more and assign new numbers to the accessions. Later, it may be possible to identify them by comparing description data with those of the TANSAO collection and any others collected subsequently. In this way, the size of the collection can be reduced to a more manageable number, keeping only those items that are not represented in the new national collection.

Vanuatu

In the 1980s, 162 taro accessions were collected throughout Vanuatu and described using the IBPGR descriptors. They were also analysed using isozyme markers. After removal of duplicates, 126 accessions remained, but these were lost due to drought and poor management. In addition to the loss of germplasm, descriptor records have also been lost or are not adequate.

As part of the national root crops programme of VARTC, re-collecting began this year, and to date more than 250 accessions have been assembled from the northern islands. These accessions are being characterised using a descriptor set devised by TANSAO. It is likely that 300–400 morphotypes exist, with some adapted to wetland, others to rain-fed conditions. The Vanuatu collection will be increased in 1999 with the addition of accessions from the southern part of the country.

The need to rationalise the collections from Vanuatu was emphasised because it is likely that large numbers of accessions will come from renewed collecting. However, rationalisation was often difficult as similar varieties collected from different locations may show variation when planted together. At present, the basis of rationalisation is not clear. Isozyme analysis is unlikely to be useful as it has indicated limited variation. It was suggested by Dr Rao that the rationalisation approach used for sweet potato could be applied to taro.

The issue of sustainability was again raised in discussions on the Vanuatu presentation, echoing concerns raised by Papua New Guinea. In the case of Vanuatu, funds were available for the next five years from EU-financed projects (SPYN and TANSAO), but after that time it is not known how collections might be maintained. Certainly those kept in the field will again become susceptible to loss, and the hope is that less expensive *in vitro* methods will have been developed by that time. The discussion emphasised the need for speedy characterisation of national collections, followed by comparisons between countries so that a regional conservation strategy can be developed which might reduce costs for all concerned. The ACIAR meeting in Lae, in March 1999 may address this problem of long-term maintenance.

Solomon Islands

No collection exists in Solomon Islands, although there are records of three having been made previously. They were lost due to inadequate funding, disease and natural disasters. The collections were not characterised, but there are records of agronomic interest. Also, a database containing 400–500 accessions remains from the collecting in 1987/88. It has accession numbers, vernacular names and isozyme profiles. It may be possible to determine geographical location from the

vernacular names. If so, then isozyme data could assist in devising a collecting strategy. In both Papua New Guinea and Solomon Islands, vernacular names are a good means of identifying varieties because each province/location has a specific name for each taro variety.

The strategy suggested by Solomon Islands is to re-collect from all provinces. High and low priority areas will be defined in each Province depending on the extent of taro grown and the ease of accessibility. The usefulness of these artificial divisions is open to conjecture, however, as some low-priority areas could contain unique genotypes, especially if they have a long history of taro cultivation. It is estimated that collecting costs would be US$5,000–6,000, and take 8–12 weeks. The Government will contribute to the task with the use of STABEX-FSP funds.

Polynesia

The situation in Polynesia was very different to that of Papua New Guinea and Solomon Islands. Collections that existed previously were relatively small in number[1]. At present, Samoa has 17 local varieties in a field gene bank (27 were held by UPS previously), and 12 of these are duplicated in tissue culture at USP. No characterisation has been carried out; however, it is known that all are susceptible to taro leaf blight. Fourteen varieties of taro are known in Tonga, on the basis of colour and striping of the petiole, but none are maintained in collections.

Niue has a very large number of varieties in relation to the size of the country. Fifty-two were collected and described by previous root crop projects, but collections no longer exist. Seven are maintained in tissue culture in the regional laboratories. In the Cook Islands, taro is grown under both rain-fed and wetland conditions. The collection once contained 34 local varieties and 26 from Niue. There is conflicting information as to what now exists, but if some are still present it is likely that the number is small.

In French Polynesia, there was a collection of more than 100 accessions, but this no longer exists. No collections have been assembled in Wallis and Futuna, but some 40–50 varieties are thought to be present.

The most straightforward and cost-effective strategy for estimating the genetic diversity of taro in Polynesia would be to collect from each country, tissue culture and virus index the plants, and then establish a comprehensive collection in one country in order to describe them and make evaluations. The question is which country? The locality would have to be free from taro leaf blight, as all varieties are likely to be susceptible to the disease and infection would make descriptor work difficult. The most appropriate and convenient location would be Fiji. If this was agreed, curators of country collections could collaborate by characterising the collections using IPGRI descriptors, identifying duplicates and using the information to develop a sub-regional conservation strategy.

ADAP

[1] Describing and Documenting Root Crops in the South Pacific. Guarino, L, and Jackson, GVH. Suva, Fiji, 1986. RAS/83/001. Field Document 12.

There is very little information on taro germplasm in ADAP countries, except for that concerning the taro leaf blight resistant/tolerant varieties of Palau and the Federated States of Micronesia. It was agreed, therefore, that collecting information on the germplasm of the sub-region would be the first activity. There was a general consensus that these countries should be welcomed to participate in the activities of TaroGen.

The question of whether any isoenzyme studies had been carried out on Micronesian taro was raised. None had been carried out due to lack of available material at the time when analyses were carried out in other countries of the region.

TANSAO

TANSAO is funded by the EU. The project, which began in January 1998, focuses on the characterisation of taro genetic resources in Papua New Guinea, Indonesia, Thailand, Malaysia, the Philippines and Vietnam. It is expected that a total of 1,700 accessions will be characterised, and the genetic diversity analysed using morphological descriptors and molecular markers (isoenzymes and AFLPs). From the collection, a core sample of 170 accessions will be selected, indexed and made available to participating countries as part of a regional network of *in vitro* exchange. TANSAO also aims to identify sources of diseases (taro leaf blight, dasheen mosaic, alomae and bobone), and to use them in targeted crosses; to assess the genetic diversity of *Phytophthora colocasiae* isolates originating from participating countries; to study the physiochemical characteristics of starch from the 170 selected genotypes; and to identify and overcome barriers preventing taro breeding.

It was acknowledged that the identification of the core sample of 170 accessions could be difficult as countries have different uses for taro and differ in their appreciation of taste and other quality characteristics.

4. GERMPLASM COLLECTION, DESCRIPTION AND DATA MANAGEMENT

Taro collecting

A paper entitled *Collecting taro genetic diversity: Elements of a strategy*, was presented by Dr Ramanatha Rao. The general principles of genetic resources collecting were given, and applied to taro in Pacific Island countries. The paper reviews the origin and domestication of taro because of its relevance to plant diversity. An Asian origin for taro is generally accepted, supported by chromosome studies and inferred from molecular analysis. Isozyme investigations showed highest diversity in taro from Indonesia, followed by Papua New Guinea and Solomon Islands. Polynesian taro showed a very narrow base. Relatively high levels of diversity were found in New Caledonia, possibly due to recent introductions. Plant diversity does to some extent determine collecting strategies, but there can be other reasons, for example, adaptive gene complexes which will respond to changes in environmental conditions.

Taro collecting in Pacific Island countries was reviewed as well as the methods used for conservation. Although some countries have had taro collections for many years, for others, the incentive to collect started quite recently with the formulation of UNDP/FAO/SPC root crop projects in the mid-1980s. Unfortunately, except for Fiji and New Caledonia, conservation of the

collections, mostly as field genebanks, has been a major difficulty and there is an urgent need to re-collect and improve maintenance.

There are various reasons for collecting taro germplasm; the most important are:

1. Missing or lost from *ex situ* collection (gap-filling collecting). TaroGen collecting will be mainly gap filling, in some cases 100 per cent! Gap filling is based on the diversity and ecogeographic information of existing collections.
2. Threatened diversity. In general, information on genetic erosion is hard to obtain, and most is anecdotal, with no system in place for monitoring its occurrence. There is a need to define the areas where the threat is high, even if this is based only on anecdotal information. In some situations, loss of diversity can be predicted with reasonable accuracy. For example, where there is monoculture, diversity is often reduced and vulnerability, especially to pests and diseases increases, which in turn can lead to further loss of diversity. The situation in Samoa is a good example: one variety was grown nationwide and this proved extremely susceptible to taro leaf blight, so much so that farmers have abandoned the crop. Other countries of Polynesia and Fiji are now vulnerable to the disease. Information on threatened diversity needs to be superimposed on that obtained from looking at the losses that have occurred in genebanks throughout the region to facilitate prioritisation of target areas for collection.
3. Needs for immediate use. Different countries have different needs, such as accessions resistant to taro leaf blight, or drought, those with early maturity, good quality and also those with adaptive traits. Information on the latest needs will have to be considered while developing the collecting strategy.
4. Diversity estimation. This can be used to develop a cost-effective conservation strategy based on ecogeographic distribution of genetic diversity, the partitioning of genetic diversity within and among populations, evolutionary relationships, and the history of domestication. Some information will be obtained in the course of fingerprinting and genetic diversity studies that are planned. When such information becomes available, it can be correlated with information on taro distribution, taro populations with unique traits etc., to further refine the conservation strategy that will be developed during the project period.

The concept of a benchmark collecting strategy was introduced by Dr Rao, based on choosing the site, calculating taro collecting importance values (TCIVs), and sampling at the site. TCIVs are arbitrary figures calculated for each division of the area where collecting is to take place, based on the following criteria:

- under-represented areas (identified from mapping passport data);
- complementary areas (genetically, environmentally or culturally different based on passport and characterisation data);
- environmentally or genetically diverse areas (previous missions showed the areas to be particularly diverse and further intensive collecting is required);
- areas with target genetic material (inferred from environmental conditions or from local knowledge); and
- threatened areas (local knowledge, visits or from monitoring).

It is proposed that each distinct taro growing area be divided into 40km x 40km grids. Each grid is then scored for each of the criteria listed above—under-represented areas, complementary areas, etc—on, say, a 1–5 scale. TCIVs are then calculated by adding the scores for each grid. Germplasm is collected in all grid squares, at a minimum of two sites (communities). If it can be determined that the material is of the same morphotype and/or environmental conditions are similar, the collecting sites should be at least 15km apart. Collecting is done more intensively (up to six communities) in grid squares which have a higher TCIV.

Sampling of all the morphotypes recognised by the collector in collaboration with the community at each sampling site is recommended. A minimum of three plants ('tops') of each morphotype is collected. 'Tops' should reach the genebank for processing within five days from collecting.

Based on these guidelines, the total number of accessions and plants that will be collected should be calculated before collecting begins. If the number is greater than that which can be effectively managed by the genebank and/or other users, the collecting strategy should be modified giving less importance to grid squares with lower TCIV. Over-collecting has to be avoided. If more than expected diversity is encountered, collecting the most popular cultivars (for immediate use), most threatened types and unique types is recommended. Information on the others can be recorded for subsequent collecting missions, for monitoring purposes or as a precursor to *in situ* conservation. The basic recommendation is for all areas of taro cultivation to be systematically and comprehensively covered, even if the same morphotypes are collected several times. There may be hidden genetic variation within morphotypes. However, the strategy can be modified. In Polynesia and Micronesia, for example, where there are a large number of small islands, the approach might be to collect on the main islands in each country and at least one other island. In each case, farmers would help produce lists of all known cultivars on each island and all these would be collected.

The effective management and use of genetic resources depends on the quality and quantity of associated data. The essential passport descriptors were outlined. It was stressed that one must not forget farmers' knowledge, in particular vernacular names and meaning, local criteria for distinguishing landraces, etc. This can help in recommending taro for a particular area, and also in evaluating on-farm conservation as it is likely that *ex situ* conservation of genetic resources will become ever more problematical in the future. It is clear that past collecting of taro in Pacific Island countries was hurried, and insufficient details were collected, especially those concerned with local uses, preferred methods of preparation and cropping systems. A decision-making process for developing a collecting plan for a particular region was outlined in the presentation

Dr Rao then discussed the usefulness of morphological descriptors and molecular markers noting that there were advantages and disadvantages in using both methods to characterise germplasm. There is the difficulty of using morphological descriptors when comparing different collections, and molecular methods can produce an inadequate picture of genetic diversity. They are complementary to other methods. Several molecular techniques exist and TaroGen may wish to focus on techniques that detect high levels of polymorphism and give consistent and repeatable results.

Maintaining taro in field genebanks is likely to be the main method of conservation for some time to come. It has the advantage that material is readily available for use; however, if it is the chosen method of conservation there is a need to be pragmatic about the size of the collection. There is also

need to consider the purpose of the collection. From past experience in Pacific Island countries, other complementary methods of conservation based on *in vitro* and *in situ* techniques will also be needed.

In vitro methods have considerable advantages, not least the potential to lower maintenance costs and safeguard losses due to insect pests, diseases and environmental factors, but research is needed before they can be applied reliably to taro. *In situ* conservation is a major component in any conservation strategy; however, for this form of conservation, it is best to choose communities where genetic diversity is being used by farmers. It is not an appropriate method if it demands cultural changes or changes to the farming system, for example to meet market demands. Nevertheless, in some circumstances it can be used for taro, as it is a major staple, culturally important and the genetic diversity is retained within traditional systems. It could also be used as a tool to monitor the impact of introducing high-yielding and taro leaf blight resistant varieties on traditional farming systems.

