ANNEX 1 - Description of the Action

1. Summary of the action:

1.1 Overall presentation:

<table>
<thead>
<tr>
<th>Title</th>
<th>Adapting clonally propagated crops to climatic and commercial changes</th>
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<tbody>
<tr>
<td>Locations of the action</td>
<td>Burkina Faso, Costa Rica, Cuba, France, Fiji, Germany, Ghana, India, Indonesia, Kenya, Nigeria, Madagascar, Nicaragua, the Philippines, Papua New Guinea, Portugal, Samoa, Slovenia, South Africa, Trinidad and Tobago, Vanuatu.</td>
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<tr>
<td>Total duration</td>
<td>60 months</td>
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| Objectives of the action | The proposal addresses **Priority 5** of the Call. The Action brings together a global team of scientists, working directly with local growers, to develop a model for the adaptation of clonally propagated crops to climatic and commercial changes. Clonally propagated crops are less adaptable to changes in environmental conditions than those propagating sexually. Changes rely on mutations or the chance flowering, seed set and selection, which are rare events. Scientists or growers cannot easily manipulate the process. Importantly, in any one region, diversity is low. To produce plants adapted to new environments - climate change, pest and disease outbreaks, market needs - it is necessary to broaden the genetic base. To do that successfully, requires cooperation between countries, the use of modern biotechnologies, and development of a network of scientists exchanging information and germplasm under the auspices of international treaties. The proposed Action is multidisciplinary and involves developing country scientists from various disciplines: agronomy, breeding, chemistry, human sciences, genetics, and virology. The Action focuses on the use of modern biotechnologies to solve climatic adaptation problems, linking countries with centres of excellence that specialise in DNA fingerprinting, virus indexing, physico-chemical analyses and isotopes studies for assessing drought resistance. The proposal uses taro (**Colocasia esculenta**)) and cocoyam (**Xanthosoma sagittifolium**) to construct the climatic adaptation model. It shows how the genetic diversity of these two aroid species can be exploited to unlock their potential to overcome environmental and commercial challenges and, in the process, increase farmers’ incomes and improve food security. The consortium is composed of institutions with extensive experience in various clonally propagated root crops species. The applicant is a regional organisation (SPC), working with four European institutions: CIRAD (France), Univ. of Maribor (Slovenia), Univ. of Madeira (Portugal), DSMZ (Germany), 16 research institutions from 16 developing countries and Bioversity Int. (associate). The global partnership formed will create and efficient and effective network of institutions undertaking research to exploit the potential of clonally propagated crops. The overall objectives are:  
  • to assemble and share genetic resources of taro from diverse genepools,  
  • to promote international collaboration among breeders and farmers,  
  • to produce, by conventional and participatory breeding, new varieties of an underexploited crop with high agronomic and commercial potential.  
  • The selection of genotypes will be based on a combination of traditional and advanced procedures, including participatory methods. Modern biotechnologies will be used for germplasm transfer, to support plant breeding and crop analysis and, where appropriate, these will be done by country partners and training given in their use. |

| Target groups | National Agricultural Research Institutions and lead farmers in 16 developing countries |
| Beneficiaries | Women, subsistence and semi-subsistence smallholders in 16 developing countries |
| Estimated results | - A global network to transfer technologies and information to 16 countries, to create enduring partnerships, and test involvement of beneficiaries in R&D programmes.  
  - Understanding the genetic basis for adaptability to climate change and the potential for commercialisation in an underutilised food crop, as a model for other crops.  
  - Linkages between research and extension enhanced through active involvement of smallholder farmers, especially women, in a programme of participatory plant breeding.  
  - Linkages between research, extension and private sector through new products development. |
| Main activities | • International network sharing resources and helping farmers with participatory breeding.  
  • International distribution of selected *in vitro* clones (virus indexed) and true taro seeds.  
  • Selection of genotypes from diverse crop gene pools and adapted to local conditions.  
  • National distribution of elite cultivars to smallholders.  
  • Participatory breeding for wide environmental and cropping systems adaptability.  
  • Characterization of physico-chemical properties and potential uses. |
1.2 Approach, methodology and outputs:
The approach is three-fold:
1. **First, to facilitate access to wide crop gene pools.** By bringing together geographically isolated gene pools, the outcomes from breeding are likely to be significant. African countries such as Ghana, Nigeria, Kenya, South Africa and Madagascar have limited genetic resources, but production statistics indicate that they are major producers. In the Caribbean and Central America, Cuba, Nicaragua and Costa Rica, respectively, have already expressed their need to obtain genetic resources from elsewhere. If the partners use TTSs to exchange genes, there will be considerable gains.

2. **Second, to establish worldwide collaboration.** There is increasing evidence that projects favouring collaboration between countries is a cost-effective way of utilising resources and producing beneficial results, and they promote sustainability. In addition, the approach can be used to overcome limited agricultural research capabilities of developing countries.

3. **Third, to make use of modern biotechnologies.** Transfers of technologies will be made, and training provided. For those countries with limited resources, the project gives them the chance to access technologies that they would otherwise not be able to afford.

A feature of the project, and one that will enhance its success, is that it takes advantage of similar work on other root and tuber crops presently being implemented by several of the project countries and their European partners. Much of the work will be done within the country partners. However, where sophisticated equipment is required, such as that for DNA fingerprinting, virus characterisation and antisera preparation, electron microscopy, immunology, virus indexing using molecular techniques and isotope work, this will not be possible, and the work will be done in European institutions by developing country scientists. Partners already have taro germplasm collections. In general, the project strategy is straightforward: its design is feasible, and major problems are not envisaged.

The **work plan** of the action is broken down according to three types of activities: a) project management, b) technological development, and c) research.

The work plan is also broken down into eight work packages aiming at reaching eight specific objectives:

1. establishment of an International Network,
2. distribution of genetic diversity,
3. exchange of TTS,
4. genetic diversity studies,
5. drought resistance evaluation,
6. understand the relationships between the physico-chemical characteristics of corms, quality and taste,
7. optimise virus indexing procedures, and
8. to secure farmers’ the long term access to taro diversity and corm quality.

The action will last **60 months.** At the beginning of the project, a core sample composed of 50 elite cultivars from distant geographic origins (presently maintained in vitro in the SPC germplasm collection) will be distributed in vitro to 16 countries.

To assist project implementation, **annual network meetings** will be held to set work plans, monitor the work and review results.

In each country, 30 selected clones will be distributed to 50 farmers in 10 villages for evaluation. Breeders will come together at the beginning of the project to agree on strategies. Targeted crosses between selected genotypes will be made and TTSs will be exchanged between countries, and breeders and farmers will evaluate them. Elite cultivars will be analysed and their physico-chemical properties, and correlated with corm quality. In each country, evaluation of the genotypes for quality will be done by farmers and consumers between years 3 and 5.

The **outputs** will be varieties better adapted to local uses, new protocols for processing corms and, in particular, an improved knowledge of taro starches for industrial potential. Molecular markers will be used to assess genetic distances between the selected parents. Full-sib progenies will be compared with their parents and the segregating physico-chemical characteristics will be studied. The progenies will also be used to study the family heritability of these characteristics. DNA will be extracted and SSR and SNP markers used to detect the major genes involved in their biosynthesis. Drought tolerance of elite and local cultivars and full-sib-progenies will be evaluated based on morphological, physiological and biochemical features, e.g. biomass, yield or photosynthetic rates. Morphological and physiological traits correlated to drought tolerance will be identified, and a strategy to screen and identify new sources of genetic material to improve taro drought tolerance will be developed. Seedlings raised from true botanical seeds, as well as their parents, will be tested for viruses, to detect if any are seed borne. Hybrids from first clonal generations will be distributed to farmers for on-farm - participatory - selection.

A **website** and at least 12 publications in international journals will guarantee the visibility of the Action. Two MsC and five Ph.D. theses will be defended.

Because all partners are national institutions with mandate to conduct such work on taro, the long term sustainability of the action is secured.
2. Relevance of the action

2.1. Relevance to the objectives, sectors, themes and specific priorities of the Call

The aim of the proposal is to develop a model for underutilised vegetatively propagated crops of high value to meet changing environments. Producing crops ready for change - changes to climate, pest and disease outbreaks or a need for processing – is particularly difficult for those that are vegetatively propagated. Genetic diversity is constrained by geographical isolation; it is based on a few chance mutations or the occasional result of sexual reproduction; either way, genetic diversity is narrow, and this limits their usefulness as environments change rapidly. To create the diversity required, the genetic base of the crops needs to be broadened. This proposal describes a way of doing this for two aroid species, (taro, *Colocasia esculenta* and cocoyam, *Xanthosoma sagittifolium*); they are underutilised crops with potential to increase farmers’ income and improve food security.

Taro and cocoyam are staples, grown organically throughout tropical and sub-tropical countries as crops of high value. Hereafter, we will use the word “taro” in a broad sense to refer to these two aroid species (unless specified). They are ‘orphan’ crops, meaning that none of the international agricultural research institutions are mandated to work on them. Taro is said to be cultivated worldwide on approximately 2 millions ha annually ([www.fao.org](http://www.fao.org)), but this figure probably grossly underestimates the true amount. The crops provide a nutritious carbohydrate source from the corms, but they are rarely processed. The leaves are especially nutritious as a vegetable. Previous attempts to improve the crops have been done mostly in isolation, and with little application of modern biotechnologies. We envisage a different way.

The proposal will unite 16 partners in developing countries and four in Europe, in a collaborative network, bringing together scientists and smallholders to adapt genotypes to forthcoming climatic change, and to exploit the potential of the crops for product development. The network with its multi-stakeholder representation will also demonstrate the wisdom of decentralised breeding, reliant on a broad genetic base, taking taro from different gene pools, facilitate the exchange of information and technologies, and provide advice over the long term, beyond the life of the project. This sharing will improve international co-operation and contribute to Europe’s participation in research initiatives conducted at the regional level on the genetics of underutilised species with promising potential for the poor of the tropics and sub-tropics.

A further departure from previous attempts to improve the crops will be the involvement of farmers in the breeding programmes, producing selections adapted to their individual needs. Not only will this ensure that the germplasm distributed meets the needs of smallholders, but also will help in the dissemination and uptake of the results from the research, linking it with extension from the outset. To underpin the work, the genetics of drought tolerance and corm quality will be determined. In this way, a resurgence of interest in taro will be created, which will help its competitive position in the face of fast changing environments. This will meet the policy directions of many of the partners that already have established research and development programmes for underutilised crop, the goals of which are to target agricultural products for domestic use and for export. The project will help to make these aspirations a reality.

2.2. Relevance to the particular needs and constraints of the target countries and/or relevant sectors

Developing countries face huge challenges to provide sufficient food to feed the extra people who will be born in the next 40 years as the population increases to 8.5-9 billions. Food security will become a dominant issue: if people do not have access to enough food of good quality to sustain active and healthy lives, political and social unrest will occur. However, it looks increasingly likely that the amounts of food required are not going to come from improvements to the major food crop staples alone. Many are thought to be approaching their maximum yield potentials. Research on presently underutilised crop, such as taro, is needed if food security is to be assured. But to bring these crops into cultivation to meet the challenges that exist will necessitate improved management practices, higher-yielding and better quality cultivars - possibly suited to marginal lands - and the development of post-harvest technologies. And, if down-stream processing is to be successful, new partnerships with the private sector will be required, to test market acceptability for the new products. However, to date, work on taro in most countries has produced few useful results: the strategies have been wanting. In particular, they have not been able to access germplasm with the diversity required, or assemble the mass of scientists required to tackle the complex problems that exist.

Many countries do not keep accurate statistics, for a crop that is grown mostly by smallholders. The yield of taro is about 5.5 t/ha on average, the lowest of all root or tuber crops. Mostly, it is the food of small, marginalised farmers, who grow the crop in swamps, irrigated terraces and/or on dry land, for home
consumption or domestic markets. In this way, taro contributes significantly to food security, agricultural diversification and income generation in numerous developing countries.

Apart from its use as a vegetable in Asia, Africa and Central America, taro also has great social importance. In many Pacific Island countries, *Colocasia* taro dominates the traditional farming system, and is an integral part of social rituals. Even on islands where the crop is no longer grown to its past extent, people still favour it over other root crops: it can be grown in areas that are too wet for other crops; the leaves can be used; and it fetches high prices on domestic and overseas markets. In Africa, South and Central America and the Caribbean, *Colocasia* taro and *Xanthosoma* cocoyam are home gardens crops, important for food security, but increasingly cultivated to satisfy export demand from markets in the USA and Europe. In Asia, the situation is somewhat different: in these regions, there is a widely perceived need to expand crop diversity to sustain food production, as rice-based cropping systems are coming under increasing pressure as populations rise.