Work on *in situ* conservation in the Pacific should be linked to an IPGRI global project trying to understand its scientific basis. The four-year project involves taro in Nepal and Vietnam, so it should provide useful information. In conclusion, it was agreed that no single method can be relied on: a complementary conservation strategy has to be used.

Following the presentation, size of collections, costs of maintenance during characterisation and in the long term, and complementary *in vitro* and *in situ* methods were discussed.

The number of replicates maintained per accession determines the amount of land required for the field genebanks and this influences how much to collect initially. There was a consensus that three plants of each accession was a sufficient number in most instances, with the number of accessions dependent on the resources of the genebank in the short and long term. If evaluation is to be carried out immediately then larger numbers should be collected, based on the assumption that three to ten plants are required (larger numbers for statistical analysis). However, collecting ten plants of one variety is often not feasible. Alternatively, a smaller number can be collected and bulked either in the field or in tissue culture.

The question of maintaining collections during characterisation in Papua New Guinea was also raised, and a suggestion made that collecting should be slowed down as there are now 612 accessions (301 in the National Taro Collection plus 311 recently collected with support from TANSAO). However, it was pointed out that little was known about the 301 taro accessions, and they could not be taken to represent a large part of the national diversity, unless in the unlikely event isozymes or other molecular techniques could be used to identify them. It was important to calculate TCIV values and then make a decision on further collecting. It was suggested also that if sufficient germplasm could be collected, a separate collection could be established in tissue culture. This would guard against losses which might occur while the field collection is being characterised.

Reducing the number of accessions of a collection to a manageable number is extremely difficult, but a practical need. Funds for germplasm conservation are usually scarce, so maintaining all the varieties collected is not an option and priorities have to be set. How to do this is a major problem, as it is difficult to predict what will be needed in the future. A pragmatic solution is to base selection

on distinctive variation, ie drought tolerance, salt tolerance, etc. and hope that the collection also contains plants with other adaptive qualities.

Even after some rationalisation has taken place, costs of maintaining collections is often a contentious issue, and no less so with taro. Some countries have a disproportionate amount of germplasm in terms of the global genepool, and would like assistance from other countries that may benefit from the collections. Within the Global Plan of Action all Pacific Island countries have agreed to take responsibility for conservation of important germplasm, and it is expected that details of this commitment would be provided shortly, in which case the importance of taro should make it a priority crop for government funding, and perhaps regional collaboration.

In order to attract funding, conserved material needs to be useful; simply maintaining germplasm in a genebank may not guarantee this. Information on material is essential and so too is the need to pay attention to quarantine concerns. In addition, there is the matter of access to material in genebanks. Full information on an accession is important, but access to the material itself is more so.

Interest in *in situ* conservation was apparent throughout the workshop, and it is unfortunate that TaroGen does not have sufficient funds to begin studies on this important aspect of conservation. It is recognised that there are obvious risks associated with *in situ* conservation, but they are probably no greater than those associated with field genebanks or *in vitro* methods. Some indication of the security of germplasm maintained by farmers will become apparent during collecting expeditions, and based on this knowledge, rescue operations can be organised later if necessary. It is likely that *in situ* conservation will become important in the future, in which case TaroGen should endeavour to obtain funds to investigate the potential of the method. IPGRI will be able to provide guidance on technical aspects of the research.

Summary of collecting strategy for the Pacific Island countries.

Countries agreed to use the benchmark sampling strategy where possible so that TCIVs can be generated and sites determined using this information. In addition, based on the discussions held and the paper presented by Dr Rao all countries would try to follow a proposed decision-making process. This is outlined below:

- Assemble a planning team to reflect the different stakeholder groups.
- Determine the extent of cultivation of taro in the region in different agroecological zones.
- Gather and analyse passport and characterisation/evaluation information on existing collections.
- If such information is lacking or insufficient, consider carrying out characterisation work on existing collections and/or mounting an exploratory genetic diversity field survey using indigenous knowledge, morphological characters and/or DNA markers.
- Determine and prioritise among present user needs.
- Visualise future needs.
- Gather information on main threats of genetic erosion.
- Identify and prioritise areas within the area of cultivation based on lack of coverage, present need and threat of genetic erosion.
- If sufficient information is available on specific diversity or specific taro types in certain areas, consider collecting of such types as a priority.

- Determine if the number of accessions resulting from the collecting programme will be manageable, if not, change sampling parameters.
- Determine the route(s) necessary to sample efficiently all priority areas.
- If available resources do not allow visiting all priority areas, investigate the possibility of decentralising collecting in some areas (ie involving NGOs, CBOs, etc.)
- If a particular route is likely to result in the collecting of too much germplasm for the transport available, or an inability to get 'tops' back to the genebank within five days of collecting, investigate decentralisation of collecting and/or collecting *in vitro*.
- Decide on and assemble a collecting team.

Following the presentation, countries reassessed how they would approach the collection of germplasm; the following are the conclusions of those considerations:

Papua New Guinea

- The following persons were identified as curators: Rosa Kambuou, Tom Okpul, Norah Omot, Peter Gendua, Jimmy Risimeri, Pere Kokoa and Janet Paofa. The site for the location of the collection will be BARC.
- There is a need to redescribe the 301 accessions of the national taro collection. Existing database information will be used to try and get some indication of where the accessions originated, however, it is unlikely that this will be successful as the accession numbers are unlikely to be accurate.
- As the maximum number of accessions that can be maintained at BARC is 600 due to restrictions on available land, either the collecting will have to be delayed until the 301 accessions are redescribed and the collection rationalised, or other arrangements found for new collections, for instance, maintenance at LAES, on farmers' land, in tissue culture in Papua New Guinea or at the SPC Regional Germplasm Centre. These various options will need to be considered before a collecting strategy is devised.
- Some regions have not been previously collected and these will be incorporated in future plans. Assistance on additional areas will also be obtained from two projects: *Mapping Agricultural Systems* and *Papua New Guinea Resource Information System*; the latter will assist in the development of a map of taro cultivation in the country. Philip Vovola and Sharryl Ivahupa will be involved in this work.
- Using all this information it was agreed that a proposal for funding to support collecting activities should be submitted to TaroGen by the middle of January 1999.

Solomon Islands

As no collection exists in Solomon Islands, re-collection throughout the country is required. The following factors will need to be considered:

- In developing a collecting strategy, the first consideration is where the collection will be maintained, whether at Tenaru Field Experiment Station, Guadalcanal; or Fote Research Station, Malaita. Tenaru is in a dry area and taro collections would require irrigation; however, it is close to Dodo Creek Research Station, and so it has the advantage of accessibility which is a major consideration for a field gene bank. In addition, there is no threat from alomae, unlike at Fote.

- On the basis of Dr Rao's paper it is likely that the collecting strategy will have to be rethought. Threatened areas have been identified during this meeting and some of the low priority areas will change. However, funding is limited, so priority areas will have to be categorised into low, medium and high, for example.
- Whether the database developed previously which contains information on past collections can be used to identify future collecting sites needs to be assessed.
- There are similar constraints to accessing material from certain provinces (a problem also noted in Papua New Guinea). Local access rules should be adhered to (see *FAO International Code of Conduct for Plant Germplasm Collecting and Transfer*), but at the same time, if a province feels strongly about germplasm within its area of jurisdiction then it should take responsibility for its conservation. However, if material cannot be collected, information will be recorded for monitoring purposes, as well as for any future *in situ* conservation programme.
- Actual numbers of plants to be collected will have to be determined at the point of collecting, but attempts should be made to collect as many morphotypes as possible, and for each one a minimum of three.
- Solomon Islands would like to maintain the collection in tissue culture as security against losses in the field genebank. If this is done at the same time as the establishment of the field genebank then it will necessitate additional plants being collected.

It was agreed that the revised proposal for collecting in Solomon Islands would be submitted by the middle of January 1999, and that funding for maintenance during the period of characterisation should be included in the proposal.

Vanuatu

The VARTC will take responsibility for collecting and maintenance of collections, continuing the work that began in 1998.

Other countries

There may be justification for further collecting in New Caledonia as wild taro have been found recently, and also it is possible that immigrants have introduced varieties that are not in the national collection. Fiji will consider further characterisation of the national collection using the latest IPGRI descriptors.

Resources permitting, TaroGen will assist Cook Islands and Niue to recollect, as unique material might be present, and encourage Futuna to make a collection of the 40-50 varieties that are cultivated in irrigated terraces. (Tonga is interested in such material as it intends to develop taro cultivation in swamplands.)

The development of a taro project in Micronesia combining the five Land Grant colleges will be discussed at a meeting of Directors of ADAP in January 1999. Collections of taro are required as well as those of *Cyrtosperma* because of the unique diversity found in that region.

Taro Descriptors

The proposed list of descriptors was circulated, based on the work of several experts. The workshop was asked to decide which ones to use for TaroGen documentation. There was a discussion about the difference between collection and accession numbers. The collection number is the one used at the time of collecting; in the case of Papua New Guinea the collection number starts with the initial of the collector. The accession number is the one that is used at the time of the accession going into the genebank. The accession numbers must stay with the sample; different ones should be given for each field genebank. The use of a geographic positioning system is recommended so that mapping can be accurate; in addition, it is preferable to use an altimeter rather than dividing altitude into arbitrary rankings. The afternoon was spent at BARC applying the descriptor list to the taro in the field collection.

The majority of descriptors was accepted, and some modifications were suggested to IPGRI to consider while finalising the descriptor list.

Database Management

The Data Interchange Protocol allows everyone to use their own software, and still exchange information. DIP is based on a fixed length ASCII file format that is not software or hardware dependent. Like any ASCII-based format, it is suitable for the exchange of alphanumerical data, the form of most genetic resource data. Although DIP is not the only way to exchange data on genetic resources, it provides a means for data exchange that is accessible through any form of computing platform. Facilitating data exchange guarantees against loss of information, as someone, somewhere will have received and stored the information.

Participants were shown that Excel 97 can be used as a database system. The functions of data validation and conditional formatting were highlighted which enable Excel 97 to be more effective as a database system. Using Word 97 and Excel 97 the ease of moving data around with the Data Interchange Protocol was demonstrated. Curators are therefore not dependent on any one specific software package and can start to collect descriptor information even when they do not have any database software. As stated earlier, DIP also facilitates the exchange of germplasm information.

Participants were shown how to transfer the descriptor field names from the database spreadsheet to a word-processing document so that a Collecting Form could be formulated for use on collecting trips. One hundred and four descriptors were selected for use in this form.

Participants were encouraged to use these systems. Training can be provided by IPGRI via e-mail from Paul Quek (P.quek@cgiar.org). It was suggested that a manual which explains the various systems step-by-step would be useful.

A paper was presented by Paul Quek on *Documenting indigenous knowledge: The need for an IK journal*. This paper suggests a means by which the knowledge generated by farmers can be documented in the same way as knowledge from the formal sector. In this way farmers' rights can be protected in recognition of their knowledge. (It has been pointed out since the meeting that a journal *Indigenous Knowledge and Development Monitor*, produced by the Centre for International Research and Advisory Networks exists.)

IV. LIST OF PARTICIPANTS

ADAB
Diana R. Greenough, ADAP Plant Diagnostic/Research Lab, Northern Marianas College
P.O. Box 1250, Saipan, MP 96950. Tel: 670 644 5902, Fax: 670 644 5910
Email: dianag@nmcnet.edu

Australia
Ian Godwin, School of Land and Food, University of Queensland, St Lucia campus
Queensland 4072, Australia, Tel: 61-7-3365-2141, Fax: 61-7-3365-1177
Email: i.godwin@mailbox.uq.edu.au

Rob Harding, QUT, School of Life Science, Gardens Point Campus, GPO Box 2434
Brisbane, QLD 4001, Australia, Tel: 617-3864-1379, Fax: 617-3864-1534
Email: r.harding@qut.edu.au

Emma Mace, School of Land and Food, University of Queensland, St Lucia Campus
Queensland 4072, Australia, Tel: 61-7-3365-1518, Fax: 61-7-3365-1177
Email: emma.mace@mailbox.uq.edu.au

Mary Milne, Department of Agricultural Economics, University of Sydney, NSW 2006,
Australia, Tel: 61-2-9351-4843, Email: m.milne@agec.usyd.edu.au

Fiji
Aliki Turagakula, MAFF Koronivia Research Station, P.O. Box 77, Nausori, Fiji.
Tel: 679-477044, Fax: 679-400262

IPGRI
Paul Quek, IPGRI-APO, P.O. Box 236, UPM Post Office, 43400 Serdang, Selangor,
Malaysia. Tel: 603-9423891, Fax: 603-9487655, Email: p.quek@cgiar.org

Ramanatha Rao, IPGRI-APO, P.O. Box 236, UPM Post Office, 43400 Serdang, Selangor
Malaysia. Tel: 603-9423891, Fax: 603-9487655, Email: v.rao@cgiar.org

New Zealand
Bob Fullerton, HortResearch, P.B. 92169, Auckland, New Zealand,
Tel: 64-9815-4200, Fax: 64-9815-4200, Email: rfullerton@hort.cri.nz

Papua New Guinea
Peter Gendua, NARI, Bubia Agricultural Research Centre, P.O. Box 1639, Lae
Papua New Guinea. Tel: 675-475-1033, Fax: 675-475-1034

Mark Johnston, NARI, P.O. Box 4415, Lae, Papua New Guinea.
Tel: 675-472-1751, Fax: 675-472-2242 Email: mjohnston@global.net.pg

Rosa Kambuou, NARI, P.O. Box 1828, Port Moresby, NCD 122, Papua New Guinea
Tel: 675-328-1068/1015, Fax: 675-328-1075

Pikah Kohun, NARI, Bubia Agricultural Research Centre, P.O. Box 1639, Lae
Papua New Guinea. Tel: 675-475-1033, Fax: 675-475-1034

Pere Kokoa, NARI-LAES Keravat, P.O. Box 204, Kokopo, ENBP, Papua New Guinea
Tel: 675-983-9145, Fax: 675-983-9129

Brown Konabe, NARI-LAES Keravat, P.O. Box 204, Kokopo, ENBP, Papua New Guinea
Tel: 675-983-9145, Fax: 675-983-9129

Tom Okpul, NARI, Bubia Agricultural Research Centre, P.O. Box 1639, Lae
Papua New Guinea. Tel: 675-475-1033/1198, Fax: 675-475-1034,
Email: nariwll@datec.com.pg

Norah Omot, NARI, Bubia Agricultural Research Centre, P.O. Box 1639, Lae
Papua New Guinea, Tel: 675-475-1033, Fax: 675-475-1034

Janet Paofa, NARI, P.O. Box 1828, Port Moresby, NCD 122, Papua New Guinea
Tel: 675-328-1068/1015, Fax: 675-328-1075

Philip Vovola, NARI, P.O. Box 4415, Lae, Papua New Guinea
Tel: 675-472-1751, Fax: 675-472-2242

Jimmy Risimeri, NARI, Bubia Agricultural Research Centre, P.O. Box 1639, Lae
Papua New Guinea. Tel: 675-475-1033, Fax: 675-475-1034
Email: nariwll@datec.com.pg

Shanyl Ivahupa, NARI, P.O. Box 4415, Lae, Papua New Guinea
Tel: 675-472-1752 Fax: 675-472-2242

Innocent Onwueme, UNITECH, Private Mail Bag, Lae, Papua New Guinea
Tel: 675-473-4450, Fax: 675-475-7196, Email: ionwueme@hotmail.com

Vanuatu
Vincent Lebot, Tagabe Research Station, Port Vila, Vanuatu.
Tel: 678-25146, Fax: 678-25146, Email: lebot@vanuatu.com.vu

Solomon Islands
Jimi Saelea, Dodo Creek Research Station, Ministry of Agriculture & Fisheries, Box G13
Honiara, Solomon Islands, Tel: 677 20308/21327/31111, Fax: 677 31037/21955

James Samu, Dodo Creek Research Station, Ministry of Agriculture & Fisheries, Box G13
Honiara, Solomon Islands, Tel: 677 31111, Fax: 677 31037

TaroGen

Param Sivan, SPC, Private Mail Bag, Suva, Fiji.
Tel: 679-370733, Fax: 679-302212, Email: ParamS@spc.org.fj

Mary Taylor, SPC, Private Mail Bag, Suva, Fiji
Tel: 679-370733, Fax: 679- 302212, Email: maryt@spc.org.fj

Annex 1

Collecting taro genetic diversity
Elements of a strategy

V. Ramanatha Rao, Luigi Guarino and Grahame Jackson[2]

1. INTRODUCTION

The strategic objective of collecting genetic resources is to obtain, conserve and make available to breeders and other users as much of the genetic diversity within a given genepool as is feasible. However, this aim has to be tempered by practical constraints: in most circumstances it will be possible to manage only a limited number of samples.

Genetic diversity is not evenly distributed in space and in time, and is not of equal value to all users. Since resources for conservation are limited, some regions have to be accorded higher priority for conservation interventions (including collecting) than others. There may be a range of reasons for this; there may be a gap in an existing collection, or important material may be threatened with disappearance in the field. Thus, the reason for collecting will determine, to a large extent, the methods used for collecting.

In this document, the general principles of genetic resources collecting are described, and applied to taro in Pacific Island countries within the region served by the Secretariat of the Pacific Community (SPC). The result is a set of guidelines which can be adapted by national, regional and international taro conservation programmes in developing priorities for collecting genetic diversity.

Formulation of a sound collecting strategy for a genepool must start with assessments of the ecogeographic pattern of genetic diversity, and its representation in existing collections. These issues are discussed in Sections 2 and 3, followed in Section 4 by conservation methods. Section 5 provides a rationale for further collecting. and Section 6 outlines a strategy. The paper concludes with brief remarks on overcoming some of the barriers which exist commonly in preventing germplasm collections being useful and made freely available to agronomists and plant breeders worldwide.

2. TARO GENETIC DIVERSITY

Taro (*Colocasia esculenta* (L.) Schott) is a root crop of the family Araceae which is found world wide. It is thought to be a crop of great antiquity. It was mentioned in Chinese literature as early as 100 B.C., and was growing in Egypt at the beginning of the Christian era (Whitney *et al.*, 1939; Plucknett *et al.*, 1970). It is a plant grown both for its corms as well as its leaves (Plucknett, 1976).

A commonly accepted view is that South East Asia is the centre of origin and domestication of taro, with Papua New Guinea a major centre of diversity (Léon, 1977). In recent years this view has been challenged. For several other crops, for instance, sugarcane, coconut and banana, a western

[2] Senior Scientist, Genetic Diversity/Conservation, Regional Office for Asia, the Pacific and Oceania, Serdang, Malaysia and Senior Scientist, Genetic Diversity, Regional Office for Americas, Cali, Colombia, International Plant Genetic Resources Institute, and Technical Director, TaroGen, Sydney, Australia

Melanesian centre of origin has been largely accepted, and there is now circumstantial evidence that taro and yam may have been domesticated in that area too. Attention has mainly focused on Papua New Guinea, with evidence of human settlement in that country as far back as 40,000 years, and of agriculture for 9,000 years (Golson, 1991; Golson and Hughes, 1980). This has increased speculation as to the food plants used. Recent finds of fossil pollen grains thought to be those of *Colocasia* and *Alocasia* on stone tools in deposits dated at 28,000 years B.P. have added to the debate (Loy *et al.*, 1992). Recent summaries can be found in Yen (1993) and Matthews (1995).

A study of chromosome numbers previously suggested the transfer of diploid taro from South East Asia into Oceania, followed by recent introduction of triploids (Yen and Wheeler, 1968). This view has now been substantially modified. From a comparison of chromosome morphology (karyotyping) of taro from the Pacific and Asia, including wild forms in Papua New Guinea, Coates *et al.* (1988) suggested a natural distribution of taro from Asia in the late Tertiary, rather than a distribution by human migrations from Asia 5,000-6,000 years ago. They recognised an Indian-South East Asian origin for at least one form, and speculated that domestication occurred in Asia and also in New Guinea, followed by transfer eastwards into Polynesia. Most wild and cultivated Pacific taro are diploids, of similar karyotype, and could have given rise to triploids by autopolyploidy. However, they are distinct from the triploid taro of Asia (Fig. 1).

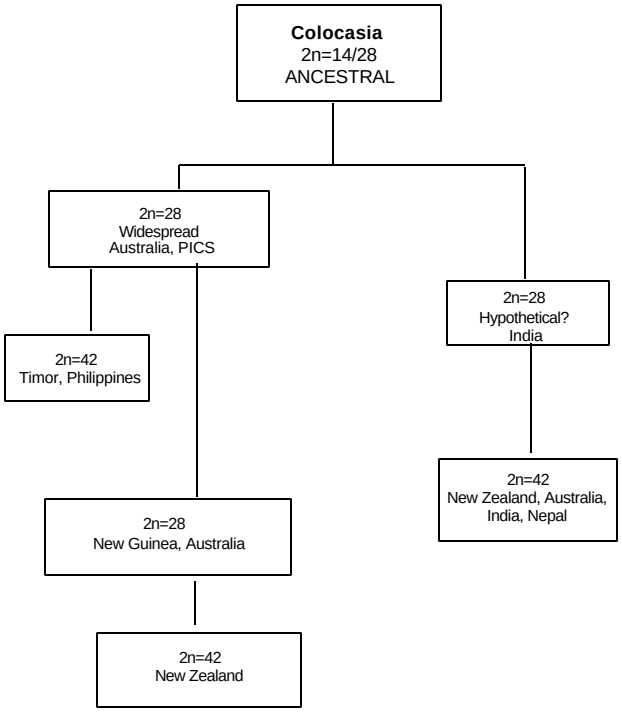

Fig. 1 Phylogenetic relationships between Asian and Pacific taro (after Coates *et al.*, 1988). Note: The scheme allows for recent introductions of triploids to New Zealand and Australia from Asia (cf Yen and Wheeler, 1968), and of a local triploid form in New Zealand derived from the dominant form of Pacific Islands, in contrast to triploid introductions.

Such a view is not entirely in agreement with ribosomal DNA analysis of the same material used for karyotyping (Matthews, 1990). An Asian origin for taro was accepted as being probable, but domestication is considered to have occurred over a wide area involving genetically and phenotypically

diverse wild forms that evolved in geographic isolation from each other. The only wild form so far identified is *C. esculenta* var. *aquatilis* whose natural range extends from northern India to Australia and Papua New Guinea, and which may be the ancestral progenitor of cultivated taro (Matthews, 1991; 1995).

In another study, comparing isoenzymes of 1417 cultivars and wild forms from Asia and Oceania (Lebot and Aradhya, 1991), results showed that a majority of taro from Indonesia differed from those of the Philippines and Oceania. Furthermore, taro from Polynesia constituted a narrow genetic base. Among 193 cultivated taro from Polynesia, all gave the same isozyme fingerprint for six enzymes, and variation for one enzyme was found in only three cultivars from French Polynesia. Hence, the cultivated taro in Cook Islands, Easter Island, Hawaii, New Zealand, Niue, Samoa and Tonga exhibit an extremely narrow genetic diversity. Greatest variation was found in taro from Indonesia, more so than in taro from Papua New Guinea, Solomon Islands and New Caledonia. Variation in Vanuatu taro was low. Substantially higher levels in New Caledonia were probably due to recent introductions from Indonesia and Vietnam.

These findings have obvious bearings on genetic resource programmes:

1. Papua New Guinea and/or Indonesia could have been areas of domestication and remain important centres of diversity;
2. genetic variation in taro from Polynesia is low compared to the range for the species;
3. wild taro may be phenotypically similar, but genetically different.

Although the origins of the crops and their areas of domestication may still be argued, what is not in dispute is the extensive phenotypic variation present in Pacific Islands. This is due to somatic mutation, sexual recombinations, and intense selection by isolated human communities for suitability in diverse environments. The importance of the genetic resources of taro in Pacific Island countries may reside, therefore, in the adaptation of cultivars to local conditions, irrespective of the genetic diversity which exists, compared to that present in the larger gene pools of the species.

3. WHAT GERMPLASM HAS BEEN COLLECTED IN THE PAST?

For most countries, the opportunity to collect, document and use their genetic resources, as well as to exchange them with others, came only recently with assistance from three UNDP/FAO root crop projects (RAS/74/017; RAS/83/001; RAS/86/034) from 1980 to 1991. Some countries, most notably, Fiji, New Caledonia, Papua New Guinea and Solomon Islands, had already assembled collections prior to this period, but for several others, collections either did not exist or were poorly representative of the total national germplasm. None of the collections were described, and a major task of the regional projects was to produce country catalogues of the germplasm, using internationally agreed taro descriptors (IBPGR, 1980). Additional resources were provided by IBPGR with interns in Solomon Islands and Papua New Guinea, and a short-term consultant assisting regionally with the documentation of the collections.

The results from the germplasm studies have been detailed in several publications (Jackson and Breen, 1985; Guarino and Jackson, 1986), and summarised (Jackson and Firman, 1987; Jackson, 1994). The work on descriptors showed the practical use to which they might be put: they showed that a reduced number of descriptors, from those published by IBPGR, could adequately distinguish varieties and avoid the otherwise daunting task of collecting data according to the published format. This, it was assumed, would provide a rapid method for identifying duplicates. The identification of duplicates is

important for three reasons. Firstly, collections can be reduced in size and this reduces costs of maintenance; secondly, it allows varietal performance to be compared between countries, including the identification of types stable in different environments; and thirdly, it avoids countries testing varieties that are already present.

Table 1 summarises the state of collections in nine countries in 1986. It can be seen that a good start had been made in a comparatively short time: collections of taro were present in most countries, although there were considerable differences in the extent to which they were considered to be representative of the total crop germplasm. Documentation of the collections and preliminary evaluations, however, presented problems.

In 1994, a survey of taro collections in Pacific Island countries was carried out by questionnaire (Jackson, 1994). By that time, total losses were noted in Cook Islands, Niue, Solomon Islands (two remained), Tonga and Vanuatu, but collections remained in Fiji, Papua New Guinea, New Caledonia and several smaller countries. The current situation of *ex situ* collections of taro in the region is discussed below. Overall, the situation is little different from 1994.

Table 1. Collections of taro in nine Pacific Island countries in 1986 and 1994.