There is potential for wider use, but this is unlikely to be realised under present circumstances, as taro is clonally propagated and natural genetic interchange between plants is low. This means that varieties have limited scope to adapt to changing environments. Unless new strategies for taro are devised, smallholders will be deprived of the potential of this crop. Many countries are well aware of the potential of taro as an export commodity, which will increase employment opportunities in flagging economies and, over time, improve living standards in rural communities. There are few crops with all its attributes. What is required now is a coherent strategy to produce cultivars that meet the requirements of growers and processors alike.

**Building on previous actions:** Most of the partners have found great difficulty in sustaining genetic improvement programmes for taro, or for any of the other crops of interest; and where programmes have been initiated, they have tended to be small, short-lasting, with few scientists and limited funding. Consequently, the results have been less than anticipated. Collections have been assembled and described, but due to the shortcomings noted, they have been lost. The Third International Taro Symposium, organised by FAO, IPGRI, CTA and SPC in May 2003, discussed the situation, and saw the need for greater collaboration between countries. A priority recommendation was the genetic improvement of taro for adaptation to changing climate. Furthermore, taro was seen as a crop with enormous trade potential to meet the demand from urban centres, locally or overseas, but corm quality needed to be improved, and processed products devised. Rapid progress was possible, but only if countries collaborated. Both drought tolerance and corm quality can be genetically improved as long as the research was based on recurrent convergent-divergent selection, combining the genetic resources present from diverse gene pools. Working independently would, simply, repeat past failures.

A previous project funded by the EU-INCO-DC (from Jan. 1998 to Dec. 2001) was seen as a model for success. In that project, accessions resistant to taro leaf blight were identified, based on an assessment of genetic diversity using molecular markers; germplasm was exchanged and breeding strategies developed by six SE Asia and Pacific countries. A core sample of 140 elite cultivars was assembled, most of which is maintained *in vitro* at the SPC regional germplasm centre in Fiji. This core sample is available for international distribution. It now needs to be supplemented with germplasm from Europe, Africa, the Caribbean and America.

International collaboration is important in countries where resources for research are small and diminishing. In all regions, there is the need for reciprocal exchanges of germplasm, as no one country is self-sufficient in genetic resources of taro, or any other crop. Most countries are content to exchange germplasm in the form of TTS from which selections have to be made in the recipient country.

A majority of the partners under this proposal are signatories of the FAO International Treaty on Plant Genetic Resources for Food and Agriculture, and are prepared to share taro germplasm under the ITPGRFA Multilateral System of Access and Benefit-sharing by Contracting Parties. There is a strong commitment within the partners to undertake the fundamental research required. The persistent attempts of individual countries to collect and conserve taro and to make use of the genetic resources over more than 50 years, even in the face of persistent failures, is evidence of their commitment.

### 2.3. The target groups, final beneficiaries, their needs and constraints

The **target groups** of this proposal are the plant breeders and other scientists working on taro worldwide, who do so in isolation. Although taro is extensively cultivated, it remains outside the remit of the international agriculture research system. Unlike other tropical root crops (cassava, sweet potato, yam), there is no CGIAR institution with a mandate to work on taro. Scientists and farmers cannot easily access new genotypes. Breeding of taro demands considerable expertise as well as the safe distribution and preservation of germplasm. Apart from the work of SPC, one of the partners for the proposed Action, little germplasm is exchanged internationally because it has to be virus-indexed. SPC has acquired expertise to do this -
experience gained from a past project funded by ACIAR - and has accumulated germplasm originating from SE Asia and the Pacific. Unfortunately, little work of this kind has been done for Africa and Central America, and so scientists there do not have access to indexed germplasm. Without this, yields will remain low and major diseases, such as root rot, and other constraints to production, are not likely to be resolved.

The intended beneficiaries of the proposal are taro growers throughout the world, those that grow the crop both for subsistence and commercial use. They are smallholders who require access to improved germplasm to overcome production constraints, and who wish to see new product development for domestic and export markets to boost incomes. Importantly, the work will maintain a traditional food of high nutritional quality and cultural significance. There are no figures of the number of taro growers in the world but considering that taro is grown in all countries of the wet lowlands (where the major part of the human population is located), it is probable that 20 per cent of the population, or in excess of 500 million people, are reliant on the crop for part of their dietary needs. Women will be the primary target in on-farm activities, as they have the greatest knowledge of varieties, and are the custodians of the genetic resources. There will be benefits to farmers from having greater diversity of germplasm giving more stable yields, and reduced losses from damaging pests and diseases.

In order to test the strategy of participatory plant selection and breeding, 5 farmers in 10 villages, in each of the participating countries, will be chosen, based on their enthusiasm to be involved, and their knowledge of the crop. Guidelines for the choice of participants will be worked out between the partners at the start of the project.

2.4. Particular added-value elements

**Environmental issues:** It is the aim of the project to provide farmers with greater diversity of germplasm to ensure sustainability and stability of the crop against adverse biotic and abiotic conditions, increased production per unit area, and to develop methods of processing that add value to the harvested corms. Extending the crop area is a possibility if marginal lands are used for cultivation, and here the project provides great potential. Whether or not these new areas will be exploited without causing environmental damage will have to be judged on a case-by-case basis, but taro does have potential for use in, e.g., swamps, which cannot be used for the production of the major food crops presently grown in the world. Taro is not new to the participating countries; it is grown, but is neglected and underutilised. Increased cultivation would not be a reason for concern or warrant environmental impact studies.

The project is likely to have a positive effect on agriculture diversity. As human populations rise there is a tendency for the number for crops to decrease, creating vulnerability, especially if the variability within the crops is also reduced. This loss of biodiversity in developing countries is of concern, and is a reason why countries are looking for underutilised and neglected crops to underpin food security.

**Gender issues:** Women have the greatest knowledge of varieties, as they are the custodians of this crop. They will be the key partners in on-farm activities and will play a major role in the participatory breeding process. However, the impact of improved varieties on their livelihood is difficult to foretell. Increased crop cultivation may create an additional burden, although increased yields per unit area might reduce the labour involved. Commercial growers, on the other hand, are mostly male, but if they expand production, women will benefit as paid labour. In some countries, men and women work together in food production, although men will often take the lead in marketing and benefit most from the cash obtained. The situation is complex and does not lend itself to simple analysis.

**Innovation:** There are now food preservation methods that require relatively unsophisticated technologies to make snack foods, vacuum packed products and speciality flours. Processed this way, taro is likely to be in demand in growing Asian, African and Central American cities, the home of increasing numbers of urban dwellers with the resources to buy traditional root crops in convenient supermarket-style packages. Recent advances in food science have not been applied to taro. At present, the high price of taro on domestic markets mitigates against ‘simple’ processing, for instance, the manufacture of flours. More complex processing is required to build a higher price, even if the finished product does not resemble the original material. An area of promise is speciality starches: the basic starch of taro is quite unique and the possibility exists that a study may result in new products of interest to starch manufacturers.
3. Description of the action:

3.1. The consortium
This is a multidisciplinary action which involves 16 developing countries and scientists from various disciplines: agronomy, breeding, chemistry, human sciences, genetics, and virology. The consortium is composed of institutions with long, relevant and extensive research experiences in various root crops species.

The applicant (SPC) is a regional organisation working for developing countries (and in Western Samoa for the present action). Partners 1, 2, 3, 4 are European institutions from different countries (France, Slovenia, Portugal, Germany). Partners: 5 (Indonesia), 6 (Papua New Guinea), 7 (Nigeria), 8 (Ghana), 9 (the Philippines), 10 (Vanuatu), 11 (Kenya), 12 (South Africa), 13 (Madagascar), 14 (Cuba), 15 (Burkina Faso), 16 (Nicaragua), 17 (Costa Rica), 18 (India) and 19 (Trinidad and Tobago) are 15 different research institutions from 15 countries.

List of participants:

<table>
<thead>
<tr>
<th>Name of the applicant</th>
<th>SPC, (Dr Mary Taylor)</th>
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<tr>
<td>Partner 1:</td>
<td>- CIRAD-BIOS, France (Dr. Vincent Lebot)</td>
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<tr>
<td>Partner 2:</td>
<td>- University of Maribor, Slovenia (Pr. Anton Ivancic)</td>
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<td>Partner 3:</td>
<td>- University of Madeira, Portugal (Dr. Miguel Carvalho)</td>
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<td>Partner 4:</td>
<td>- Virus Department DSMZ, Germany (Dr. Stephan Winter)</td>
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<td>Partner 5:</td>
<td>- LIPI, Indonesia (Dr. Made Sri Prana)</td>
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<td>Partner 6:</td>
<td>- NARI, Papua New Guinea (Dr. Birte Komolong)</td>
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<td>Partner 7:</td>
<td>- NRCRI, Nigeria (Dr. Egbichi Mbanaso)</td>
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<td>Partner 8:</td>
<td>- CSIR, Ghana (Dr. Lawrence Misa Aboagye)</td>
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<td>Partner 9:</td>
<td>- PhilRootCrops, the Philippines (Pr. Algerico Mariscal)</td>
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<td>Partner 10:</td>
<td>- VARTC, Vanuatu (Dr. Roger Malapa)</td>
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<td>Partner 11:</td>
<td>- Masinde Muliro Univ. Kenya (Dr Valerie Palapala)</td>
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<td>Partner 12:</td>
<td>- ARC, South Africa (Dr. Willem janse van Rensburg)</td>
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<td>Partner 13:</td>
<td>- FOFIFA, Madagascar (Dr. Jeannot Ramelison)</td>
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<td>Partner 14:</td>
<td>- INIVIT, Cuba (Dr. Sergio Rodrigo Morales)</td>
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<td>Partner 15:</td>
<td>- Univ. de Ouagadougou, Burkina Faso (Renan Traoré)</td>
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<td>Partner 16:</td>
<td>- University of Nicaragua, Nicaragua (Dr Guillermo Reyes)</td>
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<td>Partner 17:</td>
<td>- University of Costa Rica (Dr. Francisco Saborio)</td>
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<td>Partner 18:</td>
<td>- CTCRI, ICAR, India (Dr. S.K. Naskar)</td>
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<td>Partner 19:</td>
<td>- CARDI, Trinidad and Tobago (Dr. G. Robin)</td>
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The Action will create a R&D program bringing the work of the partners together in a complementary way, as follows:

- **SPC**, the Secretariat of the Pacific Community maintains *in vitro* the largest international germplasm collection of taro in the world and is willing to distribute it internationally. SPC will also develop a breeding programme in Western Samoa (the 16th developing country involved in the action).
- **CIRAD** (France) has expertise in taro genetics and molecular markers (SSRs and SNPs),
- University of **Maribor** (Slovenia) is the world leader in taro breeding and reproductive biology and has expertise in the physico-chemical characterisation of taro,
- University of **Madeira** (Portugal) has a long experience in drought stress resistance studies,
- **DSMZ** (Germany) has expertise in virus detection and indexing, and, finally,
- All country partners (**Indonesia, Papua New Guinea, Nigeria, Ghana, the Philippines, Vanuatu, Kenya, South Africa, Madagascar, Cuba, Burkina Faso, Nicaragua, Costa Rica, India and Trinidad and Tobago**) have expertise in taro agronomy and breeding, both at the national and regional levels.

The project intends to develop a close relationship between European institutions and those in developing countries to assist the development and transfer of skills in several biotechnologies. Scientists will be responsible for organising and carrying out project activities locally. Apart from specific interaction associated with various training activities, all partners will meet annually to review progress and set work plans. Informal and regular contacts will be frequently conducted via email.

### 3.2. The work plan

The work plan of the action is broken down according to three types of activities:

- a) project management activities,
- b) technological development, and
- c) research activities.

The work plan of the action is also broken down into **eight** work packages (**WP**). These work packages aim at reaching the **eight specific objectives**:

1. to establish an *International Network for Edible Aroids* (INEA), a network for an orphan crop cultivated over 2 million ha worldwide (**WP1**),
2. to distribute genetic diversity of taro internationally so that solutions to climate change can occur incrementally as environmental conditions change, as well to select varieties chosen by farmers for their corm quality and adaptability to diverse farming systems and agro-ecological situations (**WP2**),
3. to develop a network worldwide for the international exchange of TTS as a means of exchanging germplasm of broad genetic diversity (**WP3**),
4. to study genetic diversity and analyse Mendelian segregations of major chemical components (**WP4**),
5. to evaluate drought resistance of elite and local cultivars and full-sib progenies, using different morphological, biochemical and molecular markers, to identify the traits correlated with drought tolerance in taro (**WP5**),
6. to analyse the intra-clonal and inter-genotype variation of the nutritional traits of corms from cultivars grown in a controlled environment in order to understand the relationships between the physico-chemical characteristics of corms, drought induced stress, quality and taste (**WP6**),
7. to further develop and optimise virus indexing procedures for taro to facilitate the international movement of germplasm (**WP7**),
8. to secure farmers’ the long term access to taro diversity and corm quality (**WP8**).