Country	1986	1994	Country	1986	1994
American Samoa	-	12	Papua New Guinea		
Cook Islands	57	0	LAES[3]	-	48
CNMI[4]	-	6	Laloki	135	0
Fiji	72	78	Bubia	120	450
French Polynesia	-	34	Aiyura	52	?
FSM[5]	-	0	Saramandi	-	23
Guam UG	-	6	Samoa		
Hawaii	-	>400[a]	MAFF&M[6]	20	17
Kiribati	-	6[b]	USP	28	106[c]
Marshall Islands	-	20	Solomon Islands	31	2
New Caledonia	?	86	Tonga	14	21[b]
Niue	52	0	Tuvalu	13	13
Palau	-	6	Vanuatu	138	0

[a] Local, as well as accessions from Asian and Pacific countries; [b] Importations from USP/IRETA[7]. Tonga also has importations from Hawaii; [c] In tissue culture.

3.1 Polynesia

3.1.1 American Samoa

[3] Lowlands Agricultural Experiment Station
[4] Commonwealth of the Northern Marianas
[5] Federated States of Micronesia
[6] Ministry of Agriculture, Forests, Fisheries and Meteorology
[7] University of the South Pacific/Institute for Research, Extension and Training in Agriculture

Collections of local germplasm are no longer maintained, due in part to extreme susceptibility of cultivars to taro leaf blight. About 20 cultivars have been introduced from Palau and these are being multiplied for distribution to growers.

3.1.2 Cook Islands

In 1982, a preliminary description was made of the taro of Cook Islands, and they were photographed (RS Nauta, unpublished). Descriptions were completed in 1985/6. In 1986, 26 of the 57 varieties were from Niue (Guarino and Jackson, 1986). The present status of collections at Totokuitu Research Station is not known to the authors, but in 1994 none were present

3.1.3 Fiji

The collection of 78 accessions continues to be maintained at Koronivia Research Station. Varietal evaluations have been documented (Haynes and Sivan, 1977; Sivan, 1981).

3.1.4 French Polynesia

The present status of the collection is unknown to the authors. Previously, accessions were held *in vitro* (Leon Mu, personal communication).

3.1.5 Niue

Some 50 varieties have been described in Niue, a large number in relation to the land mass of the atoll. Eleven cultivars are in tissue culture at USP, Alafua. These were considered to be the most important on the atoll, and the qualities have been documented (Jackson, 1990).

3.1.6 Samoa

MAFF&M no longer maintains a collection of taro, nor does USP. Some local cultivars and about 20 from FSM, Palau and the Philippines have been used as parents in a breeding programme and are still maintained. MAFF&M has seedlings from these crosses under evaluation.

USP holds a collection of about 140 accessions of taro *in vitro*. These are from most Pacific Island countries, with the exception of Papua New Guinea and Solomon Islands, where lethal virus diseases and the lack of virus indexing techniques prevent the safe international movement of germplasm. Some are duplicated at SPC, Fiji.

3.1.7 Tonga

In 1994, Vaini Research Station was maintaining taro from USP, Alafua and also importations from Hawaii. The present status of the collection is unknown to the authors.

3.2 Micronesia

A small collection of taro is maintained in Guam, but elsewhere collections no longer exist.

3.3 Melanesia

3.3.1 New Caledonia

The collection in New Caledonia is complete and characterised using TANSAO descriptors. There are 120 accessions, including some from Wallis and French Polynesia. Selections have been made and the collection is maintained in two locations: Port Lagurre and Wagap Research Stations. The collections are representative of the diversity in the country (Vincent Lebot; personal communication). A few of the most popular cultivars are in the USP, Alafua tissue culture collection.

3.3.2 Vanuatu

Collections of the 1980s have been lost completely and are being re-assembled by the Vanuatu Agricultural Research and Training Centre, with support from CIRAD[8]. So far, about 100 accessions have been collected, but they have not yet been characterised. Some accessions are maintained in Hawaii (John Cho, University of Hawaii; personal communication); these are: Van 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 18, 19, 20, 22, 24, 25, 26, 32, 33, 36, 37, 38, 43, 44, 46, 49, 54, 55, 61, 63, 64, 70, 78, 84, 90, 94, 96, 97, 98, 100, 102, 103, 106, 110, 114, 119, 121, 123, 129 and 161. The numbers refer to the accessions previously described and evaluated (Van Wijmeersch and Bule, 1988).

Selected varieties from the evaluations are: Van 1, 7, 9, 30, 38, 43, 50, 52, 54, 57, 76, 81, 83, 85, 89, 97, 106, 114, 119, 123, 127, 129, 136, 144. Many of these are maintained as tissue cultures at USP, Alafua.

3.3.3 Solomon Islands

A collection of taro containing 187 accessions was assembled at Dala Experiment Station in 1969. Most were from Malaita. The collection was assessed for yield, resistance to taro beetle (*Papuana* spp.) and storage (Gollifer, 1970). Descriptions of leaf and corm morphology were sent to Dr D.J. Rogers, Taximetrics Laboratory, University of Colorado, USA, for use in devising a system of classifying taro. In addition, the collection was screened for resistance to taro leaf blight (*Phytophthora colocasiae*) and to the virus diseases, alomae and bobone.

The collection was destroyed in 1974 by alomae. With the start of taro breeding programmes against taro leaf blight in the early 1980s, taro varieties were again collected. From a small collection of about 35 maintained for the first phase of the programme, the collection was expanded in a national collection by the late-1980s, and maintained at Avu Avu, Guadalcanal. This collection contained several hundred accessions and contributed varieties to the second phase of mass recurrent selection. With the decline in external funding for taro breeding, the collection was later abandoned.

3.3.4 Papua New Guinea

The national collection of taro is maintained at Bubia Agricultural Research Centre. Initially, there were more than 600 accessions, but the number had declined to 437 by 1996 due to the pest infestations, unfavourable weather and poor maintenance (Kambuou, 1996). Further losses occurred in the drought of 1997, reducing the collection to about 300 accessions. The collection has been only partially characterised using modified IBPGR descriptors, and important passport data is missing. More recently, it has become apparent that accessions cannot be properly identified and a new collection is required. Smaller collections exist at LAES, Keravat (100) and Saramandi Research station (20). Neither of these smaller collections has been described.

[8] Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France

The number of taro maintained in 1995, and their derivation within Papua New Guinea is shown in Fig. 2. From Fig. 2 it is apparent that there are taro growing areas in Papua New Guinea that have not been visited by collecting expeditions. These areas include Bougainville, the Rabaraba area of Milne Bay Province, and West New Britain and Oro Provinces. The past collecting expeditions concentrated on the major taro growing areas of Morobe, Madang, East Sepik, East New Britain, Manus and Central Province.

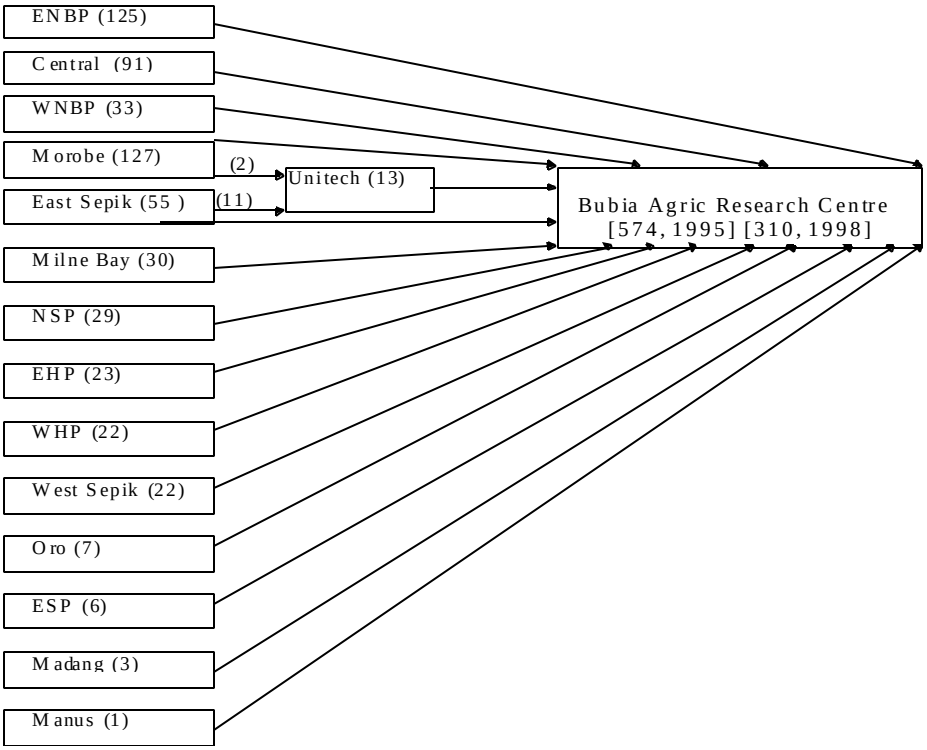

Fig. 2 Movement of PNG taro germplasm to the national germplasm collection Bubia Agricultural Research Centre (BARC), 1985-1995 (from Milne *et al*., in preparation)

4. METHODS OF CONSERVATION OF TARO COLLECTIONS

A basic approach to taro genetic resource conservation and use through a multidisciplinary understanding of diversity, agroecosystems and complementary conservation methods has been suggested (Ramanatha Rao, 1994). Currently, taro conservation is focused on *ex situ* field collections, with national breeding efforts concentrated around them. However, these collections can be expensive to maintain and are vulnerable to natural disasters and disease outbreaks. There appear to be two important considerations in the long-term conservation of *ex situ* collections: first, the linkage between long-term conservation and use—if this is not realised, conservation is neglected and genetic erosion occurs (IPGRI, 1995); second, rationalisation of collections to a manageable size (Ramanatha and Schmiediche, 1996), and structured on the basis of use of accessions, type of material and genetic diversity (Nissilä *et al*., 1997).

Other methods of *ex situ* conservation are being used or investigated. It is possible to conserve taro *in vitro*, by cryopreservation (Takagi *et al*., 1997) or as slow-growing plantlets in culture by adjusting temperatures (Staritsky *et al*., 1986). Maintaining cultures *in vitro*, with extensive intervals between sub-culturing, will have distinct advantages over field genebanks. By contrast, where long-term conservation of germplasm is the aim, cryopreservation at very low temperatures, usually that of liquid nitrogen (-196°C), is the only method currently available.

Tissue culture offers some solutions to the problems associated with field collections, but it is not without its own limitations. Collections are not as vulnerable to external factors, such as pests, diseases and natural disasters, and maintenance costs can be low, but the initial costs to equip and staff a tissue culture laboratory are high; there is a need for recurrent funding; contamination of cultures is a possibility; and genetic changes may occur due to stresses imposed by storage conditions. Tissue culture has been used in Pacific Island countries mainly as a means of transferring vegetatively propagated crops, and for satisfying quarantine regulations. It has not been explored as a method of germplasm conservation, except for the small, active collections maintained by USP and SPC.

In order to determine the conditions and costs involved, a pilot *in vitro* active genebank will be established by the AusAID/SPC project *Taro Genetic Resources: Conservation and Utilization* (TaroGen) in order to provide information on which countries can make decisions on conservation strategies.

Collecting germplasm for *ex situ* storage is not the only feasible conservation strategy. According to the Convention on Biological Diversity, *in situ* conservation refers to the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they developed their distinctive characteristics. *In situ* conservation of taro has not been explored, but could hold promise in areas of high diversity, where local communities are actively managing the genetic diversity of the crop.

There are many areas in Melanesia where taro, in particular, is a major staple, culturally important, and where genetic diversity is purposely retained within traditional systems that are unlikely to change radically in the foreseeable future. TaroGen will assist the Farm Support Association, a non-governmental organisation in Vanuatu to work with communities in a pilot project to develop guidelines for *in situ* conservation that may serve the region.

Monitoring taro genetic resources in any of the areas chosen for *in situ* conservation research will need careful documentation of varieties, both those that are currently grown and those of the past. Periodic visits would be required to document changes, by re-collecting cultivar names, and by confirming the authenticity of cultivars using morphological descriptors and, if possible, molecular methods. Research of this kind would be well placed to measure the impact of high yielding taro varieties, either selections from indigenous collections or those from breeding programmes.

The idea of on-farm conservation is not entirely new to Pacific Island countries. With the recent interest in conservation through development ideologies, some thought has been given to utilising traditional crops in novel, ecologically sound, ways, as commercial alternatives to logging rainforests. Non-government organisations have been particularly prominent in this initiative. In Vanuatu, for instance, the Foundation for the Peoples of the South Pacific has encouraged the collection, planting and marketing of *Dioscorea nummularia*, so-called wild yam, in order to provide sustainable ways of using forest resources (Suliana Siwatibau, Program Co-ordinator, personal communication). Making use of germplasm in commercial ventures of this kind, and at the same time reinforcing traditional

conservation concepts and practices, may make more sense than passively monitoring diversity in the hope that losses will not occur.

Ideally, on-farm conservation should be used to complement *ex situ* collections. No single approach is likely to be effective in conserving the full range of variation within any crop genepool and at the same time ensuring that it is valuable to breeders and other users, and taro is no exception. Collecting germplasm for *ex situ* conservation should thus be regarded as one of the components in a comprehensive strategy for conservation of taro genetic resources.

5. WHAT ADDITIONAL GERMPLASM NEEDS TO BE COLLECTED?

Although countries have tried to conserve taro germplasm in field and *in vitro* genebanks, the efforts have not resulted in permanent collections. Further collecting is required, coupled with better methods of conservation. In general, collecting may be justified if:

1. diversity is missing or has been lost from existing *ex situ* collections;
2. diversity is in imminent danger of disappearing from the field;
3. diversity is needed for immediate use;
4. diversity estimation is needed to develop a cost-effective conservation strategy.

5.1 Diversity is missing or has been lost from existing *ex situ* collections

The various existing *ex situ* collections may not be fully representative of the germplasm available in the field, with significant geographic and ecological gaps remaining. Most often, gap-filling-collecting focuses on inadequately covered geographical regions, which may be quite extensive. Occasionally, specific environmental conditions may be targeted. For example, high-altitude or wetland areas may be under-represented in taro collections, and may thus be a target for collection even though there is no immediate need for breeding programmes. Alternatively, breeders might wish to see if taro leaf blight tolerant varieties exist in areas not well covered in previous missions. Specific genotypes are sometimes targeted, e.g. varieties of known appearance and/or local name which are not found in a collection.

The losses that have occurred in the past few years in taro collections in the Pacific region are well documented (Jackson, 1994). There are numerous reasons for the losses, but generally, they are no different from those reported for other root crops in other regions of the world (Henshaw *et al.*, 1980; Hanson, 1986; Jarret and Florkowski, 1990; Malaurie *et al.*, 1993). They include the high cost of maintenance of plants that require frequent harvesting and replanting; and the destruction of plants by cyclones and lethal diseases (Table 2). In addition to the loss of germplasm, descriptor records have also been lost.

Unfortunately, losses of stored germplasm have occurred in countries where root crop genetic resources are greatest. When the histories of germplasm collections are analysed, it becomes apparent that in many countries they have been lost over and over again. Some examples are worth stating. A collection of approximately 200 taro cultivars was destroyed by alomae in Solomon Islands in 1975 (Jackson, 1981). In Papua New Guinea, losses from the same disease occurred in collections at Keravat in 1974 and 1985 (authors' observations), and were reported to have reduced the collection

from 200 accessions to 20 in 1980 (Kesevan and Aburu, 1982). The collection now maintained at Bubia Agricultural Research Centre, Lae, once contained more than 600 accessions; there are now only 310. Extensive collections of taro previously established in Vanuatu and only partially described have been lost recently due to labour disputes. Micronesian collections have shared the same fate. At least three collections of taro have been made in recent years, and then abandoned.

Future collecting strategies will, therefore, have to take note of the reasons for previous losses. It is obvious that collections should be kept in places free from lethal diseases or methods of control determined before collections are made. Above all, it will be necessary to determine manageable numbers of accessions that can be maintained with the resources available.

Table 2. Losses of taro (and yam) in Pacific Island collections.

Country	Year	Collection	Reason for Loss
FSM (Pohnpei)	1994	Taro	Lack of staff
Papua New Guinea	1980	Taro (partial)	Alomae disease
Solomon Islands	1974	Taro	Alomae disease
Solomon Islands	1991	Taro	Cost of maintenance
Solomon Islands	1978	Yam	Anthracnose disease
Samoa	1986	Taro & yam	Cost of maintenance
Tonga	1985	Taro	Drought
USA (Hawaii)			
Lyon Arboretum	1988	Taro (most)	Unknown
Vanuatu	1976	Taro	Drought
Vanuatu	1994	Taro & yam	Lack of staff

Dates are indicative only. In many cases, losses occurred over several years.

5.2 Diversity is in imminent danger of disappearing from the field

Much indigenous germplasm may be under threat from genetic erosion in different areas and for different reasons. In some countries, the competing demands placed on labour to produce crops both for food and cash, have seen a trend towards the replacement of traditional cultivars by a smaller number selected or bred for high yield in monoculture (Guarino and Jackson, 1986). The loss of this traditional diversity may have serious repercussions: it may mean that in the face of serious pest outbreaks (Gagne, 1982), or a need for other characteristics—nutritional quality, ecological adaptation including climatic changes, food processing potential, pharmaceutical products, or some as yet undefined need—cultivars will not be available to evaluate. Nowhere can this have more meaning than in Samoa where, to meet domestic and export demands, predominantly one variety was grown nationwide and where, in 1993, the introduction of taro leaf blight decimated production.

There is no guide as to the pace of genetic erosion of taro in Pacific Island countries. Knowledge of what is happening in farmers' fields is poor, and mostly anecdotal (Yen, 1979; Kesevan and Aburu, 1982); nowhere in the region is there any monitoring to gauge whether cultivars and their wild relatives are being lost and, if they are, the rate at which this is occurring.

In some countries, however, the evidence may not be hard to find. In Solomon Islands and Papua New Guinea, the occurrence of taro leaf blight during or after World War II brought about a revolution in cropping patterns, which still continues today as the disease spreads to new areas (Packard, 1975; Rooney, 1980; Morren and Hyndman, 1987). Before the advent of taro leaf blight in Solomon Islands, taro and yam were the principal crops. Today, sweet potato accounts for most of the land devoted to food production. Anecdotal evidence suggests that in that country, and in Papua New Guinea, many cultivars are no longer grown, but whether these can still be found as feral populations (Simin *et al.*, 1996), or in areas where taro leaf blight is not yet present, is unknown. Kesevan and Aburu (1982) suggest that in the New Guinea islands, as well as on the mainland, taro production has declined in response to population pressure, plant diseases and the introduction of high yielding species, such as *Xanthosoma*, sweet potato and cassava. The displacement of taro by sweet potato in that country, began 300-500 years ago, and is still continuing (Yen, 1963; Waddell, 1972; Clarke, 1977).

Declining taro production has also been recorded in Micronesia where, in the Federated States of Micronesia, it has been attributed to pests and diseases and today taro ranks behind breadfruit, yam, banana and imported rice as a staple food (Raynor and Silbanus, 1992). According to Santos (1992), all the cultivars now present in the Federated States of Micronesia have been introduced since European contact, many in recent years, most likely in response to the impact of taro leaf blight. In Palau, too, production is decreasing (Ngiralmau, 1992). Perhaps the best documented evidence for genetic erosion in taro is that reported by Whitney *et al.* (1939) from Hawaii. They estimated that more than half the traditional cultivars were no longer in existence, and were able to record only eight of 25 cultivar groups previously recognised by Hawaiians.

In addition to the loss of cultivars due to disease and the other factors mentioned above, there has probably been a general reduction in the number of varieties of food crops grown in response to what has been called the 'disintensification' of agriculture throughout the Pacific in this century (Thaman, 1984; Ward, 1987). What remains today, with the decline in intensive taro and yam production systems is an impoverished version of that which previously existed. If this is true, then it would inevitably have been accompanied by a loss of crop diversity. Certainly, if growers had selected taro specifically adapted to wetland production, cultivars would have been lost as irrigation techniques fell into disuse. The concern in Pacific Island countries is that, with a decline in production, traditional knowledge of cultivation practices will also be lost, and this impacts on cultural values as, in most Pacific Island countries, food production and social structures are inextricably entwined (Coursey, 1977).

From the review above, it can be seen that there are gaps in the information concerning the threat to genetic diversity in different areas in the region. These gaps need to be determined so that they can be considered in relation to the losses that have occurred in genebanks so that areas can be targeted for re-collection.

5.3 Diversity is needed for immediate use

Diversity that is missing or lost from existing *ex situ* collections and that is threatened in the field may well be needed to fulfil some currently unpredictable future need, and may thus be a priority for collecting. Another major reason for collecting is demand for diversity for immediate use made by taro improvement activities. Efforts to breed taro by conventional means began in Solomon Islands in 1978. Subsequently, programs developed in Fiji, Papua New Guinea and Samoa, and more recently at the University of Hawaii. The following is a brief summary of the objectives and achievements of these programmes.

5.3.1 Fiji

Taro breeding started in Fiji in 1979 to produce varieties for improved export quality, taro leaf blight not being present in the country. The first line to be released was Samoa Hybrid, a seedling selection from an open-pollinated plant of variety Samoa (Sivan and Tavaiqia, 1984; Wilson *et al.*, 1992). The success of finding a plant of excellent quality from just 20 seeds, stimulated further work. Pollinations were made between the ten most popular varieties of the country. About 2,400 plants were grown and 15 lines selected for further evaluation (Sivan, 1992). From these, three have been released to growers: Wararasa ('best of the best'), and two others, Vula Ono and Maleka Jina. It was apparent that improved genotypes can be obtained relatively easily by using plants of good quality as parents.

5.3.2 Papua New Guinea

Taro breeding in Papua New Guinea and also Solomon Islands has been primarily aimed at disease control. Plants are attacked by several serious plant pathogens of wide distribution; these are: taro leaf blight, *Phytophthora colocasiae* (Hicks, 1967; Gollifer and Brown, 1974; Jackson and Gollifer, 1975; Putter, 1976) and the virus diseases known as alomae and bobone (vernacular names from Solomon Islands where the viruses were first reported) (Gollifer and Brown, 1972; James *et al.*, 1973; Kenten and Woods, 1973; Gollifer *et al.*, 1978; Shaw *et al.*, 1979). In addition, and in both countries, a disease caused by a newly determined nematode, *Hirschmanniella miticausa*, is also locally important (Mortimer *et al.*, 1981; Bridge *et al.*, 1983).

Beginning in 1992, the national collection has been screened for leaf blight resistance, and three wild varieties from East New Britain Province were found to be resistant. A breeding programme using mass recurrent techniques started in late 1993. The main focus of the taro programme in Papua New Guinea is to control the diseases mentioned above, but other considerations include yield, early maturity and adaptation to specific environments (Ivancic *et al.* 1996; South Pacific Commission, 1996). A base population was created consisting of cultivars from the national germplasm collection, and the three wild varieties (Ph 15, Ph 17, Ph 21), a wild variety from Bangkok, and hybrids from Solomon Islands. At present, cycle-3 progeny are being evaluated, as well as selections made in cycle 2.

There are, however, fundamental problems within the programme concerning the choice of parents to establish the base population. In general, progeny from the breeding cycles are of poor quality although highly resistant to taro leaf blight. The problem of quality and the possibility of vertical resistance to taro leaf blight being present in the breeding populations was discussed at a meeting organised by TaroGen in July 1998. The meeting recommended that genetic tests should be made to determine if vertical resistance is present, and in order to increase the quality of the taro, selections should be crossed to traditional cultivars. In addition, Micronesian taro should be introduced into Papua New Guinea and incorporated into the breeding population.

5.3.3 Solomon Islands

Breeding taro to increase resistance to diseases began in Solomon Islands in 1978. It took advantage of two discoveries: gibberellic acid promotes flower production (Alumu and McDavid, 1978); and seedlings from a wild Bangkok variety were highly resistant to taro leaf blight. From 1980 until 1992, support for the programme came from several UNDP/FAO root crop projects. From the outset the strategy was to develop breeding techniques while awaiting cultivars from India which were reported to have field resistance to the disease.

Initially, there were three separate backcross programmes attempting to increase disease resistance in favoured cultivars (Jackson and Pelomo, 1980; Jackson, 1981; Patel *et al.*, 1984). Later, this approach

was abandoned in favour of a recurrent selection strategy in which lines were chosen for resistance to all three diseases (Ivancic *et al.,* 1992). A base population of 250 genotypes was established, including lines retrieved from previous programmes, traditional cultivars, and two wild varieties. In all, more than 350 crosses were made to establish the first cycle, and the progeny were evaluated in different islands for reaction to major diseases. Soon after the programme ceased. Some lines (8-10) from the programme are being maintained, but they have not been evaluated. Only one line from the back-cross breeding programme of the mid-1980s (LA16) has reached farmers, and this continues to perform well. It is resistant to disease, has large corms and acceptable taste.

5.3.4 Samoa

The programme at USP, Samoa began in 1982. Its aims were similar to the programme in Fiji: to produce taro with high yields and drought resistance, suitable for domestic and overseas markets. The programme also had a regional perspective, with clones distributed to six Pacific Island countries for evaluation (Sivan and Liyanage, 1992). The outcome was Alafua Sunrise, released in 1988 (Wilson *et al*., 1992). This clone was shown to out-yield the popular cultivar Niue by 50 to 130%, although not widely accepted by the farming community (Fairbairn-Dunlop, 1992).

Until the outbreak of taro leaf blight, other clones derived from Alafua Sunrise and traditional cultivars were under test. Some of these appeared to combine high yield and drought resistance with the eating qualities desired. It is of interest to note that the two cultivars released, Samoa Hybrid from Fiji and Alafua Sunrise from Samoa, have yielded well in all the countries where they have been tested, indicating good adaptation to different environments. They are, however, very susceptible to taro leaf blight

With the spread of taro leaf blight to Samoa in 1993, there has been renewed interest in taro breeding. In 1996, crosses were made between Micronesian and local taro varieties and the progeny are now under test at government research stations and farms.

5.3.5 University of Hawaii

Collections of germplasm have been maintained in Hawaii since the 1920s, and in recent years additions have been made with large numbers of clones imported from Indonesia, Malaysia, the Philippines, and a few from China, India and Japan. A total of about 400 is now maintained. The traditional germplasm has been documented (Whitney *et al.,* 1939), and the more recent collections are being characterised using a modified IPGRI descriptor list (de la Peña, 1992). The collection holds 70 Hawaiian cultivars.