### 3.3. Roles and responsibilities of partners:

**The applicant** (SPC Centre for Pacific Crops & Trees, CEPACT, Fiji) is a regional technical organization for 22 Pacific island countries with programmes in fisheries, agriculture and health. The agriculture programme includes regional projects in fruit fly control, integrated pest management, and plant protection, with attention to capacity building, training, publications, and technical assistance. There is an emphasis on root and tuber crops for cash and food, because of their importance in all parts of the Pacific - Melanesian, Micronesian and Polynesia. SPC with its CePACT provides member countries with access to improved varieties of a wide variety of crops - bananas, taro, sweet potatoes and yams - for testing. The Land Resources Division is one of the several SPC programmes through which the Commission provides, on request of its member countries, technical assistance, advices, information, and clearing-house services. The Programme goals are to:
• promote land and agricultural management practices which are currently acceptable and both economically and environmentally sustainable;
• strengthen national capabilities to reduce losses due to crop pests (insects, pathogens and weeds) and animal diseases already present, and prevent the introduction of new pests and diseases,
• facilitate trade through improved quarantine procedures;
• strengthen access to and use of sound sustainable development information for all stakeholders.

The Land Resources Division is based in Fiji. It has a complement of qualified and experienced staff, both from the Pacific Islands and elsewhere. Strategies used to ensure that the activities and projects undertaken by the programme are appropriate and relevant include technical meetings, such as the Regional Technical Meetings of Plant Protection and the Heads of Agriculture and Forestry Services (HOAFS); direct country requests and staff travel; attendance at various workshops and conferences (including those organised by other programmes of SPC and tele-conferencing via PEACESAT). To make the best possible use of available resources and to avoid duplication, the Programme has established formal links and excellent working relationships with a number of national, regional and international organisations and institutions. The Programme depends on a number of funding sources for support. These include the regular budget of SPC (drawn primarily from member country contributions), and special contributions by donor agencies and metropolitan member countries for staff and their activities.

Lead collaborating scientist: Dr. Mary Taylor, Qualifications: Ph.D. Tissue Culture
Mailing Address: South Pacific Commission, Private Mail Bag, Suva, Fiji.
Phone: (679) 370 733, Facsimile: (679) 370 021, E-mail: MaryT@spc.int

Recent publications relevant to the project:
Expert Consultation on the status of biotechnology in agriculture in Asia and the Pacific, Bangkok, Thailand.


The applicant, SPC (Secretariat of the Pacific Community), will propagate in vitro selected genotypes and distribute them to 16 developing country partners so that they can be used for genetic base broadening, direct distribution to farmers and for breeding activities. SPC will also support evaluation in Pacific Island countries through its Pacific Agricultural Plant Genetic Resources Network, PAPGREN. In collaboration with DSMZ, SPC will virus test/index germplasm prior to distribution and evaluate/optimise virus elimination techniques as necessary. In collaboration with the University of Madeira, SPC will carry out preliminary drought tolerance screening work in vitro.

SPC will also conduct distribution, breeding and on-farm activities in Western Samoa, a country which has been severely affected by the taro leaf blight introduction in 1993. A taro breeder will be hired and based in Samoa to develop activities according to three work packages (WP2, WP3 and WP8). The taro breeder based in Samoa will be under the scientific supervision of CIRAD and Maribor.

Partner 1, CIRAD (scientific coordinator), France: will coordinate the project, train scientists, organise meetings and will produce reports. CIRAD will also conduct genetic studies using DNA markers (SSR, SNP) (one European PhD), and will provide training to non-EU partners (a PhD candidate from Burkina Faso will be trained to molecular markers use and analysis). CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) is a French research organisation specialising in tropical and sub-tropical agriculture and tropical crops genetic improvement.

Partner 2, University of Maribor, Slovenia: will provide scientific backstopping to country partners on taro breeding and visual tools for on-farm screening and selection of genotypes. Maribor will conduct various studies to assess the reproductive potential of taro genotypes and the impact of GA3 on flowering induction. Maribor will advise on practical breeding protocols and long term crop improvement strategies.
The University of Maribor will also analyse the physico-chemical characteristics of taro corms, in particular, the variation between cultivars growing under controlled environmental conditions, between cultivars originating from 16 different countries, and between full-sib progenies. In addition, Maribor will collaborate with Madeira in Portugal in the analysis of biochemical traits associated with drought tolerance, characterising the effects of drought induced stress on the physico-chemical characteristics of the corms. The University of Maribor will also conduct an in depth assessment of the physico-chemical characteristics of taro starches, and assess their potential industrial uses.

Partner 3, University of Madeira, Portugal will study drought tolerance on a limited number of cultivars and full-sib progenies, selected by partners in developing countries, and also on local Madeiran and Canarian genepools. Drought tolerance studies will be performed under controlled conditions and in field trials. Taro drought tolerance will be screened and evaluated based on different markers related to the stress response, such as morphological descriptors, biomass, yield, protein or molecular markers. A strategy to screen and identify new sources of genetic material to improve taro drought tolerance will be developed. During the project implementation, Madeira will co-operate with Maribor (Slovenia) in the analysis of the influence of drought on agronomic and nutritional characteristics of taro cultivars, supplying samples for the physico-chemical characterisation of the corms, as well as with country partners in the selection of drought tolerant varieties. Madeira will provide training to non-EU partners to carry out planned experimental work.

Partner 4, DSMZ, Germany: will assist the project with virus indexing. The initial task will undertake a survey, to ensure that the protocols already established detect all viruses present in the germplasm of interest. Where strain differences are indicated, molecular techniques for virus detection may be needed. For accessions where symptoms of virus infection are observed, but ELISA detects no virus, transmission studies to alternative/indicator hosts and EM will be used to determine if previously unidentified viruses or virus strains are present. Virus-indexing procedures will be developed to test seedling populations and to determine the potential for seed transmitted. Guidelines for the safe international movement of true taro seed will be up-dated, and training in virus indexing will be given to non-EU partners as appropriate.

Country Partners 5-19: will receive 50 genotypes in vitro from SPC (three tubes of each) in order to increase the genetic diversity existing in their breeding programmes. Once received by the partner countries, these genotypes will be field propagated, evaluated and selected for on-farm experiments. Thirty genotypes (a selection of the best local and introduced genotypes) will be distributed to five farmers in 10 villages (total of 50 lead farmers in each country). In collaboration with Maribor, all country partners will initiate a breeding scheme and produce true taro seeds via targeted controlled crosses. They will choose the parents according to their performances and traits. Some may be local and other introduced genotypes. F₁ hybrids will be raised and clones propagated after selection of the best genotypes. C₁ (first generation clones) will be distributed to farmers for on-farm evaluation. True seeds obtained from controlled crosses (full-sib progenies) will be shared with other partners. In the mean time, samples will be sent to CIRAD, Maribor, Madeira and DSMZ for specific studies: leaf samples for DNA extraction and genetic diversity studies, dry matter samples for physico-chemical characterisation, propagules for drought analyses and plant tissues for virus studies. Partners 5-19 will receive training in data analysis and will also develop tasks more specific to their local programmes and conditions (as well as their MSc and PhD programmes).

Associate: BIOVERSITY international will assist in coordinating activities as well as providing scientific backstopping to developing country partners. Bioversity will be involved through its Global Partnerships Programme and the Platform for Agrobiodiversity Research (PAR). Bioversity will use its Associate status as to leverage additional international interest in the proposed Action. It is relevant to have Bioversity involved because of its outreach in developing countries as well as its networking expertise.

Relationship between work packages and partners is graphically represented in Figure 1.
Figure 1: Graphical representation of relationships between partners and work packages (WP).
4. Specific expected results of the proposed action:

1- International distribution of allelic diversity to maximise the use of genetic resources originating from distinct gene pools will be achieved while promoting collaboration among breeders at the international level, and between breeders and farmers at the national level. The action will secure adaptation to climatic changes by developing genotypes for drought resistance and consumers acceptance, and to select them “on-farm” for wide environmental adaptability.

2- In all participating countries, the outputs of this Action will include genetic base broadening and adaptation of taro to climatic changes over the long term. Research activities will improve the scientific understanding of taro genetics and adaptation to drought.

3- Farmers’ varietal portfolios will be diversified via the distribution of selected genotypes. These genotypes will be selected on their chemical composition, but ultimately according to criteria set by producers and consumers. Fifty varieties will be distributed in vitro (virus indexed) to 16 countries. They will be propagated and field evaluated first by researchers and then by farmers. In each country, the best 30 selected varieties (including local and introduced ones) will be distributed to 10 villages (five lead farmers in each village), and evaluated on-farm using participatory methods. At the end of the Action (after 60 months) many more farmers will have new varieties obtained via traditional social networks for sharing germplasm between farmers.

4- The national distribution of elite cultivars to smallholders will have a direct impact on the diversity maintained in the targeted villages because these cultivars will be selected for their distant genetic backgrounds.

5- Networking between scientists and participatory breeding with farmers will strengthen collaboration between stakeholders worldwide. An International Network for Edible Aroids (INEA) will be established to improve the long term sustainability of the Action.

6- At least twelve papers will be published in international journals with high impact factors.

7- Finally, the development of a global system for adaptation to climatic changes will be applicable to other root crops species and the project will, therefore, have much wider impact over time.

8- The scientific work packages will produce data on the genetics (WP 4), physiology (WP 5), physico-chemistry (WP 6), and virology (WP 7) of taro. Training in advanced biotechnologies will be given and transfer of technologies will be carried out. The project will allow two MSc theses to be defended (one from Madeira and one in Papua New Guinea) as well as five PhDs (in Burkina Faso, France, Germany, Slovenia, South Africa).

The scientific expertise required for the Action and the tasks required are balanced between EU and non-EU partners. In addition to breeding and assisting farmers in the evaluation of progeny, non-EU partners will also be involved in the application of various biotechnologies that form part of the individual work packages. Experts in research from non-EU countries have been identified and are directly involved in the project.

Specific expected results (deliverables list):

**WP 1 Project coordination (specific objective 1):**

1. Development of a website and platform to support an International Network for Edible Aroids (INEA).
2. Fulfilment of financial, administrative and coordination obligations.
3. Production and circulation of annual reports.
4. Monitoring of project activities.

**WP 2 In vitro distribution and propagation (specific objective 2):**

5. International distribution of 50 selected genotypes to all country partners.
6. Field propagation of introduced genotypes, evaluation, comparison with local ones, and
7. Distribution of 30 selected genotypes to 10 village communities per country (five farmers per village).

**WP 3 Assistance to breeding programmes (specific objective 3):**

8. Controlled crosses conducted in each participating country.
9. Hybrid seeds generated and F₁ hybrids raised.
10. Hybrid clones distributed to five farmers in 10 villages (total of 50 farmers per country).
11. One PhD defended on taro breeding in South Africa (Mr WS Jansen van Rensburg).
WP 4 Genetic Studies (specific objective 4):
12. DNA fingerprints of elite cultivars used as parents in crosses.
13. Genetic distances determined between parents.
14. Segregation of molecular markers studied within and between seven full-sib progenies.
15. Markers associated to major genes, if any, identified (on morphological traits, i.e. leaf shape-area).
16. First heritability trial established and harvested (on major chemical compounds related to quality).
17. Second heritability trial established and harvested.
18. Potential major genes controlling corm quality identified (e.g. amylose, starch, sugars)
19. One PhD defended on the genetic diversity of taro (for a scientist from Burkina Faso (Mr Renan Traoré)
20. One PhD defended on genetic studies of association between markers and physico-chemical characteristics.
21. Four papers published in international journals.

WP 5 Drought tolerance studies (specific objective 5):
22. Field assays for drought tolerance studies established.
23. Morpho-agronomic traits associated with drought tolerance accurately identified and evaluated.
24. Physiological and biochemical markers analysed and correlation studies completed.
25. Chemical analysis of corms from drought stressed plants, or showing drought tolerance, analyzed.
26. Association of different traits and markers with drought tolerance studied.
27. One MSc defended on taro drought tolerance.
28. Two papers published in international journals.

WP 6 Physico-chemical characterization of the corms (specific objective 6):
29. Intra-clonal variation of chemotypes studied and determined.
30. Physico-chemical characteristics/variation of selected cultivars studied and correlated with molecular markers.
31. Physico-chemical characteristics/variation between and within full-sib families studied and correlated with molecular markers.
32. Assessment of physico-chemical characteristics variation due to drought and correlation with molecular markers analysed.
33. One PhD thesis defended on the influence of stress on corm quality
34. Two papers published in international journals.

WP 7 Virus indexing and safe movement of germplasm (specific objective 7):
35. Virus diversity study conducted. Information on viruses/virus strains infecting germplasm collections and breeding lines in each of the participating countries.
36. Protocols for virus indexing seedling populations of taro fully optimised.
37. Parents and seedlings raised successfully.
38. Information on the rate of transmission in true seed of the important viruses or virus strains infecting taro breeding lines.
39. Guidelines for the safe movement/exchange of true taro seed between project partner countries.
40. One PhD defended on viruses identification/indexation studies
41. Two papers published in international journals.