Taro breeding at the Kauai Branch Station, University of Hawaii, started in 1988 (de la Peña, 1992). The programme is attempting to develop high yielding varieties suitable for *poi*, taro chips and table use. Two hybrids have been released and several hundred progeny are under evaluation. None have been selected for taro leaf blight resistance. The disease is present, but it is not considered a problem (Ramon de la Peña, Kauai Branch Station, personal communication).

5.4 Diversity estimation is needed to develop a conservation strategy

Germplasm collecting may be done as part of a research programme to find out more about the genepool. Information on various topics will be necessary to develop a sound and cost-effective

conservation strategy, e.g. the ecogeographic distribution of genetic diversity, the partitioning of genetic diversity within and among populations, reproductive biology, taxonomic boundaries, evolutionary relationships, and the history of domestication. Obtaining this information will often depend on studies of conserved germplasm.

6. STRATEGIES FOR GERMPLASM COLLECTING

6.1 A benchmark sampling strategy

The following basic elements of a taro collecting strategy are proposed:

6.1.1 Choosing sites

- Divide each distinct taro growing area in the mandate region into 40km x 40km grids.
- Superimpose the location of the following different types of areas:

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

- Calculate a "taro collecting importance value" (TCIV) for each grid square based on the presence and priority value of each of these types of areas in the grid.
- Collect germplasm in all grid squares, at a minimum of two sites (communities) in each grid. If the material is of the same morphotype and/or environmental conditions are similar, leave a minimum of 15 km between collecting sites.
- Collect more intensively (up to six communities) in grid squares which have a higher TCIV.

6.1.2 Sampling at the site

- The recommended method for vegetatively propagated crops is sampling of all the morphotypes recognised by the collector in collaboration with the community at each sampling site.
- Aim for a minimum of three plants ('tops') of each morphotype found in the village to allow for losses in transit and after planting.
- 'Tops' should reach the genebank for processing a maximum of five days after collecting.

The basic recommendation is for all the areas of taro cultivation to be systematically and comprehensively covered, even if that means collecting the same morphotype several times. This is because there may be hidden genetic variation within morphotypes. Particular users might express a need for material adapted to specific conditions, and this would thus become a high priority of the collecting programme. However, it is important to realise that an approach to collecting which only

includes the targeting of specific characters and adaptations will not be appropriate for conservation purposes, as it will likely miss characters and adaptations that are not a priority now, but which may become important breeding objectives in the future. It should not be seen as a replacement for comprehensive coverage. Such an integrated approach to collecting takes into account both explicit present needs and also unknown future needs. Depending on resources, the collecting programme could be organised in two complementary (possibly chronologically overlapping) phases, the first aiming for comprehensive coverage and the second for material with specific adaptations or characteristics.

The possibility of decentralising some aspects of the collecting activities in some areas could be considered if it proves unworkable for a single team from the taro genebank to bring back enough accessions in time during a given trip, or to visit all grid squares with high TCIVs within a reasonable period (e.g. from outlying islands). Extension workers, researchers at regional universities and regional research stations, staff of local non-government organisations (NGOs), community-based organisations (CBOs) and community groups are often integrated into collecting teams in the field, but they could also be commissioned to collect in their respective localities and to forward material and data on a regular basis to the genebank. The genebank would need to provide appropriate training in sampling, documentation and germplasm handling, and possibly some funds, but in some circumstances this may prove a more efficient approach than mounting a collecting mission from a central location. Even if they are not involved in the actual collecting, the locally-based organisations can support the collector in assessing the feasibility of itineraries, determining what equipment and supplies will be necessary, deciding on the most appropriate timing for collecting and in obtaining guides, transport, etc. Such a "network" will also form a useful early-warning system for genetic erosion.

6.2 Modifications of the benchmark strategy

Further recommendation may be made for collecting taro in Pacific Island countries, taking into account the special circumstances of the region. Polynesia and Micronesia consist of a large number of relatively small islands, some of which are more difficult to reach than others. *In such circumstances, it is possible to envisage collecting* ***all*** *the morphotypes locally recognised on some islands.* For example, collecting all varieties on Niue and the main islands of the Cook Islands, Tonga, the Samoas and Micronesia (or at least the ones that have been lost from collections) should not be particularly difficult. Each morphotype should be collected from at least two different farmers on each island to enable later assessment of genetic variation within morphotypes.

A possible strategy is to use past records of collections and a group interview with local farmers to develop an exhaustive list of cultivar names for each island, which could then be used as a checklist during fieldwork. Although the main island will be the largest and easiest to collect, it may not have the largest number of varieties (e.g. in Cook Islands, compare Rarotonga with the islands of Atiu and Mangaia) because it is likely to have been more exposed to some of the factors leading to genetic erosion. A workable approach might be to collect on the main island in each country, plus at least one other island, to be chosen based on available resources and the ability to get material back to the genebank in time. Again, on outlying islands morphotypes should be collected irrespective of whether they have already been collected on the main island. In specific instances, one or more islands may be chosen for collecting where specific taro types are known to exist.

The situation in Melanesia is different. Not only is taro genetic diversity likely to be much higher, but this sub-region also consists of larger islands and isolated communities which will be more difficult to sample in the exhaustive manner suggested for Polynesia. Here the benchmark sampling strategy

outlined above could be implemented. Based on the guidelines, the number of accessions and plants that are likely to be collected should be estimated before the collecting starts. If the number is more than can be managed effectively by the genebank and/or other users, collecting in lower TCIV grid squares might be modified in different ways. For example, in areas where the threat of genetic erosion is low, it would be acceptable to collect only the more popular or common varieties, though of course it would be useful to gather information on the others in case it becomes possible to collect them in the future. In relatively homogeneous and accessible taro growing areas, it might only be necessary to collect in one grid, rather than in all the grids within the area.

It is important to avoid over-collecting. If, during collecting more than expected diversity is encountered, it is best to collect the more popular cultivars (for immediate use), threatened and unique types. As noted earlier, information should be obtained on the others. It may be possible to collect them later, or include them in an *in situ* conservation programme.

6.3 Importance of passport data

The successful management and use of genetic resources conserved *ex situ* depends to a large extent on the quality and quantity of the data associated with the accessions. It is important for germplasm collectors to carefully document "passport data" for each accession, i.e. data relating to accession identification, the location of the collecting site, and the physical, biotic and human environment. Although germplasm lacking such data is still useful, accurate passport data will help the users to assess the adaptation of material, to identify the duplicates, and to plan future missions.

In a situation where collecting will be carried out by a number of researchers from many countries, and the material exchanged and conserved in regional as well as national collections (as in this project), it is important that collectors develop and use a standard set of passport descriptors. IPGRI has developed a collecting form for taro incorporating: (i) lists of habitats appropriate to the crop; (ii) key morphological descriptors; and (iii) appropriate indigenous knowledge.

6.4 Importance of farmer knowledge in collecting

Farmers have an intimate knowledge of their surroundings and of the genetic resources they manage. This can be an important part of the passport data associated with accessions, and includes:

- the vernacular names of cultivars;
- local criteria for distinguishing among them, and their relationship to each other in any folk taxonomy;
- differences between types as perceived by farmers/growers;
- important characteristics, e.g. appearance, properties, environmental preferences and uses;
- localities where they may be found, and the rules of access to them;
- the agricultural and management practices with which they are associated;
- the origin (history) of planting material, including any selection practices that may have been applied;
- the character of any changes in farming practices, land management and natural habitats in the target area.

These different kinds of information can be very important in collecting, e.g. in the processes of:

- locating target areas and material;
- deciding what to collect, and how;
- documenting (and thus using) the collection;
- assessing the "completeness" of collections;
- understanding the origin and distribution of diversity;

- assessing the extent and threat of genetic erosion.

What emerges clearly from an analysis of the taro collections that have been made in the past in the Pacific Island countries is that in the rush to collect germplasm, insufficient detail has been given to collecting data in the field. In particular, there has been a lack of attention to the local uses of the accessions, the preferred method of preparation, as well as the cropping systems of which they were a part. This was realised by Larsen (1984) who tried to overcome the deficiency by carrying out cooking trials on many of the 150 taro accessions collected in Vanuatu. It was also a problem when attempts were made to publish the main attributes of taro cultivars available to Pacific Island countries as pathogen-tested *in vitro* cultures (Jackson, 1990).

A collecting programme should have a strategy for the documentation and use of farmer knowledge. Specific questions for farmers should be incorporated in the collecting form, but indigenous knowledge is unevenly distributed, error-prone in its transfer, fragile and location-specific. Collectors may therefore require training in specialised participatory methodologies such as participatory rural appraisal, in particular the use of visual methods (sketches, ranking, diagramming, cognitive mapping). Important considerations include how to choose informants, the best time for consultations, whether individual interviews should be complemented with group discussions, and ethical issues such as informed consent and anonymity. Farmers should at all times be seen as an integral part of the collecting team.

6.5 Collecting and using morphometric data

Descriptions of the morphological characteristics and reactions of accessions to pests, diseases and stresses of an accession are very useful for plant breeders and other users of genetic diversity. Such data can be used to guide further collecting. There is much information available on the varieties of taro grown in Pacific Island countries, even though the collections have been lost, and much is not easily accessed. Taro collections in Cook Islands, Fiji, Niue, Papua New Guinea, Tonga, Vanuatu and Samoa have been characterised and evaluated on yield, disease resistance and taste and maturity (Gollifer, 1970; Guarino and Jackson, 1986; Haynes and Sivan, 1977; Hicks, 1967; Jackson and Gerlach, 1985; Matarangi, 1984; Ooka and Trujillo, 1982; Sivan, 1984; Van Wijmeersch, 1986; Van Wijmeersch *et al.*, 1988). Furthermore, for many popular cultivars of taro, chemical composition has been determined (Bradbury and Holloway, 1988). Analyses have been done on major constituents, minerals, organic acid anions, vitamins, amino acids and anti-nutritional factors. Both corms and leaves have been analysed, and investigations have been made into the acrid principle.

Morphological characterisation data have a number of limitations. Differential heritabilities, pleiotropic and epistatic effects, polygenic control and genotype x environment interactions that are often associated with morphological characters can make estimation of genetic variation difficult. In many cases, long-term crossing and inheritance studies will be needed for precise estimations. There is also the problem that most genetic variation is hidden and is not apparent at the phenotypic level, so that morphologically similar material may in fact be genetically quite different (c.f. Matthews, 1990). Conversely, morphologically different material may be very similar genetically (c.f. Lebot and Aradhya, 1991). Despite these drawbacks, morphometric methods have been used in various crops, including taro.

While morphological descriptors were useful in detecting phenotypically similar accessions present in the same collection, they were of less use when comparisons were made between collections at different sites in the same country or in different countries. The problem was partly related to a

reliance on colour descriptors and their patterns of distribution, which varied due to the age of the plant and environmental conditions. The problem is well illustrated by comparing the descriptors of one of the most popular cultivars in many Pacific Island countries, cultivar "Niue", the taro of commerce. "Niue" is found in Samoa, where it has that name; in Niue, it is known as "Fase"; in Fiji, as "Tausala ni Samoa"; and in Vanuatu, as "Naololo". When comparisons were made using 12 descriptors, the data failed to show similarities that would indicate that the taro listed under those names were the same in each country (Guarino and Jackson, 1986). The fact that they were was checked by growing them at Koronivia Research Station, Fiji. Limitations in the use of descriptors to differentiate cultivars has far reaching consequences: costs of maintenance are increased; there is the concern that countries will be sent germplasm they already have; and it adds to the cost of international exchange if similar cultivars from different countries are sent for virus indexing. Complementary methods of describing accessions are required. Some of these are described in the next section.

Morphological characters used in characterisation should be highly heritable, not influenced by age and easy to record with precision. IPGRI is developing a draft descriptor list for taro which highlights particularly discriminatory characters. Analysis of morphological characters usually takes the form of calculation of means, ranges, variances and various types of multivariate analyses. Simple analysis of variance is usually sufficient for assessing the extent of differences among populations for individual traits and determining coefficients of variation for these traits. Multivariate analysis is used to compare several traits at the same time. There are several methods and the choice will depend on the objective, though they all depend on a distance measure being calculated among all entities, or accessions. If the objective is to obtain an overall impression of the variation among accessions, principal component analysis plots will be useful. Discriminant analysis can be used to differentiate among populations taking into account variation within the populations. Clustering techniques can be used to produce dendrograms, and unique clusters identified for sampling.

Characterisation and evaluation of the entire regional collection in one place (or at most 2-3 localities in contrasting agro-ecologies) should follow collecting in the region. Much will depend on quarantine considerations, but the possibility exists for Polynesian taro being compared in Fiji, and the entire collection in Papua New Guinea. In neither instance is there a probability of new pest introductions, although it would be prudent to grow plants from meristems, and if possible, index them for viruses. The characterisation and evaluation of agronomic and quality traits could be carried out by a small team of researchers involved in TaroGen. Morphological work should be followed by molecular marker analysis to help identify duplicates, and designate a core collection. On the basis of the results of the characterisation and evaluation, participating countries would be in a position to decide what material they would be most interested in maintaining. This would be the focus at the conservation workshop in the second year of TaroGen.

6.6 Use of molecular markers to improve techniques for locating diversity

As has already been pointed out, characterisation and evaluation of taro populations based on morphological and agronomic traits provide only a simplified and somewhat inadequate picture of diversity. Similarly, variation in isozymes can be limited in discriminatory capacity. More recently, taro germplasm has been characterised using various DNA markers (Irwin *et al.*, 1998; Matthews, 1990; Matthews *et al.*, 1992).

Such DNA markers are an attractive option for the characterisation of plant genetic resources because they provide data on a very large number of "characters", show no interaction with stage of growth or the environment, can be assayed rapidly and provide data that can be easily entered into databases and analysed by standard methods. However, it must be recognised that these molecular

methods are complementary to other methods that are generally used, for example, morphological characterisation, as well as to each other. Different methods can be useful for different purposes as they target different parts of the genome and have different properties (Ayad *et al.*, 1997). Thus, microsatellites detect more diversity than RFLPs, but share with them the capacity to detect heterozygosity. RAPDs, though cheap, are notorious for their variation among laboratories and cannot detect heterozygotes. Microsatellites have the potential to be developed as kits which do not require radioactive labelling and can be deployed in a much wider range of laboratories than RFLPs using much smaller amounts of plant tissue. AFLPs, though expensive, are not subject to the repeatability problems associated with RAPDs.

A network of researchers such as that associated with TaroGen will probably want to concentrate on techniques which (i) detect high levels of polymorphism, so that closely related material can be differentiated, and (ii) give consistent and repeatable results across sites and conditions so that data and materials can be shared. These will be the guiding strategies of the ACIAR-funded project *Virus Indexing and DNA Fingerprinting for the International Movement and Conservation of Taro Germplasm* which will operate in close association with TaroGen.

The ACIAR project will provide a valuable resource for germplasm management and utilisation. Genetic diversity will be assessed, both within localised genepools, such as for Polynesia or Melanesia, and across the geographical distribution of the species (Ian Godwin, University of Queensland; personal communication). The DNA data will also be useful in setting the size and composition of the core collection which will be conserved in a Regional Germplasm Centre at SPC.

6.7 A decision-making process

Based on this discussion, the following steps may be suggested for the process of developing a collecting plan for a particular mandate region:

1. Assemble a planning team to reflect the different stakeholder groups.
2. Determine the extent of cultivation of taro in the region in different agro-ecological zones.
3. Gather and analyse passport and characterisation/evaluation information on existing collections.
4. If such information is lacking or insufficient, consider carrying out characterisation work on existing collections and/or mounting an exploratory genetic diversity field survey using indigenous knowledge, morphological characters and/or DNA markers.
5. Determine and prioritise among present user needs.
6. Gather information on main threats of genetic erosion.
7. Identify and prioritise areas within the area of cultivation based on lack of coverage, present need and threat of genetic erosion.
8. Determine if the number of accessions resulting from the collecting programme will be manageable. If not, change sampling parameters.
9. Determine the route(s) necessary to sample all priority areas most efficiently.
10. If available resources do not allow visiting all priority areas, investigate possibility of decentralising collecting in some areas.
11. If a particular route is likely to result in the collection of too much germplasm for the transport available, or in an inability to get 'tops' back to the genebank within five days of collecting, investigate decentralisation of collecting and/or collecting *in vitro*.
12. Decide on and assemble a collecting team.

7. IMPROVING THE USE OF COLLECTED GERMPLASM

To the conservationist, it is necessary to collect as much genetic diversity as possible. However, not all diversity is equally useful at any one time to breeders or other users, though of course the needs of users differ and change with time. A comprehensive strategy for taro genetic resources management should be able to accommodate both of these perspectives, so that the maximum benefit can be derived by conserving the maximum genetic diversity, making the entire programme cost-effective and self-sustaining. Various factors delay and impede the use of material that has been collected and is being conserved in genebanks. These include lack of information on conserved material, access restrictions and plant health considerations. A strategy for overcoming some of the barriers for using taro will need to be developed. This may include the following elements:

- comprehensive characterisation and evaluation of conserved germplasm;
- centralised documentation of accession information;
- policy on access to genetic resources;
- safe transfer guidelines;
- improved breeding strategies;
- conservation through use.

If breeders and other users do not know what material is being conserved, or have only the most basic information on accessions, they can hardly be expected to use it. The availability of comprehensive characterisation and evaluation data on the material in genebanks based on complementary, standardised sets of morphological, agronomic, biochemical and molecular markers in a readily accessible central database would be an important step in increasing use. Standardised protocols for passport, morphological characterisation and evaluation data documentation need to be developed, including those for molecular characterisation. The new descriptor list for taro being developed by IPGRI in consultation with crop experts is a step in this direction.

There would be little point in users having full information about a particular accession if they then had no access to the material itself. TaroGen will play an important role in developing access policies for regional taro genebanks and implementing safe transfer guidelines for taro germplasm. It is fortunate that it has the assistance of the ACIAR project to provide the virus indexing capability that will make the international transfer of germplasm a reality. *In vitro* conservation/multiplication of material and disease indexing will be crucial aspects of a strategy for increasing exchange and use.

Finally, it is important to keep in mind that breeders are not the only users of conserved germplasm, and that genebanks are not the only way of conserving germplasm. One of the advantages of an *in situ*, on-farm, approach to conservation is that genetic resources continue to be actively used by the farmers and communities who have contributed to shaping them over generations. Indeed, developing a strategy for taro conservation through the increased use of diversity by farmers is perhaps the greatest challenge facing this project and the taro research community.

8. REFERENCES

Alumu, S. and McDavid, C.R. 1978. Promotion of flowering in edible aroids by gibberellic acid. *Tropical Agriculture (Trinidad)* **55** 81-86.

Ayad, W.G., Hodgkin, T., Jaradat, A. and Ramanatha Rao, V. 1997. *Molecular genetic techniques for plant genetic resources*. In: Report of a Workshop, 9-11 October 1995. Rome, Italy International Plant Genetic Resources Institute, Rome, Italy. 137 pp.

Bradbury, J.H. and Holloway, W.D. 1988. *Chemistry of tropical root crops: significance for nutrition and agriculture in the Pacific*. Australian Centre for International Agriculture Research, Canberra. pp. 201.

Bridge, J., Mortimer, J.J. and Jackson, G.V.H. 1983. *Hirschmanniella miticausa* n. sp. (Nematoda: Pratylenchidae) and its pathogenicity on taro *(Colocasia esculenta)*. *Revue de Nématologie* **6**: 285-290.

Clarke, W.C. 1977. A change of subsistence staple in prehistoric New Guinea. In: *Proceedings of the 3rd symposium of the international Society for Tropical Root Crops*. Ed: C.L.A. Leakey. pp. 159-163. 2-9 December, 1973. International Institute of Tropical Agriculture, Ibadan.

Coates, D.J., Yen, D.E. and Gaffey, P.M. 1988. Chromosome variation in taro, *Colocasia*: implications for origin in the Pacific. *Cytologia* **53**: 551-560.

Coursey, D.G. 1977. The status of root crops: a cultural-historical perspective. In: *Regional meeting on the production of root crops*. pp. 125-130. 24-29 October, 1975. Technical Paper 174. South Pacific Commission, Noumea.

de la Peña, R.S. 1992. The University of Hawaii taro germplasm nursery and breeding programme. In: *Proceedings of the workshop on taro and tanier modelling*. Ed: U. Singh. pp. 7-9. Research Extension Series 136. College of Tropical Agriculture and Human Resources, University of Hawaii.

Fairbairn-Dunlop, P. 1992. Some comments on asking the right questions, getting the right answers. In: *Proceedings of the sustainable taro culture for the Pacific conference*. Ed: L. Ferentinos. pp. 73-77. 24-25 September, 1992. East-West Centre, University of Hawaii.

Gagne, W. 1982. Staple crops in subsistence agriculture: Their major insect pests, with emphasis on biogeographical and ecological aspects. *In: Biogeography and Ecology of New Guinea*. Ed: J. Gressitt. pp. 229-258. D.W. Junk, The Hague.

Gollifer, D.E. 1970. Preliminary observations on the performance of cultivars of taro (*Colocasia esculenta* L.) in the British Solomon Islands with notes on the incidence of taro leaf blight (*Phytophthora colocasiae* Rac.) and other diseases. In: *Proceedings of the 2nd symposium of the International Society for Tropical Root Crops*. Volume II. pp. 56-60. College of Tropical Agriculture, Honolulu.

Gollifer, D.E. and Brown, J.F. 1974. *Phytophthora* leaf blight of *Colocasia esculenta* in the British Solomon Islands. *Papua New Guinea Agricultural Journal* **25**: 6-11.

Gollifer, D.E. and Brown, J.H. 1972. Virus diseases of *Colocasia esculenta* (L.) Schott in Solomon Islands. *Plant Disease Reporter* **56**: 597-599.

Gollifer, D.E., Jackson, G.V.H., Dabek, A.J. and Plumb, R.T. 1978. Incidence, effects on yield of virus diseases of taro *Colocasia esculenta* in the Solomon Islands. *Annals of Applied Biology* **88**: 131-135.

Golson, J. 1991. Bulmer phase II. early agriculture in New Guinea highlands. In: A. Pawley. Ed. *Man and a half*. pp. 484-491. Polynesian Society, Auckland.

Golson, J. and Hughes, P.J. 1980. The appearance of plant and animal domestication in New Guinea. *Journal de la Société des Océanistes* **36**: 294-303.

Guarino, L. and Jackson, G.V.H. 1986. *Describing and documenting root crops in the South Pacific*. FAO RAS/83/001. Field Document 12. Suva, Fiji. 141 pp.

Hanson, J. 1986. Methods of storing tropical root crop germplasm with special reference to yam. *FAO/IBPGR Plant Genetic Resources Newsletter* **64**: 24-32.

Haynes, P.H. and Sivan, P. 1977. Towards the development of integrated root crops research and production in Fiji. In: *Regional meeting on the production of root crops*. pp. 51-61. 24-29 October, 1975. Technical Paper 174. South Pacific Commission, Noumea.

Henshaw, G.G., O'Hara, J.F. and Westcott, R.J. 1980. Tissue culture methods for the storage and utilization of potato germplasm. In: *Tissue culture methods for plant pathologists*. Eds. D.S. Ingram and J.P. Helgeson. pp. 71-76. Blackwell, Oxford.

Hicks, P.G. 1967. Resistance of *Colocasia esculenta* to leaf blight caused by *Phytophthora colocasiae*. *Papua New Guinea Agricultural Journal* **19**: 1-4.

IBPGR. 1980. Descriptors for *Colocasia*. Rome. AGP/IBPGR/79/52. 16 p.

IPGRI. 1995. *Field genebank management, problems and potential solutions*. Report of a Workshop. University of Puerto Rico, Mayaguez, 12-18 November 1995. International Institute of Plant Genetic Resources, Rome, Italy.

Irwin, S.V., Kaufusi, P., Banks, K., de la Peña, R. and Cho, J.J. 1998. Molecular characterization of taro (*Colocasia esculenta*) using RAPD markers. *Euphytica* **99**: 183-189.

Ivancic, A., Kokoa, P., Simin, A. and Gunua, T. 1996. Mendelian Studies of resistance to taro leaf blight. In: *The Second Taro Symposium.*. Eds. Jackson, G.V.H. and Wagih, M.E. pp. 97-100. Proceedings of an international meeting, 23-24 November 1994. Cenderawasih University, Manokwari, Indonesia.

Ivancic, A., Liloqula, R., Levela, H., Saelea, J. and Wagatora, D. 1992. Genetic resistance to alomae-bobone virus complex, the lethal disease of taro (*Colocasia esculenta* (L.) Schott). In: *Proceedings of the sustainable taro culture for the Pacific conference*. Ed: L. Ferentinos. pp. 48-54. 24-25 September, 1992. East-West Centre, University of Hawaii.

Jackson, G.V.H. 1981. Root crop genetic resources of Solomon Islands. In: *Crop genetic resources of the Far East and the Pacific*. Eds: J.T. Williams and J.L. Creech. pp. 93-108. International Board for Plant Genetic Resources. Funny Press, Bangkok.

Jackson, G.V.H. 1990. Pathogen-tested taro. *FAO Plant Protection Bulletin* **38**: 145-150.

Jackson, G.V.H. 1994. *Taro and yam genetic resources in the Pacific and Asia*. A report prepared for the Australian Centre for International Agricultural Research and the International Plant Genetic Resources Institute. Anutech, Canberra.

Jackson, G.V.H. and Breen, J.A. 1985. *Collecting, describing and evaluating root crops*. FAO RAS/83/001. Field Document 8. Suva, Fiji. 95 pp.

Jackson, G.V.H. and Firman, I.D. 1987. Characterization and preliminary evaluation of root crop germplasm in the South Pacific with special reference to pests and diseases. *IBPGR Regional Committee for Southeast Asia Newsletter. Special issue*: 19-23.

Jackson, G.V.H. and Gollifer, D.E. 1975. Diseases and pest problems of taro (*Colocasia esculenta* L. Schott) in the British Solomon Islands. *Pest Articles and News Summaries* **21**: 45-53.

Jackson, G.V.H. and Pelomo, P.M. 1980. Breeding for resistance to disease of taro (*Colocasia esculenta*) in Solomon Islands. In: *International symposium on taro and cocoyam.* 24-25 September 1979. Leyte, Philippines. International Foundation of Science, Provisional Report No. 5. pp. 287-298.