WP 8 Distribution of allelic diversity (specific objective 8):
42. Introduced elite genotypes distributed to farmers and propagated in their plots.
43. Introduced elite genotypes harvested and assessed by farmers
44. C1s (first clonal generation) propagated and distributed to farmers.
45. On-farm trials harvested and participatory evaluation of C1 quality conducted.
46. On MSc defended in Papua New Guinea (Mr Jeffrey Waki).
47. Two papers published in international journals.
5. Detailed activities:

**WP 1: Project management activities**
Considering the international scope of the Action and the importance of management and scientific activities, WP1 is sub-divided in two WPs:

WP 1.1. Project management activities, and
WP 1.2. Scientific coordination activities.

**WP 1.1: Project management activities**
*(Dr. Mary Taylor, MaryT@spc.int)*

**Description of the work:**
*The applicant (SPC)* will be the contact person for the European Commission. SPC will be responsible for the day-to-day financial management of the project. The Contracting Authority will pay the grant to the *Applicant (SPC)* following the provisions set up in Art. 15 of the Annex II of the standard contract. SPC will be responsible for the management of the grant. Following preliminary discussions with partners, individual contracts between the applicant and individuals partners will be signed. SPC will take overall responsibility for project management and for acquiring the project funds. All partners will meet at the beginning of the project to refine the strategic plan and formulate an Action Plan for the first year. In proceeding years, annual meetings, rotated between country partners, will be held to review results and plan for the years activities.

SPC support services will deal with the receipt, allocation and transmission of the EU Commission’s financial contribution to the project partners, administration of the account held on trust, the control of payments, the provision of financial reports, the analysis and processing of audit results, permanent financial control and comparison of estimates and actual costs. SPC will be the permanent contact point for the EU Commission concerning payments, cost statements and general questions regarding accounting, financial and legal matters for the project. Most of management activities will be undertaken by the applicant but provisions are made for partner’s contribution to these activities. The Applicant, SPC, is supported by the Administrative and Financial Services of his institution. Annual budgets will be agreed at annual meetings. Periodic contacts will be made to ensure that the project activities begin and are completed efficiently and within budgets.

A *partnership agreement* will be drawn up in accordance with EU requirements and signed by all partners to specify all their responsibilities, rights and duties concerning this project. It will further detail the internal organisation of the partnership, its governance structure and management procedures. The Partnership Agreement will also identify all intellectual property rights issues (IPRs) brought to the project as pre-existing know-how, and the IPRs of the knowledge generated by the project.

**WP 1.2. Scientific coordination activities**
*(Dr. Vincent Lebot, lebot@cirad.fr)*

**Description of the work:**
*CIRAD* will be responsible for the day-to-day scientific coordination of the project. The project scientific co-ordinator, *CIRAD*, is assisted by *SPC* and *Biodiversity International*. CIRAD will be responsible for the circulation of information, the collation of scientific annual reports from the partners and the production of a terminal report detailing the successes of the project. Periodic visits (at least once a year from at least one European partner) will be made to all country partners to discuss the work programme and to help overcome any difficulties that might occur. Annual reports will be published and distributed to project partners. Formal publication of information generated by the project will be done in international journals. Results from genetic and breeding studies, physiology, virology and the physico-chemical characterisation of the corms will be published in international journals (at least 12, may be more) with high impact factors. A platform and web site will be developed by a professional webmaster hired by CIRAD, the scientific coordinator. Annual work plans will be agreed at meetings of the country partners and commissioned institutions. The venue for the meetings will be decided in year 1. Periodic visits will be made to ensure that the project activities begin and are completed efficiently and within budget.

The *project management structure* adopted for this project is composed of three levels: decision taking, project coordination and scientific production.

**Decision taking:** A Steering Committee will be composed of one representative of each participant institution and will be chaired by the project scientific co-ordinator (*CIRAD*). Each project Steering Committee member has the empowerment from his institution to commit staff and other resources required by the project.

**Project scientific coordination:** Progress will be monitored regularly to avoid partners failing to deliver their project inputs. This will be the role of CIRAD, the co-ordinator and the lead contractors for each WP. Annual meetings and on-site visits will be organised to ensure that deliverables are on time and of high quality. Expected and unexpected results will be reviewed, as well as any scientific and technical
difficulties encountered. Research progress will be evaluated in comparison with the planned delivery list and the timetable. In order to conform to the work plan, to achieve the initial objectives and to obtain the agreement of all partners involved in the different tasks, work packages and protocols, the Annual meeting will provide the opportunity to discuss activities for the next period. This process will allow possible re-evaluation of some strategies and re-orientation of the research if required.

**Scientific production:** The project activities are structured in eight work packages with a lead contractor nominated for the detailed co-ordination, planning, monitoring and reporting of each activity. Regularly, each lead contractor will submit to the scientific coordinator a short report on progress made, problems and solutions or alternatives. Except for WP1 and WP2, all WPs will produce university degrees: two MScs and five PhDs. Information flows will be both, top-down and bottom-up (see Figure 1), aiming at ensuring maximum transparency for all partners involved and maximising synergies between them during the five years of the project. All information (i.e. meetings minutes, publications, reports, etc.) will be communicated to the scientific coordinator who will be responsible for dispatching this information to the various project stakeholders, including the European Commission. Communication with partners outside the partnership (i.e. local authorities, private sector…) will be done via the web site and the platform. To initiate such communication flows, various means will be used (e.g. the opening up of a web site, organisation of regular meetings and visits, preparation of status/progress and final reports, publications in national and international scientific journals). At the beginning of the project, a meeting will be organised in Vanuatu (where a taro breeding programme is on-going) to launch the project activities and define strategies and train partners in taro breeding techniques.

**Deliverables of WP1:**
2. Fulfilment of financial, administrative and coordination obligations.
3. Production and circulation of annual reports.
4. Monitoring of project activities.

**WP 2: In vitro propagation of selected elite cultivars for international distribution to farmers**
**Partner in charge of WP2: SPC** (Dr Mary Taylor, MaryT@spc.int)

**Objectives:**
- International distribution of 50 selected genotypes to all country partners
- Field propagation of selected genotypes, and
- Distribution of 30 selected genotypes to 10 village communities per country (five farmers per village).

**Description of the work:**
The CePaCT maintains a collection of some 850 accessions of taro in vitro and has established an effective and efficient multiplication protocol to facilitate distribution of taro to its 22 member countries. SPC will assemble a core sample composed of 50 genotypes representing high genetic diversity (genotypes from different geographic origins). These genotypes are from different Asian and Pacific countries and are preserved in vitro in the Centre for Pacific Crops and Trees (CePaCT) in SPC, Suva (Fiji). They have already been DNA fingerprinted and their genetic distances are known and documented. A set of three in vitro clones of each genotype will be sent via courier to all country partners (150 clones per country).

The taro multiplication system used by CePaCT utilizes TDZ and BAP at relatively low levels within a four-stage multiplication protocol. Upon reception, all country partners will field propagate these genotypes and use rapid multiplication techniques to bulk the material on station. These introduced genotypes will be evaluated and compared (germplasm collection evaluation) to the local ones. After evaluation, 30 genotypes, corresponding to a combination of elite local and introduced characteristics, will be selected and propagated for distribution to farmers. By month 24, the first selected genotypes (30 per country) will be planted in farm trials. First results are expected by months 30-36 (in some countries, the maturity period of high yielding cultivars is more than 8 months).

**Deliverables of WP2:**
5. International distribution of 50 selected genotypes to all country partners, three clones per genotype,
6. Field propagation of introduced genotypes, evaluation, comparison with local ones, and
7. Distribution of 30 selected genotypes to 10 village communities per country (5 farmers per village).
**WP 3: Breeding and on-farm participatory selection and evaluation.**

Partner in charge of WP 3: University of Maribor (Pr. Anton Ivancic, anton.ivancic@uni-mb.si)

Objectives:
- To produce full-sib hybrid progenies through targeted crosses involving selected cultivars,
- To produce superior hybrids and select specific sources of genes for various traits of interest.

**Description of the work:**

Breeding programs in all participating countries will conduct targeted crosses between selected elite cultivars. They will be assisted by the applicant, CIRAD, and Maribor from Europe. Maribor will collaborate with all country partners (5-19) to develop a breeding scheme adapted to each partner, according to the characteristics and constraints of the local germplasm. Maribor will develop protocols using visual tools which can be used on-farm with growers to select genotypes and will train local scientists in breeding techniques (use of GA$_3$, controlled hybridization, seeds and seedlings management). Full-sib progenies will be produced. Seedlings will be raised and C$_1$ hybrid plants will be distributed to farmers for on-farm evaluation (WP 8).

Elite cultivars will be intercrossed. The main criteria for selecting the parental materials will be their agronomic performances and good taste. Flowering will be induced (where needed) by GA$_3$ (at the concentrations of 200-300 ppm). Inflorescences of female components will be emasculated one day before becoming fragrant, and pollinated. For preventing uncontrolled pollination, cotton wool will be used. Seeds from successful crosses will be extracted and dried, and planted in pots which will be placed in special water ‘beds’. When of sufficient size, they will be planted in shaded nurseries, and later in the field. The first selection (resistance against diseases, and tolerance to drought) will take place in the field four months after planting (for disease resistance, stolons and suckers production), whereas the second selection will take place four months later at harvest. This selection process will include growth vigour, yield, quality parameters, resistance against pests and diseases, and tolerance to drought. The University of Madeira will assist Maribor and country partners in developing protocols for field screening and evaluation of taro drought tolerance/resistance. Crosses will be conducted during the hottest period of the year, at the beginning and/or at the end of the rainy season. Where disease resistance is the objective, as in the case of *Xanthosoma*, the hybrids will be grown in areas where root rot disease is prevalent. The plants from the nursery will be given (C$_1$)$_s$ straight away to farmers for evaluation.

All country partners (5-19) will conduct on-farm assessment of selected genotypes (cultivars and hybrids in the first - C$_1$ - generation) for the quality of their corn using participatory methods. All country partners will exchange TTS in years 4 and 5 of the project in order to initiate an international convergent-divergent breeding scheme (exchange of TTS and recurrent selection), introduce allelic diversity and strengthen the position of taro towards forthcoming climatic changes. CIRAD and Maribor will liaise with all country partners to organize the international exchange of TTS between partners. This will allow the establishment of a long term breeding scheme using a multi-population approach.

**Deliverables of WP3:**

8. Controlled crosses conducted in each participating country,
9. Hybrid seeds generated and F$_1$ hybrids raised,
10. Hybrid clones distributed to five farmers in 10 villages.
11. One PhD defended on taro breeding in South Africa (Mr Wilhem Jansen van Rensburg)

**WP 4: DNA fingerprinting of cultivars and full-sib families and heritability studies**

Partner in charge of WP 4: CIRAD (Dr. Marie-France Duval, marie-france.duval@cirad.fr)

Objectives:
- To fingerprint 300 selected traditional cultivars (20 cultivars per country) with SSRs and SNPs markers and complement the fingerprinting of the 50 selected accessions of the core sample using the new markers developed.
- To fingerprint 800 F$_1$ hybrids (representing eight full-sib families) and their parents.
- To identify major molecular markers associated with genes controlling the physico-chemical characteristics of corms.
- To understand heritability of corm quality characteristics.

**Description of the work:**

New markers will be developed at the beginning of the project. Five of the 50 accessions selected for international distribution, will be chosen according to their genetic diversity and contrasting phenotypes (corm quality – including acridity and drought resistance). They will be used to construct cDNA libraries (leaf and corm). The material will be prepared using RNA-later procedure coupled to rapid freezing at -80°C and shipped to CIRAD (Montpellier, France). Libraries will be sequenced using second generation sequencing tools (Roche 454 GS-FLX, ABI Solid or Illumina Solexa 1G, available through the French
National Centre of Genotyping). Uni-gene sets will be analysed, both in terms of representation of the expressed genome, and for new molecular markers (SSRs and/or SNPs) by the sequence analysis pipeline method developed at CIRAD under the ARCAD project, http://www.agropolis-fondation.fr/uk/our-actions/our-flagship-programmes/arcad-2.html, and also for SSRs and SNPs using the ESTtik pipeline, http://esttik.cirad.fr/). These new markers will be added to existing SSR markers (Hu et al., 2008; Li et al., unpublished; Noyer et al., unpublished). Large scale screening technology will be used and the markers found will be selected (either classical SSR, detected through a LICOR-IR2 system or Illumina Bead Express SNP genotyping). In order to check for genetic diversity, pairwise distance matrices will be computed using the Simple Matching Index. The resulting matrices will be subjected to Neighbour Joining tree analysis with the software packages NTSYS-PC and DARwin 5.0. (Perrier et al., 2006)

**Genetic diversity study:** All country partners (5-19) will select their most representative local cultivars (overall 300 accessions corresponding to 20 cultivars in each country). Leaf samples will be sent to CIRAD for fingerprinting with a set of SSR markers already available to assess the genetic diversity of taro worldwide (PhD thesis subject for Burkinabé scientist, Mr Renan Traoré, aiming at characterising the genetic diversity).