Jackson, G.V.H. and Gerlach, W.W.P. 1985. *Pythium* rots of taro. *Advisory Leaflet* **20**. South Pacific Commission, Noumea. 6 pp.

James, M., Kenten, R.H. and Woods, R.D. 1973. Virus-like particles associated with taro diseases of *Colocasia esculenta* (L.) Schott in the Solomon Islands. *Journal of General Virology* **21**: 145-153.

Jarret, R.L. and Florkowski, W.J. 1990. *In vitro* field genebank maintenance of sweet potato germplasm: major costs and considerations. *Hortscience* **25**:141-146.

Kambuou, R.N. (1996). *A discussion paper: Formation of a national plant genetic resources committee*. Paper presented at a national pant genetic resources workshop, 21-24 October, Port Moresby, Papua New Guinea. DAL/IPGRI.

Kenten, R.H. and Woods, R.D. 1973. Viruses of *Colocasia esculenta* and *Xanthosoma saggitifolium. Pest Articles and News Summaries* **19**: 145-155.

Kesevan, V. and Aburu, K. 1982. Conservation of plant genetic resources. In: *Traditional conservation in Papua New Guinea: Implications for today*. Eds: L. Morauta, J. Pernetta and W. Heaney. pp. 379-384. 27-31 October 1980. Boroko, Papua New Guinea.

Larsen, A. 1984. *Notes on root crops in Vanuatu.* FAO RAS/83/001. Field Document 5. Suva, Fiji. 32pp.

Lebot, V. and Aradhya, K.M. 1991. Isozyme variation in taro [*Colocasia esculenta*) (L.) Schott] from Asia and Oceania. *Euphytica* **56**: 55-66.

Léon, J. 1977. Origin, evolution, and early dispersal of root and tuber crops. In: *Proceedings of the 4th symposium of the International Society for Tropical Root Crops*. Eds: J. Cook, R. MacIntyre and M. Graham. pp. 20-36. 1-7 August, 1976. International Development Research Centre, Ottawa, Canada.

Loy, T.H., Spriggs, M. and Wickler, S. 1992. Direct evidence for human use of plants 28,000 years ago: starch residues on stone artefacts from the northern Solomon Islands. *Antiquity* **66**: 898-912.

Malaurie, B., Pungu, O., Dumont, R. and Trouslot, M-F. 1993. The creation of an *in vitro* germplasm collection of yam (*Dioscorea* spp.) for genetic resources preservation. *Euphytica* **65**: 113-122.

Matarangi, A. 1984. Important taro varieties in the Cook Islands. In: *Edible aroids*. Ed: S. Chandra. pp. 24-27. Clarendon Press, Oxford.

Matthews, P., Matsushita, Y., Sata, T., and Hirai, M. 1992. Ribosomal and mitochondrial variation in Japanese taro (*Colocasia esculenta* (L.) Schott). Japanese Journal of Breeding **42**: 2336-2340.

Matthews, P.J. 1990. *The origins, dispersal and domestication of taro*. Ph.D. Thesis. Australian National University, Canberra.

Matthews, P.J. 1991. A possible tropical wildtype taro: *Colocasia esculenta* var. *aquatilis*. *Indo-Pacific Prehistory Bulletin* **11**: 69-81.

Matthews, P.J. 1995. Aroids and the Austronesians. *Tropics* **4**: 105-126.

Milne, M., Godden, D., Kennedy, J., Kambuou, R. (In press). Evaluating the benefits of conserved crop germplasm in PNG. *43rd Annual Conference of the Australian Agricultural and Resource Economics Society*. Christchurch, New Zealand.

Morren, G.E.B. and Hyndman, D.C. 1987. The taro monoculture of central New Guinea. *Human Ecology* **15**: 301-315.

Mortimer, J.J., Bridge, J. and Jackson, G.V.H. 1981. *Hirschmanniella* sp., an endoparasitic nematode associated with miti-miti disease of taro corms in Solomon Islands. *FAO Plant Protection Bulletin* **29**: 9-11.

Ngiralmau, M. 1992. Taro research in Palau since 1990. In: *Proceedings of the sustainable taro culture for the Pacific conference*. Ed: L. Ferentinos. pp. 110-111. 24-25 September, 1992. East-West Centre, University of Hawaii.

Nissilä, E.A.J., Ramanatha Rao, V., Engelmann, F. and Riley, K.W. (In press). *Ex situ* strategies for complementary conservation of Asia sweet potatoes. *Plant Genetic Resources Newsletter*. Food and Agriculture Organization of the United Nations and the International Plant Genetic Resources Institute, Rome, Italy.

Ooka, J.J. and Trujillo, E.E. 1982. Taro diseases and their control. In: *Taro cultivation in the South Pacific*. pp. 52-66. Handbook No. 22. South Pacific Commission, Noumea.

Packard, J.C. 1975. *The Bougainville taro blight.* Miscellaneous work paper. Pacific Islands Studies Program, University of Hawaii. 144 pp.

Patel, M.Z., Saelea, J. and Jackson, G.V.H. 1984. Breeding strategies for controlling diseases of taro in Solomon Islands. In: *Proceeding 6th symposium of the International Society for Tropical Root Cops.* pp. 143-156. 21-26 February 1983. CIP, Lima, Peru..

Plucknett, D.L. 1976. Edible aroids. In: *Evolution of crop plants*. Ed: N.W. Simmonds. pp. 10-12. Longman, London.

Plucknett, D.L., de la Peña, R.S., Obero, F. 1970. Taro (*Colocasia esculenta* (L.) Schott: a review. Field Crop Abstracts **23**: 419-426.

Putter, C.A.J. 1976. The phenology and epidemiology of *Phytophthora colocasiae* Racib. on taro in the East New Britain Province, Papua New Guinea. M.Sc. Thesis. Department of Biology, University of Papua New Guinea. 188 pp.

Ramanatha Rao, V. 1994. Taro genetic resources: conservation and use. In: *The Second Taro Symposium.* Eds. Jackson, G.V.H. and Wagih, M.E. pp. 19-28. Proceedings of an international meeting, 23-24 November 1994. Cenderawasih University, Manokwari, Indonesia.

Raynor, B. and Silbanus, S. 1992. Ecology of *Colocasia* taro production on Pohnpei. In: *Proceedings of the sustainable taro culture for the Pacific conference*. Ed: L. Ferentinos. pp. 20-24. 24-25 September, 1992. East-West Centre, University of Hawaii.

Rooney, W. 1980. Changing food supply systems in eastern inland Manus. In: *Proceedings of the National Food Crops Conference*. 14-18 July, 1980. Port Moresby, Papua New Guinea.

Santos, G.H. 1992. *Colocasia* taro varieties on Pohnpei. In: *Proceedings of the sustainable taro culture for the Pacific conference*. Ed: L. Ferentinos. pp. 8-10. 24-25 September, 1992. East-West Centre, University of Hawaii.

Shaw, D.E., Plumb, R.T. and Jackson, G.V.H. 1979. Virus diseases of taro (*Colocasia esculenta*) and *Xanthosoma* sp. in Papua New Guinea. *Papua New Guinea Agricultural Journal* **30**: 71-97.

Simin, A, Ivancic, A., Ososo, E. & Okpul, T. 1996. Variation of wild taro (Colocasia esculenta (L.) Schott) in Papua New Guinea. In: *The Second Taro Symposium.*. Eds. Jackson, G.V.H. and Wagih, M.E. pp. 32-40. Proceedings of an international meeting, 23-24 November 1994, Cenderawasih University, Manokwari, Indonesia.

Sivan, P. 1981. Review of taro research and production in Fiji. *Fiji Agricultural Journal* **43**: 59-67.

Sivan, P. 1984. Review of taro research and production in Fiji. In: *Edible aroids.* Ed: S. Chandra. pp. 52-63. Clarendon Press. Oxford.

Sivan, P. 1992. Taro breeding in the South Pacific. In: *Proceedings of the workshop on taro and tanier modelling.* Ed: U. Singh. pp. 1-6. University of Hawaii.

Sivan, P. and Liyanage, A. De S. 1992. Breeding and evaluation of taro (*Colocasia esculenta*) for the South Pacific. In: *Proceedings of the sustainable taro culture for the Pacific conference*. Ed: L. Ferentinos. pp. 1-5. 24-25 September, 1992. East-West Centre, University of Hawaii.

Sivan, P. and Tavaiqia, M.B. 1984. First taro variety developed from breeding programme released for commercial production in Fiji. *Fiji Agricultural Journal* **48**: 1-4.

South Pacific Commission. 1996. Taro Seminar II. Proceedings. Papua New Guinea, Lae, 26-30 June 1995. Noumea, New Caledonia.

Staritsky, G., Dekkers, A.J., Louwaars, N.P. and Zandvoort, E.A. 1986. *In vitro* conservation of aroid germplasm at reduced temperatures and under osmotic stress. In: *Plant tissue culture and its agricultural applications*. Eds: L.A. Withers and P.G. Anderson. pp. 227-283. Butterworth, London.

Takagi, H., Thinh, N.T., Islam, O.M., Senboku, T. & Sakai, A. 1997. Cryopreservation of *in vitro*-grown shoot tips of taro (*Colocasia esculenta* (L.) Schott) by vitrification. 1. Investigation of basic conditions of the vitrification procedure. Plant-Cell-Reports **16**: 9, 594-599.

Thaman, R.R. 1984. Intensification of edible aroid cultivation in the Pacific islands. In: *Edible aroids*. Eds: S. Chandra. pp. 102-122. Clarendon Press. Oxford.

Van Wijmeersch, P. 1986. *Root crops production in Tonga*. FAO RAS/83/001. Field Document 13. Suva, Fiji. 80 pp.

Van Wijmeersch, P. and Bule, F. 1988. *Research and development of root crops in Vanuatu*. FAO project reports on TCP/VAN/4403 and TCP/VAN/6652, Field Document. Ministry of Agriculture, Forestry and Fisheries/FAO. Santo, Vanuatu. 128 pp.

Waddell, E.W. 1972. The mound builders. Agricultural practices, environment, and society in the Central Highlands of New Guinea. University of Washington Press, Seattle and London. 253 pp.

Ward, R.G. 1987. The future of agricultural research in the South Pacific. In: *The planning and management of agricultural research in the South Pacific*. Report of a Workshop. pp. 33-39. 5-16 October 1989, Alafua, Western Samoa. ISNAR, The Hague.

Whitney, L.D., Bowers, F.A.I. and Takahashi, M. 1939. Taro varieties in Hawaii. *Hawaii Agricultural Experiment Station Bulletin* **84**: 1-86.

Wilson, J.E., Sivan, P. and Munroe, C. 1992. 'Alafua Sunrise' and 'Samoa Hybrid' improve the production of taro (*Colocasia esculenta* (L.) Schott) in the Pacific. In: *Proceeding of the 9th symposium of the International Society for Tropical Root Crops*. Accra, Ghana.

Yen, D.E. 1963. Sweet potato variation and its relation to human migrations in the Pacific. In: *Plants and migrations of Pacific peoples*. Ed: J. Barrau. Bishop Museum Press.

Yen, D.E. 1979. Pacific production systems. In: *South Pacific agricultural survey 1979. Pacific agriculture: Choices and constraints*. Eds: R.G. Ward and A.S. Proctor. pp. 67-100. Asian Development Bank, Manila.

Yen, D.E. 1993. The origins of subsistence agriculture in Oceania and the potentials for future tropical food crops. *Economic Botany* **47**: 3-14.

Yen, D.E. and Wheeler, J.M. 1968. Introduction of taro into the Pacific: the indications of the chromosome numbers. *Ethnology* **7**: 259-267.

Annex 2

LIST OF ABBREVIATIONS AND ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
ADAP	Agricultural Development in the American Pacific
AFLP	Amplified Fragment Length Polymorphism
AusAID	Australian Agency for International Development
BARC	Bubia Agricultural Research Centre
CBO	Community-based organisations
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
DAL	Department of Agriculture and Livestock (Papua New Guinea)
DNA	Deoxyribonucleic acid
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
Hort-Research	The Horticulture and Food Research Institute of New Zealand Ltd
IK	Indigenous knowledge
IBPGR	International Board for Plant Genetic Resources
IPGRI	International Plant Genetic Resources Institute
ISSR	Inter-simple sequence repeat amplification
LEAS	Lowlands Agricultural Experiment Station
MAFF&M	Ministry of Agriculture, Forestry and Fisheries & Meteorology
NARI	National Agricultural Research Institute, Papua New Guinea
NGO	Non-governmental organisation
NZODA	New Zealand Overseas Development Agency
QUT	Queensland University of Technology
RFLP	Restriction Fragment Length Polymorphism
SPC	Secretariat of the Pacific Community
SPYN	South Pacific Yam Network
SSR	Simple Sequence Repeat
STABEX-FSP	Stabilization of Export Earnings from Agricultural Commodities: Farmer-Support Programme
TANSAO	Taro Network for Southeast Asia and Oceania
TaroGen	Taro Genetic Resources: Conservation and Utilization
TCIV	Taro Collecting Importance Value
UNDP	United Nations Development Programme
UNITECH	Papua New Guinea University of Technology
UQ	University of Queensland
USP	University of the South Pacific
VARTC	Vanuatu Agricultural Research and Training Centre