**Selection of the parents:** Since taro cultivars are always vegetatively propagated, it is important to check for their genetic differences. The aim of this work is to assist local breeding programmes and to determine if the cultivars selected locally exhibit enough genetic diversity to be used as different parents to generate true seeds with a high level of genetic variation. All country partners (5-19) will select their best cultivars for crossing. Leaf samples (local best cultivars and 50 selected accessions internationally distributed) will be sent to CIRAD for genotyping with a set of already available SSRs markers to assess for genetic diversity. We expect that quite a few samples will be duplicates (some will be duplicates of selected local cultivars while others will be duplicates from the 50 cultivars internationally distributed). The selected cultivars will also be analysed for the physico-chemical variation of their corms (see WP 6).

**Analysis of the progenies for segregation of quality traits:** F₁ hybrids planted in lines with their parents will be analysed in year 3 by all country partners (5-19) who will collect leaf samples from F₁ hybrids and their parents. DNA extraction, and SSR and SNPs analyses, will be done by CIRAD. Field trials involving eight families (full-sibs) and their parents will be established by partner 10 (in Vanuatu as this partner already has an on-going breeding programme with sufficient expertise). A first family heritability trial will be established in year 3 and a second trial will be established in year 4 by partner 10 (Vanuatu). Leaf samples of these eight full-sib progenies sharing at least two parents will be sent to CIRAD. All samples will be analysed with all available SSR and SNPs markers in order to map the new markers and to trace the potential occurrence of major genes involved in the biosynthesis of chemotypes. Corms of F₁ hybrids and full-sib progenies fingerprinted will be analysed for their physico-chemical characteristics when mature (see WP 6). Overall, approx. 800 hybrids will be fingerprinted with DNA markers. Progenies are expected to segregate due to the high levels of heterozygosity of the parental materials. Segregating ratios will be analysed according to classical Mendelian principles. For the family heritability, a randomised complete block design will be established with 4 replications and 9 plants per treatment (1 x 1m spacing) (36 plants per family), including all their parents (16 clones). These field trials will be analysed for corm flesh colour, corm fibre colour, dry matter content, starch, amylose, proteins, minerals, sugars (see WP6). For the estimation of heritability, regression offspring - parent mean (h² = b) will be computed. Correlations between major characteristics will be studied.

**Deliverables of WP4:**
12. DNA fingerprints of elite cultivars used as parents in crosses.
13. Genetic distances determined between parents.
14. Segregation of molecular markers studied within and between eight full-sib progenies.
15. New markers developed and mapped, Markers associated to major genes, if any, identified.
16. First heritability trial established and harvested.
17. Second heritability trial established and harvested.
18. Potential major genes controlling corm quality identified.
19. One PhD defended on the genetic diversity of taro (Burkina Faso scientist Mr. Renan Traoré).
20. One PhD defended on association studies between markers and physico-chemical characteristics.
21. Four papers published in international journals.

**References:**
Dereeper, A; Argout, X; Billot, C; Rami, JF; Ruiz M (2007) SAT, a flexible and optimized Web application for SSR marker development. BMC Bioinformatics 8: 465.
WP 5: Drought resistance of elite cultivars and seedlings.
Partner in charge of WP 5: University of Madeira (Dr. Miguel Carvalho, quercus@uma.pt)

Objectives:
- To analyse the drought tolerance of 100 selected cultivars grown in a controlled environmental conditions and field trials.
- To identify the agronomic and molecular traits related to drought tolerance.
- To identify specific mechanisms involved in the enhancement of tolerance.

Description of work:
The University of Madeira will evaluate drought tolerance in selected cultivars and their seedlings under controlled experimental conditions and field trials in Madeira (Portugal). The evaluation of drought tolerance will be performed using morphological, physiological, biochemical and molecular features, biomass tests, yield and photosynthetic rates, and will aim to identify agronomic, physiological and molecular traits correlated with tolerance. The study will be conducted in Europe with clones of elite cultivars received from all country partners through the SPC, and cultivars obtained among local (Madeira and Canaries) germplasm. These cultivars will have been fingerprinted with molecular markers in WP 4 and the physico-chemical characteristics of their corms analysed in WP 6. Molecular and nutritional evaluation data will be compared with results of drought tolerance studies with the final goal to identify markers that allow the fast detection of useful traits.

The work on drought tolerance will be also performed locally by all partners (5-19) on selected cultivars and their parents. Madeira will advise all country partners on the development of suitable protocols for screening and characterising drought tolerance/resistance. The field trials established by the partners will identify morphological and agronomic features to evaluate drought tolerance in different environments. The same cultivars will be also grown in Southern Europe where rainfall is much less. Approximately, 100 cultivars (50 genotypes selected for distribution by SPC, plus another 50 selected from among local germplasm) will be analysed for variations in drought tolerance.

Plant material will be sampled for drought tolerance analysis, namely tissues and DNA samples will be collected and stored for biochemical and molecular studies. At harvest, plants will be collected and morpho-agronomic parameters measured. During the first year (series 1) screening of all genotypes in relation to drought tolerance will be performed with the evaluation of major agronomic, physiological and biochemical traits. The results will give a useful estimate of the variation in drought tolerance among taro cultivars. The first screening is expected to reduce the number of genotypes showing improved drought tolerance to a smaller more manageable number.

A second series of experiments will be performed on a smaller number of plants of cultivars and seedlings showing enhanced drought tolerance. As in the first series, the morpho-agronomic parameters will include yield and length of growth stages, and the physiological and biochemical parameters will include biomass tests, photosynthetic rates, protein analysis and/or determination of the 12C and 13C ratios. The molecular studies will also include screening with specific molecular markers, potentially associated with drought tolerance. Corm samples from the two series (year 1 and 2) will also be analysed in relation to the variation of their physico-chemical proprieties by Maribor (see WP 6). The aim is to detect if there is an incidence of drought induced stress on the quality of the corms. Thus, at the conclusion of the studies, it is expected that our knowledge of taro drought tolerance and its variation will have increased, especially in ways to detect useful traits using morpho-agronomic and molecular methods.

Deliverables of WP5:
22. Field assays for drought tolerance studies established.
23. Morpho-agronomic traits associated with drought tolerance accurately identified and evaluated.
24. Physiological and biochemical markersanalysed and correlation studies completed.
25. Chemical analysis of corms grown under drought stress carried out.
26. Association of different traits and markers with drought tolerance studied.
27. One MSc defended on taro drought tolerance at the University of Madeira.
28. Two papers published in international journals.
WP 6: Physico-chemical characterisation of corms of selected genotypes.
Partner in charge of WP 6: University of Maribor, Slovenia (Dr Janja Kristl, janja.kristl@uni-mb.si)

Objectives:
- To select cultivars based on their corms physico-chemical characteristics.
- To study the intra-clonal variation of these physico-chemical characteristics.
- To correlate the physico-chemical characteristics with “good taste”.
- To study segregations of physico-chemical characteristics in eight full-sib progenies.

Description of work:
These studies aim at identifying cultivars with improved agronomic qualities and nutritional composition, as well as determining if variability in chemical composition can be used as an indicator for drought tolerance. Corms from selected cultivars grown in controlled conditions (common plot) will be harvested by all country partners 5-19. Fresh corms will be sliced into chips and oven dried at 60°C in developing countries, and samples will be sent to Maribor who will study the physico-chemical characteristics of genotypes grown by all country partners 5-19. In Maribor analyses will be done for residual moisture, starch, amylase, proteins, minerals and total sugars. The analysis will be carried out using spectrophotometry, digestion, HPLC and GC techniques. Details are as follows:

a) Intra-clonal variation of the physico-chemical characteristics will be tested by partner 10 who will clone 10 elite cultivars. Maribor will measure the variation within and between 5 clones of each cultivar (5 replicates per cultivar) as well as the variation within and between cultivars, in order to assess the robustness of the chemotypes. Overall, Maribor will analyse 50 samples for this study (5x10).

b) One hundred selected cultivars (approx. 10 per country, planted and harvested at the same time within the same plot) will be analysed. Dry matter samples will be sent by partners 5-19 to Maribor (total of 150 samples). These selected elite cultivars will be used in targeted crosses.

c) During years 3 and 4, two family heritabilities field trials involving eight families (full-sibs) and their parents will be established by partner 10 (in Vanuatu). Corms of F1 hybrids and full-sib progenies will be analysed in Maribor for their physico-chemical characteristics when mature. Overall, approx. 800 hybrids will be analysed in year 3 and in year 4. Each plant will be analysed for corm flesh colour, corm fibre colour, dry matter content, starch, amylase, proteins, minerals and sugars. Correlations between major characteristics will be studied. Fresh corms harvested from the two heritability trials will be divided into two samples: one will be dried for analysis, the other will be boiled and tested by local consumers in a blind panel testing exercise. Consumers will score them on a scale from 1 (very poor) to 6 (excellent). The exercise will be repeated twice (year 2 and 3) and results will be correlated with physico-chemical characteristics of the corms.

d) Samples of 100 selected genotypes, with two replicates per sample, obtained during the studies on drought tolerance will also be analysed in relation to their physico-chemical proprieties (see WP 5).

Overall, Maribor will analyse approximately 1100 dry matter samples in five years (approx. 220 samples per year).

Deliverables of WP6:
29. Intra-clonal variation of chemotypes studied and determined.
30. Physico-chemical characteristics between selected cultivars studied and correlated with molecular markers.
31. Physico-chemical characteristics between and within full-sib families studied and correlated with molecular markers.
32. Assessment of physico-chemical characteristics due to drought and correlation with molecular markers.
33. One PhD defended at the University of Maribor.
34. Two papers published in international journals.

WP 7: Virus detection and identification on seedlings from true taro seeds.
Partner in charge of WP 7: DSMZ (Dr Stephan Winter, stephan.winter@jki.bund.de)

Objectives:
- To develop and optimise virus indexing (detection and identification) procedures for TTS.
- To facilitate the international exchange of germplasm collection.

Description of work:
DSMZ will review literature on viruses of taro and related aroids, and adapt and optimize diagnostic tools for the viruses/virus strains present in the project partner counties so that the tools can be used to detect viruses in seedling populations. All country partners (5-19) will send to DSMZ corms or leaf material of taro accessions from collections with potential to be used as parental lines for virus indexing in order to
make an assessment of the diversity of viruses and strains present in each collection. International exchange of true botanical seeds will be a task of the second half of the project. At the start of the project, DSMZ will study the possibility of virus transmission with true botanical seeds.

**Country partners (5-19)** will send to DSMZ a limited number of cuttings of each cultivar used as parent or, leaf material (whichever is the most convenient), and true botanical seeds of progenies resulting from crosses involving these parents (WP 3). DSMZ will adapt and optimise virus-testing (indexing) methods already developed for viruses/virus strains of Colocasia esculenta and other aroids. This will indicate the viruses and strains likely to be present in true seeds. To date, DsMV has been reported to be common in aroid species throughout Asia, the Pacific and Central America. Initial indexing of parent plants will be done using serological methods. Antisera for Dasheen mosaic virus (DsMV- potyvirus) is readily available from commercial sources or research laboratories. Antisera for other taro viruses will be obtained from various institutions (i.e., the Queensland University of Technology, Australia).

**Partners 5-19** will also send to DSMZ batches of true seed from identified crosses. The seed will be germinated and planted out in an insect-free glasshouse. At about the three-leaf stage leaf samples (probably pooled from 20 seedlings) will be tested for the presence of each of the viruses or virus strains. In this way, many hundreds of seedlings will be tested; if a pooled sample tests positive, then each of the plants represented in the pooled sample will be tested individually. Based on the results, guidelines will be developed for the virus-indexing of parental breeding lines in the partner countries, and information on the potential for viruses or virus strains to be disseminated in true botanical seed will be made available to the relevant authorities.

Sensitive molecular diagnostic tests will be developed for early virus indexing in seedling populations. Because the transmission of viruses by true seed is generally at a very low rate, it is necessary to efficiently screen many thousands of seedling plants to detect the rare cases of virus transmission. If freedom from viruses in plantlets (seedlings) is confirmed, true botanical seeds will be made available for international exchange as early as year 2 of the project. If virus transmission in seed is found, then the potential risk presented by these viruses or strains will be assessed to provide countries with a decision framework to accept or reject true botanical seeds. Transfer of virus indexing techniques to all country partners 5-19 is guaranteed, where necessary, DSMZ will provide training so that initial screening can be done in the country partner institutions. Guidelines for reliable virus indexing and safe movement of aroids germplasm will be developed. Training in advanced biotechnologies will be given and transfer of technologies will be done. Scientists working for SPC will be trained by DSMZ in indexing procedures.

**Deliverables of WP7:**
35. Diversity study conducted. Information on viruses/virus strains infecting germplasm collections and breeding lines in each of the participating countries.
36. Protocols for virus indexing seedling populations of taro fully optimised.
37. Antisera and virus positive controls available for testing and reference
38. Information on the probable rate of transmission of the important viruses or virus strains in true seed.
39. Guidelines for the safe movement/exchange of true taro seed between project partner countries.
40. One PhD defended in virology.
41. Two papers published in international journals.

**WP 8: On-farm participatory selection of elite cultivars and hybrids in C1 generation**
**Partner in charge of WP8: Bioversity International** (Dr. Danny Hunter, d.hunter@cgiar.org)

**Objectives:**
- To evaluate the introduced elite clones with farmers
- To distribute and evaluate with farmers hybrids in C1 generation.

**Description of the work:**
Bioversity will collaborate with CIRAD and Maribor to assist all country partners (5-19). All country partners (5-19) will make a special effort to ensure good geographical coverage of the country taro producing areas when initially selecting villages and farmers. Farmers will complete an information form on attendance of their first meeting that provides researchers with information on-farming systems, farmers’ profiles and needs. Taro focused participatory rural appraisals (PRAs) will be conducted with farmer groups (five per village in ten villages) to learn more about taro production problems, perception of taro cultivars and criteria in the selection of a cultivar. PRAs will be conducted by a facilitator and will include farm visits and observation, key informants, informal interviews and scoring and ranking exercises. Farmers will be requested to notify researchers as cultivars mature so accurate data can be collected. All corms and planting materials will remain the property of the farmers. Farmers will be requested to bring corms of cultivars for assessment of quality in blind taste panels conducted with the ten farmers and their families in each village. The project will involve both men and women in the participatory plant breeding work (PPB). As taro is
clonally propagated, this PPB work will be essentially the selection of $C_1$s (plant from the first clonal generation of $F_1$ hybrids) rather than breeding per se. It is expected that men will focus essentially on the agronomic performances of the new varieties, while women, who cook the corms, will give an assessment on their cooking behaviour and taste. Both will be taken into consideration in the on-farm evaluation process.

**Deliverables of WP8:**
42. Introduced elite genotypes distributed to farmers and propagated in their plots.
43. Introduced elite genotypes harvested and assessed by farmers
44. $C_1$s propagated and distributed to farmers.
45. On-farm trials harvested and participatory evaluation of $C_1$ quality conducted.
46. One MSc thesis defended in Papua New guinea (Mr Jeffrey Waki from NARI)
47. Two papers published in international journals.

**Work Packages list:**

<table>
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<tr>
<th>WP No</th>
<th>Work package title</th>
<th>Lead Contractor</th>
<th>Person-Months</th>
<th>Start Month</th>
<th>End Month</th>
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<tr>
<td>WP 1</td>
<td>Project co-ordination and management</td>
<td>SPC &amp; CIRAD</td>
<td>110</td>
<td>1</td>
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<td>6</td>
<td>60</td>
<td>8,9,10,11</td>
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<td>Drought resistance of elite cultivars and seedlings</td>
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<td>72</td>
<td>12</td>
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<td>12</td>
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<td>WP 7</td>
<td>Virus detection and identification on seedlings from true seeds</td>
<td>DSMZ</td>
<td>72</td>
<td>6</td>
<td>60</td>
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<td>WP 8</td>
<td><em>On-farm</em> trials and participatory activities</td>
<td>Bioversity &amp; partners</td>
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6. Methodology:

6.1. Methods for implementation and reasons for the proposed methodology

Fundamental problems of taro breeding have been studied\(^1\)\(^2\)\(^3\)\(^4\). Breeding programmes have attempted to produce clonal material\(^5\). Clonal selections may have local potential, but are unlikely to suit most countries where environments are highly variable and genotype by environment (G x E) interactions preclude the widespread adaptations of a few varieties\(^6\). Distribution of new lines is constrained by the inherent low rate of multiplication of the crop, the large numbers of growers and the isolation of communities. As yet, no improved varieties has been distributed widely, growers’ participation has been limited, with little devolution of responsibility from the formal breeding centres\(^7\).

From molecular studies, it is known that there are distinct genepools where independent domestication has occurred\(^8\). It is also known that the diversity of diploid taro cultivars is rather low\(^9\). For example, work on taro leaf blight concluded that plant breeders should start with cultivars with wide genetic distances\(^10\) as the variability of the pathogen is high. Microsatellite markers have been developed for taro\(^11\)\(^12\) and allow an accurate assessment of genetic distances, maximising the chance of obtaining significant variation in the offspring\(^13\). For breeding purposes, therefore, there is a need to use germplasm from different genepools to broaden the base of the programmes\(^14\)\(^15\)\(^16\). Valuable germplasm exist in different geographical regions, and it is of utmost importance to explore its potential\(^17\).

Seeds can be generated in large quantities, with thousands of seedlings grown in small nurseries with minimum efforts. This has the advantage of maintaining genetic diversity, in contrast to the selection of a relatively small number of clones, whose diversity is fixed by vegetative propagation. Visual tools can be

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used at an early stage to screen progenies\textsuperscript{18} for likely corm and morphological characteristics. The use of seed and greater farmer involvement in plant breeding can be used to exploit G x E interactions through decentralised evaluation and selection. Seed also has the advantage that it is easy to exchange between countries, introducing characteristics that can easily be exploited by plant breeders. There is need, however, to ensure that it meets quarantine standards.

Taro is, unfortunately, the host of a number of viruses\textsuperscript{19}, and international transfers of germplasm need to be indexed to ensure that they are healthy\textsuperscript{20}. This is time consuming and expensive. Dasheen mosaic virus (DsMV, \textit{Potyvirus}) has a world-wide distribution, and probably exists as strains of differing pathogenicity in different countries\textsuperscript{21}. Similarly, Alomae disease, caused by a mixed infection of Bobovirus (Rhabdovirus) and Taro bacilliform virus (Badnavirus) is lethal in some varieties of taro\textsuperscript{22}. Broadening of the genetic base of breeding programmes need to take account of the possible introduction of viruses with transfers. The use of true seeds offers a practical solution. The necessary prerequisite is, however, to demonstrate that the most deadly viruses or virus strains are not seed borne.

Little is known about drought resistance of taro, and no research has been conducted to assess the potential of the species. Some cultivars tolerate relatively long periods of drought, but most do not. Breeding for adaptability to specific environments requires detailed evaluations of the existing germplasm, not only within one country, but also world wide, across the entire gene pool. The variability required to suit the present agro-ecological conditions, never mind a future influenced by climatic change, can only be obtained from segregating populations of parents of diverse origins\textsuperscript{23}. If crosses focus on a few traits known to be important, then progress is likely to be rapid\textsuperscript{24}.

There are several major problems which must be overcome in order to fully utilise the potential of taro for consumption and processing. The texture of corms varies after cooking, some are acrid, and there is a lack of information on the physico-chemical characteristics of the starches that hinders utilisation. Further, taro corms do not present a uniform shape at harvest, thus making it difficult for mechanical peeling and marketing as fresh products. Internal colour of raw corms ranges from white to dark purple and may include combinations of two or more colours. Development of new products is also hindered by high market prices, and flours are not competitive with those from cereals. More novel uses are required. For example, the recent ventures into organically grown, blanched, dried taro flakes produced for incorporation into baby food\textsuperscript{25}, or extruded snack foods. However, of greater potential is the manufacture of specialty starches based on the unusual carbohydrate profile of taro containing a large spectrum of glucose polymers. There is also a large variation in the content of proteins, sugars, minerals, starch, amylose and dry matter\textsuperscript{26}. The large range of values found for proteins, for example, shows that there is considerable potential for improvement\textsuperscript{27}. What is needed is a better understanding between the relationship of chemical composition and taste. Molecular tools could be used to facilitate this, leading to marker assisted selection and/or conventional selection of parents for breeding. There is a need to work with farmers and other consumers on taste issues and to carry out participatory evaluation to investigate relationships among different genotypes and organoleptic properties.

The geographic distribution of allelic diversity: a relevant methodology:


It is known that the genetic base of taro is narrow in most countries, vulnerable to introduced pathogens and that it must be broadened if taro is to be able to respond to rapid environmental changes. However, in order to be acceptable to farmers, and to be kept as part of their varietal portfolio, any new genotypes must exhibit an interesting attribute or perform better than those cultivated presently. Also, to be useful for breeders in the future, these genotypes need to have sexual reproductive potential, which means that their ploidy levels, and other factors involved in genetic compatibility, must be understood. Considering the economic situation of taro producers, and the low-input cultivation systems in which the crop is grown, an appropriate approach is to increase farmers' long-term access to useful genes. This can be done by harbouring the geographical distribution of allelic diversity, as follows:

1. assembling a core sample representing the useful diversity of the species,
2. distributing genotypes for direct use or for breeding,
3. distributing genes as clones in segregating progenies,
4. selecting clones with local adaptation.

Experiences with cross-fertilizing or allogamous species indicate that germplasm collections composed of 50-60 carefully chosen genotypes can assemble a significant allelic diversity. They represent a minimum effective population size which, under random mating and normal pressure of natural selection, enables the maintenance of a sufficiently high level of genetic diversity without significant negative effects of inbreeding. If 50 individuals cannot be considered a core collection (representing the genetic diversity present in a species), they can be considered a core sample, representing a set of genotypes which can be recombined to generate useful progenies for farmers' evaluation.

To make the most of the genetic resources inherent in a core sample, it is necessary to have access to data on genetic distances, and these cannot be obtained by plant descriptors. Only DNA markers can provide that information. While such markers are undoubtedly more objective in sampling the genome, and probably provide the best measure of genetic diversity, there are practical constraints in applying them to taro. Application of the markers requires a high level of technical skills, equipment and resources, together with a centralised and rigorous system of data collection, exchange and analysis. Also, the core sample requires accessions from distant geographic origins, and this causes logistical problems. However, a core sample has been established for taro in part of the gene pool - SE Asia and Melanesia - and the result outweighed all the difficulties in bringing these taro genotypes together and using them. The core sample, in this case, is presently maintained in vitro in SPC laboratories in Suva, Fiji.

Taro farmers often give priority to taste rather than yield, especially when the crop is grown for home use. For plant breeders, therefore, quality in terms of dry matter content, cooking texture and taste, become a priority. Aroids are often considered solely as subsistence or famine relief foods, not as vegetables for urban centres. However, there is considerable variation in corm characteristics, sufficient to suggest that this variation can be exploited by plant breeders. This is supported by evidence from other root crops; for instance, differences between the starches of West Africa yam varieties affect the quality of fufu. The uses of starches are determined by their physical and chemical characteristics, and these vary between varieties. An understanding of how properties are influenced by variety is, therefore, of critical importance in assessing the potential of genotypes.

**Distribution of genotypic diversity:** The easiest way to distribute allelic diversity is to identify useful genotypes (a core sample), and to exchange them internationally for direct distribution to farmers. However, the core sample has to go through a transit centre where viruses can be detected, and where therapy can take place if they are infected. At present, there is no way that this can be done. Therefore, the proposed Action will develop an international network facilitating taro exchange. Once the core sample has been distributed in vitro, field multiplication will allow with direct distribution to farmers. When this is done over a wide geographical area, such as proposed for this Action, and if the genotypes satisfy farmers’ needs, they will insert the exotic germplasm into their portfolio of varieties, and this will increase the allelic diversity of the crop. As these genotypes are clonally propagated, farmers can exchange and distribute them further. This approach necessitates that uptake strategies are simultaneously developed, and easily implemented. This simple system presents many advantages. The distribution and preservation of allelic diversity avoids “putting all the eggs in one basket”. The core sample is distributed to as many partners as possible who subsequently propagate and distribute it. It is, therefore, a fully decentralised system which can address production problems rapidly. With an efficient transit centre, such as that at SPC, the direct introduction and distribution of genotypes can broaden the cultivated genetic base of taro, and replenish vulnerable national

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collections that are genetically narrow, and that have limited potential for improvement by conventional breeding methods.

**Distribution of allelic diversity:** In practice, the distribution of allelic diversity involves first, the composition of a core sample. Selected taro genotypes of the core sample are then intercrossed, and the F₁s raised for distribution as C₁ clonal stock to farmers. Visual tools can be used at an early stage to screen progenies for likely corn and morphological characteristics, so that only hybrid plants in their first clonal generation (C₁₁) with some form of potential are distributed. Once F₁s have been screened for deleterious characters, greater farmer involvement in the C₁ screening process can be used to exploit G × E interactions through decentralised evaluation and selection. For taro, one fruit cluster may contain more than 10,000 seeds. When germination is properly organised in a screen house, raising 200,000 seedlings is a possibility. Selected hybrids are then available for growers and/or transferred to the field to produce C₁₅. Preferably, preliminary screening of the F₁s is done on station and the selected C₁ clones divided into small batches, each going to a different farmer. This has the advantage of rapidly distributing allelic diversity.

**Farmers’ selection of clones with local adaptation:** On station, assessment of chemotype is difficult when hundreds or thousands of progenies have to be tested, but if C₁₅ are distributed to farmers, participatory evaluation of clonal material is feasible. There are some risks of distributing taro clones which have not been evaluated for appropriate chemical composition, but farmers will automatically discard them early in their selection process. In different countries, aroids can be prepared in different ways which require different chemotypes. Farmers will select varieties which satisfy their cooking and/or processing requirements, which are quite variable, and adopt them if they show potential.

**To summarise:** G × E interactions are important, and because of the low multiplication rate of the planting material, it takes several years before multi-location trials can be concluded. The consequence is that the selection process is directly affected by the absence of replications in different environments. Participatory selection bypasses this potentially lengthy process. Taro farmers will select clones adapted to local environmental conditions and consumer preferences, and the selection will later be recombined by plant breeders creating another lot of clones for farmers to evaluate. In this case, vegetative propagation makes the breeding process relatively straightforward and efficient because it maintains the genetic make-up of the selections. Additionally, if a farmer select an outstanding genotype, it is likely that he or she will soon be in a position to exchange it with others.

7. Organisational structure and team proposed for implementation of the action:

The Action brings together 19 partners in a global consortium, *The International Network for Edible Aroids (INEA)*. The Network is managed by SPC, an international organisation with 60 years experience in development assistance, with headquarters for agriculture in Fiji. The research, coordinated by CIRAD, SPC and Bioversity International, will be divided into a number of themes, with subject-matter specialists in charge of each: distribution of germplasm (SPC); plant breeding (Maribor); genetic diversity (CIRAD); drought resistance (Madeira); physico-chemical analyses (Maribor); and virus indexing (DSMZ). A steering committee of all the partners will be formed and meet annually to discuss progress of the themes and plan for the coming year. Each country partner will nominate a national project coordinator who will attend steering committee meetings, and be the contact person liaising with the scientific coordinator. It will be the responsibility of the national project coordinator to ensure that plant breeding studies, and cultivar evaluations are done on research stations and with farmers, and to keep the scientific coordinator and the steering committee informed of progress.

8. The means proposed for the implementation:

The Applicant and the partners are institutions already equipped to conduct similar work. The project will supply sufficient equipment and chemicals as required for the activities. Consumables will be provided for plant breeding (e.g., hormones to induce flowering, growing the seeds), molecular analyses, plant tissue culture and virus indexing. As far as it is practical, the biotechnological aspects of the project will be done in the partner countries. It is recognised, however, that many of the advanced biotechnologies that will be used in this Action cannot be transferred from the European countries to the developing country partners. Nevertheless, there is provision in the design for students from the country partners to carry out research in the labs of the European research institutes and universities. The work packages described under 1.3.4 outline the research degrees that are expected under the different themes.
9. The planned activities in order to ensure the visibility of the action and the EC funding:

The Communication and Visibility Plan aims at ensuring that communication and visibility across the International Network for Edible Aroids (INEA) are well co-ordinated, effectively managed and responsive to the diverse information needs of country partners, research and teaching institutions, farmers and other members of the public, and the donor. The target groups are:
- Participating scientists and staff of 19 agriculture research organizations of the INEA,
- Participating lead farmers and rural communities,
- The EU delegations in the partners’ countries,
- Other persons and organizations interested in the research of the Action, but not directly involved.

The **specific objectives** of the Communication and Visibility Plan are to:
- Ensure that INEA members can communicate directly and rapidly with each other,
- At the beginning of the Action, specify the roles of the national country partners, European research institutions, and participating lead farmers, and document their expectations,
- At the beginning of the Action, obtain formal agreement from each of the country partners, the European research institutions, and participating lead farmers, on their roles and commitments,
- Provide means so that the public can access the results of the Action and other information as considered relevant to their needs,
- Provide reports to the EU delegations in the partners’ countries on the progress of the Action in a timely manner.

**SPC** as Applicant and **CIRAD** as Project Scientific coordinator will be overall in charge of the Communication and Visibility Plan. At the beginning of the Action, a meeting will be organised in Vanuatu to launch the Project activities and define strategies. A partner-driven Internet communication tool – an electronic mailing list – will be set up allowing messages to be moderated and exchanged rapidly and simultaneously between partners. Such a system will allow messages to be archived for ease of retrieval. Scientific papers pertaining to the accomplishment of the Action’s research responsibilities will be communicated to the scientific coordinator in the first instance, before agreement is given to publish in journals or to present at professional meetings. For minutes of meeting (national or international) and progress reports, a Wiki will be created so that partners can publish information directly on the web site, and allow comment by others. It will be accessible by partners only. Communication with partners outside the partnership (i.e. local authorities, private sector, rural communities will be done in a number of ways:
- a web site will be created for project progress reports (annual, terminal, etc), and published and unpublished literature on edible aroids for ease of access by Project scientists and other interested persons. Building this database of literature will demand an extensive search of the world’s databases, and also visits to country and regional institutions to obtain unpublished information.
- the Project will present its findings locally during national research organisation field days, trade shows, and the like. The results of such events will be placed on the website.
- leaflets and posters will be designed and distributed providing information on the success of the Action as and when developments occur, and articles in local newspapers and on radio/TV will provide support.

**Indicators of achievements:**
- an electronic mailing list established, with archived messages,
- a Wiki and website for partner and public information sharing, respectively,
- a number of scientific papers published,
- a database of edible aroid literature (published and “grey”) established online,
- a number of field days, newspaper reports, radio programs reporting project successes,
- a number of leaflets and posters produced.

**Human resources:** **PestNet**, a non-government organisation, registered in Fiji, will take charge of the communication and visibility activities under the Action, working under the direction of the Applicant and the Scientific Coordinator. **PestNet** has successfully played a similar role in TaroGen, when its Chair, Dr. GVH Jackson, created a website ([http://www.spc.int/TaroGen/](http://www.spc.int/TaroGen/)) for information and collaboration between scientists of country partners and research organisations elsewhere. **PestNet** presently runs a global list of 800 members exchanging information and advice on crop protection matters worldwide, providing it with the experience to cope with the communication and visibility needs of the present Action.

**Financial implications** (see budget): **PestNet** will be subcontracted by **CIRAD** to develop the web site-platform.
The web site will be established in close cooperation with the Commission Delegation or the responsible officials in the EuropeAid Cooperation Office who can ensure coherence to EU policy, and provide links to the relevant Commission sites. Links will be made to the websites of the local EU Commission Delegation and the EuropeAid Cooperation Office. At the end of the action, the website will be copied onto CD-rom and transmitted to the Delegation for possible further use in its general communication activities and for archival purposes. The communication and visibility strategic plan will be in line with the EC visibility guidelines.

10. Sustainability :

10.1. Expected impact of the action (quantified data on technical, economic, social, and policy levels) 

The expected impact of the Action is to improve productivity of taro by increasing the genetic diversity of the crop. The success anticipated will remove the vulnerability that exists against adverse biotic and abiotic threats, as well as developing methods of processing that add value. The aim is not to increase the area of production but, by increasing genetic diversity, there is the possibility that taro could be used to exploit marginal areas, e.g., swamps and forests, which cannot sustain production of the major food crops presently grown in the world.

Previously, there was a concern in some countries that flourishing taro exports were the reason for indiscriminate clearing of virgin forests, but this has been an exception, and an event unlikely to result from the outcome of this Action. Taro is not new to the region, it is grown, but neglected and under-utilised according to FAO, IPGRI and countries’ national research plans. Increased cultivation would not be a reason for concern or warrant environmental impact studies.

The financial impact may be relatively greater per capita in the Pacific than in Asia where the crop is minor in comparison to cereals. But the Pacific is probably the region most vulnerable to climatic change. It is conceivable that national and household health budgets will be affected positively by increased taro consumption. Increased use of taro leaves as fresh vegetable may lead to a decline in the high incidence of anaemia in urban populations. However, any changes that do occur will be difficult to ascribe solely to increased supplies of taro as monitoring in most countries is poor. A more realistic outcome of the projects’ activities in the long term would see taro offering a steady, but increasing, return on investment to rural communities, in some countries a more secure future for taro exports, and in all a supplement to other sources of carbohydrate and nutrients.

Taking a broader view of impact, it has to be seen in terms of heightened concerns about the loss of bio-diversity in developing countries, and the potential of under-utilised and neglected crops to underpin food security. Populations in SE Asia will increase dramatically in the next two decades. But most good arable land is already cultivated with cereals or pulses, and yields may not increase further without copious inputs. In the Pacific, where root crops are already extensively grown, improvements are needed if food security is to keep pace with populations that are expected to double in the next 20 to 30 years. In both regions, taro offers solutions to the exploitation of marginal lands with low impact on fragile environments.

The desire of countries to form a viable network for taro breeding is compatible with the aims of the Revised International Undertaking on Plant Genetic Resources for Food and Agriculture, adopted as the International Treaty by the FAO Conference on 3 November 2001. Taro is included in the multilateral system of access and benefit sharing of plant genetic resources for food and agriculture. Specifically, the breeding component of the project relates to Article 6 – Sustainable Use of Plant Genetic Resources, which inter alia includes a) strengthening research which enhances and conserves biological diversity by intra-specific variation for the benefit of farmers; b) promoting plant breeding with the participation of farmers, particularly in developing countries; c) broadening the genetic base of crops and increasing the range of genetic diversity; as well as d) promoting the expanded use of local and locally adapted crops, varieties and underexploited species available to farmers.

Crop improvement is generally a slow process and programmes involving asexually propagated crops are no exception. In 5 years, it is possible to make a significant contribution to taro production in the partners’ countries, however, it will be difficult to measure the impact because of the difficulty in obtaining production statistics. The project realises the limitations, and makes no bold claims for an outstanding success in such a short time. Crosses will be made, seeds generated, shared and tested, and farmers, who will be involved in on-farm selection and testing will have direct benefits (they will be able to multiply and grow the best selected materials, and share them with other farmers).

Recent advances in food science have not been applied to taro. At present, the high price of taro on domestic markets mitigates against ‘simple’ processing, for instance, the manufacture of flours. More complex processing is required to build a higher price, even if the finished product does not resemble the original material. An area of promise is speciality starches. Commonly, they are derived from corn.
However, because the basic starch of taro is different from that of corn, the possibility exists that a study may result in unique products of interest to starch manufacturers.

There are no aspects of the work that have negative environmental or ethical considerations. However, there are some risks. For instance, the proposed drought and chemical studies (WP 5 & WP6) depend on establishing genetic markers and the use of conventional breeding techniques to produce cultivars with the characteristics desired to overcome the vicissitudes of climate change, and the identification of potentially useful commercial products. Success is also dependent upon the transfer of germplasm through the SPC quarantine centre, but in this case the risk is minimized by the inclusion of virus-indexing at an activity of the project (WP7).

Furthermore, the risks associated with obtaining countries’ compliance to share intellectual property are unlikely to be realised, as a majority of countries are signatories of the INTPGRFA, and sharing under the project will be done under the MTA for crops, such as taro, that are part of the Multilateral System of Access and Benefit Sharing.

Traditional varieties, propagated asexually, would rarely qualify for intellectual property rights protection under a plant breeders right or a patent, and such protection may not be desirable anyway as traditional farmers will usually wish to continue managing and exchanging their traditional plant varieties in the same way that they have always dealt with them. If PBR protection was sought for such varieties, several matters would need to be addressed:
- the ability to register a community, as opposed to an individual, as the collective owner of the variety, as many varieties will have been used for considerable periods of time, they may no longer be able to meet the requirement that they be “distinct”;
- genetically similar plant material going by different names in different communities will need to be clearly identified so as to prevent respective claims.

One essential aspect of that effort will be the accelerated movement of germplasm across borders and between continents. Concerns regarding protection of farmer’s rights and national germplasm collections will be addressed by the project to ensure continued rapid transfer of materials between countries and regions so that these genetic resources are effectively distributed to farmers.

**Gender issues:**

The roles played by men, women and children in taro crop husbandry vary so widely across developing countries that any comments on gender implications are necessarily generalisations. Several scenarios are possible. It might be argued that increased potential for taro production will create additional work for women, as they play a major part in production in many (e.g., Melanesian) countries. On the other hand, increased yields per unit area might reduce labour demand. It is possible that village youth groups may become involved in production, and this would benefit the rural unemployed. Commercial growers, on the other hand, are often male, but if they expand production, women may benefit as paid labour. In many countries, men and women work together in taro production, although men will often take the lead in marketing and benefit most from the cash obtained. The situation is complex and does not lend itself to a simple answer. However, the project will attempt to involve both men and women farmers in the PPB work.

**10.2. Dissemination plan and possibilities for replication and extension of the action outcomes**

Several aspects of the work conducted by the project will benefit European countries as taro is a species grown in southern Europe (Spain, Portugal and Cyprus) and in French overseas tropical territories. The project also includes aspects of science that are of mutual interest to both developing country partners and the EU. The research on drought resistance may benefit temperate crops, and the physico-chemical analyses of starches will contribute to the more fundamental research on starch biosynthesis. Also, sources of starches or other polysaccharides with different properties desired for European food processing may be identified. There is sufficient overlap between the developing country partners and the European institutes involved in the various activities of the project for the outputs of the research to be of interest to all. Information from the studies undertaken will reach a wide audience: research institutions through reports and scientific papers, and extension literature; and to farmers through direct contact.

**10.3. Main preconditions and assumptions during and after the implementation phase**

All partners are willing to share and exchange germplasm, to propagate and distribute it to growers as part of the routine activities of their respective institutions. This will continue to be the case for many years following the project termination, because this type of work is part of their official functions. Once these varieties are distributed to growers, several scenarios can be envisaged:
they are readily adopted, maintained and included into farmers varietal portfolios, and are therefore broadening the genetic bases cultivated locally,
• taro remains a subsistence crop with limited commercial growth,
• new taro uses and products attract the private sector and stimulate taro production.

Whatever the scenario, partners will have initiated a major change and genetic improvement in their respective countries. European partners will have access to new, original, scientific data opening new perspectives in agrobiodiversity research involving a dynamic strategy for *in situ* conservation of taro genetic resources (*i.e.* exchanging genes as true seeds rather than genotypes as cultivars propagated asexually). The project will disseminate true taro seeds originating from different gene pools. It will be the first time in the history of taro breeding that dissemination of this kind has occurred, and will have long-term impact for both scientists and farmers.

10.4. Securing sustainability after the completion of the action

All country partners are national institution having taro research and development within their mandates. Under 1.4.3, the importance of taro improvement in the strategic plans of one of the partners is provided as an example of the commitment of countries taking part in this Action. Plans of other partners are similar. Financial and institutional sustainability of the national research institutions is guaranteed by their respective governments.

a. **Financial sustainability**: All partners and institutions involved in this Action are funded with public budgets. These institutions are under the umbrellas of the Ministries of Agriculture, Research or Education in their respective countries. Financing of follow-up activities, after the action has ended will continue as these institutions are interested in pursuing and developing research programmes on taro, a crop important in all participating countries. The sources of revenue for covering all future operating and maintenance costs, and salaries of scientists in charge of taro research are secured as part of these institutions budgets.

b. **Institutional sustainability**: All partners are institutional structures that would allow the results of the action to continue to be in place after the end of the action. In some cases (Burkina Faso, Papua New Guinea and South Africa), significant capacity building will be produced within the action (1 MSc and 2 PhDs). Breeding programmes of these institutions will take the advantage of the germplasm received for developing new varieties.

c. **Policy level sustainability**: In all countries, adaptation of crops to climatic changes is a major concern for national agricultural policies. Additionally, vegetatively propagated crops are important economically, and the approach taken for taro will represent an interesting case for developing new strategies and policies. The method used to develop an international network will be of great interest for other crops.
11. Duration and indicative action plan for implementing the action:

The duration of the action will be 60 months.

The following action plan for the first 12 months of implementation gives an overview of the preparation and implementation for each work package.

<table>
<thead>
<tr>
<th>Year 1</th>
<th>months : 1 2 3 4 5 6 7 8 9 10 11 12</th>
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</thead>
<tbody>
<tr>
<td>WP1</td>
<td></td>
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<tr>
<td></td>
<td><strong>Project coordination and management:</strong></td>
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<tr>
<td></td>
<td>Partnership agreements signed and returned to applicant</td>
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<tr>
<td></td>
<td>Launching meeting organised in Santo, Vanuatu</td>
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<tr>
<td></td>
<td>Work plans discussed and accepted</td>
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<tr>
<td>WP2</td>
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<tr>
<td></td>
<td><strong>in vitro distribution and field propagation:</strong></td>
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<tr>
<td></td>
<td>Technician hired and assigned full time on in vitro propagation</td>
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<tr>
<td></td>
<td><em>In vitro</em> propagation of 50 genotypes (x 3 x 14)</td>
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<tr>
<td></td>
<td>Shipments of first lots of genotypes to partners</td>
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<tr>
<td></td>
<td>Reception through quarantine, transplantation in nurseries and propagation</td>
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<tr>
<td>WP3</td>
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<td></td>
<td><strong>Breeding and on-farm participatory selection:</strong></td>
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<tr>
<td></td>
<td>First workshop on Aroids breeding techniques organized in Santo, Vanuatu</td>
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<td></td>
<td>First crosses conducted in developing countries</td>
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<tr>
<td>WP4</td>
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<td></td>
<td><strong>DNA markers (SSRs &amp; SNP) fingerprinting:</strong></td>
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<tr>
<td></td>
<td>Development of new markers (SNPs)</td>
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<td></td>
<td>Partners prepare samples for WP4</td>
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<tr>
<td></td>
<td>Launching of first PhD programme on genetic diversity</td>
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<td>Recruitment of second PhD candidate</td>
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<td>WP5</td>
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<td></td>
<td><strong>Drought Resistance Studies</strong></td>
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<td></td>
<td>Recruitment of post doc researcher</td>
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<td></td>
<td>Partners send propagules for WP5</td>
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<td></td>
<td>Establishment of first drought experiments</td>
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<td>WP6</td>
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<td></td>
<td><strong>Physico-chemical characterization</strong></td>
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<td></td>
<td>Recruitment of PhD candidate</td>
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<tr>
<td></td>
<td>Partners prepare samples for WP6</td>
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<tr>
<td></td>
<td>Received samples are being analysed</td>
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<tr>
<td>WP7</td>
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<td></td>
<td><strong>Viruses detection and identification</strong></td>
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<td></td>
<td>Recruitment of PhD candidate</td>
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<tr>
<td></td>
<td>Partners prepare and send samples for WP7</td>
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<tr>
<td>WP8</td>
<td></td>
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<tr>
<td></td>
<td><strong>On-farm trials and participatory activities</strong></td>
</tr>
<tr>
<td></td>
<td>Surveys are conducted to select villages and farmers</td>
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<tr>
<td></td>
<td>PRAs conducted in ten villages</td>
</tr>
</tbody>
</table>

The action plan for each of the subsequent years is more general and lists the main activities foreseen for those years. To this end, it is divided into six-month interim periods (*NB: A more detailed action plan for each subsequent year will be submitted before receipt of new pre-financing payments, pursuant to Article 2.1 of the General Conditions of the grant contract*).
### Time table of activities (Applicant = A, all country partners = CP):

<table>
<thead>
<tr>
<th>Work Package :</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Partners</th>
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</thead>
<tbody>
<tr>
<td><strong>Seminars</strong></td>
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<tr>
<td><strong>WP1. Project coordination and management</strong></td>
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<tr>
<td>1. Development of a web site and platform</td>
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<tr>
<td>2. Financial and administrative reporting</td>
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<tr>
<td>3. Production and circulation of annual reports</td>
<td></td>
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<td>A</td>
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<tr>
<td>4. Monitoring of project activities (annual meetings)</td>
<td></td>
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<td>A</td>
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<tr>
<td><strong>WP2. In vitro distribution and field propagation</strong></td>
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<tr>
<td>5. <em>In vitro</em> propagation and distribution of 50 vars</td>
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<tr>
<td>6. Field propagation</td>
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<td>CP</td>
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<tr>
<td>7. Distribution of 30 selected varieties to farmers</td>
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<td>CP</td>
</tr>
<tr>
<td><strong>WP3. Breeding &amp; on-farm participatory selection</strong></td>
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<td>8. Conduct controlled crosses</td>
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<td>2 + CP</td>
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<tr>
<td>9. Raise F1 hybrids</td>
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<td>CP</td>
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<tr>
<td>10. Distribute C1s to farmers</td>
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<td>CP</td>
</tr>
<tr>
<td>11. One PhD on breeding (South Africa)</td>
<td></td>
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<tr>
<td><strong>WP4. DNA (SSRs &amp; SNP) fingerprinting</strong></td>
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<tr>
<td>12. Fingerprinting of elite cultivars</td>
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<tr>
<td>13. Determine genetic distances between parents</td>
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<td>A</td>
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<tr>
<td>14. Study segregations of F&lt;sub&gt;1&lt;/sub&gt;s</td>
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<td>A</td>
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<tr>
<td>15. New markers developed and mapped</td>
<td></td>
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<td>A</td>
</tr>
<tr>
<td>16. Establish and harvest first heritability trial</td>
<td></td>
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<td>CP</td>
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<tr>
<td>17. Establish and harvest second heritability trial</td>
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<td>CP</td>
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<tr>
<td>18. Identify potential major genes</td>
<td></td>
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</tr>
<tr>
<td>19. One PhD on genetic diversity (Burkina Faso)</td>
<td></td>
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<tr>
<td>20. One PhD on association studies (France)</td>
<td></td>
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<td>A</td>
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<tr>
<td>21. Four papers published in international journals</td>
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<tr>
<td><strong>WP5. Drought resistance studies</strong></td>
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<tr>
<td>22. Establishment of field experiments</td>
<td></td>
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<td>3 + CP</td>
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<tr>
<td>23. Evaluation of morpho-agronomic traits</td>
<td></td>
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<tr>
<td>24. Physiological and biochemical marker analysis</td>
<td></td>
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<tr>
<td>25. Corms from cultivars stressed analysed</td>
<td></td>
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<tr>
<td>26. Traits and markers association with drought</td>
<td></td>
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</tr>
<tr>
<td>27. One MSc on drought tolerance (Portugal)</td>
<td></td>
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<td>3</td>
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<tr>
<td>28. Two papers published</td>
<td></td>
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<tr>
<td><strong>WP6. Physico chemical characterisation</strong></td>
<td></td>
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<tr>
<td>29. Intra clonal variation</td>
<td></td>
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<tr>
<td>30. Variation between selected cultivars</td>
<td></td>
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<tr>
<td>31. Variation within and between full-sibs families</td>
<td></td>
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<tr>
<td>32. Drought effect on corm characteristics</td>
<td></td>
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<tr>
<td>33. One PhD defended (Slovenia)</td>
<td></td>
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<tr>
<td>34. Two papers published in international journals</td>
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<tr>
<td><strong>WP7. Viruses detection and identification</strong></td>
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<tr>
<td>35. Diversity of viruses and strains</td>
<td></td>
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<td>4</td>
</tr>
<tr>
<td>36. Develop and optimize virus testing protocols</td>
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<tr>
<td>37. Raise parents and seedlings</td>
<td></td>
<td></td>
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<td>4</td>
</tr>
<tr>
<td>38. Detect viruses in parents and seedlings</td>
<td></td>
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</tr>
<tr>
<td>39. One PhD defended (Germany)</td>
<td></td>
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<tr>
<td>40. Formulate guidelines for exchange of seeds</td>
<td></td>
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<td>4</td>
</tr>
<tr>
<td>41. Two papers published in international journals</td>
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<tr>
<td><strong>WP8. On-farm trials and participatory activities</strong></td>
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<tr>
<td>42. Selected genotypes distributed to farmers</td>
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<tr>
<td>43. Selected genotypes evaluated by farmers</td>
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<td>CP</td>
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<tr>
<td>44. C1s propagated and distributed to farmers</td>
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<td>CP</td>
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<tr>
<td>45. On-farm trial harvested and quality tests done</td>
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<td>CP</td>
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<tr>
<td>46. One MSc defended (Papua New Guinea)</td>
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<tr>
<td>47. Two papers published in international journals</td>
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<td>A + CP</td>
</tr>
</tbody>
</table>
### 12. Logical framework for the project:

<table>
<thead>
<tr>
<th>Intervention logic</th>
<th>Objectively verifiable indicators of achievement</th>
<th>Sources and means of verification</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall objectives</td>
<td>- To increase the diversity of taro, in order to sustain production in the face of climate change, and to promote commercialisation, for improved rural livelihoods</td>
<td>- number of genotypes distributed to 14 countries, - 30 varieties distributed to 700 lead farmers, - an international network functioning</td>
<td>- clonally propagated crops have limited scope for adaptation to climatic changes, - introduction of allelic diversity contributes to cropping systems resilience.</td>
</tr>
<tr>
<td>Specific objectives</td>
<td>- To safely transfer germplasm internationally in order to maximise the use of genetic resources from diverse gene pools; - To produce new varieties of taro with high agronomic and commercial potential by conventional and participatory breeding; - To promote international collaboration among breeders and farmers.</td>
<td>- the international edible aroids network is established, - introduced genotypes into farmers fields, - new varieties accepted, - drought resistance studies, - physico-chemical studies, - efficient virus indexing procedures, - a new system is in place to distribute aroids diversity.</td>
<td>- no constraints from local Quarantine Departments to the introduction of edible aroids genotypes, virus indexed and in vitro.</td>
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<tr>
<td>Expected results</td>
<td>- Crops with potential to withstand demands of climatic change. - Transfers of taro germplasm as true seed for farmer’s selection. - Genetic base broadening leading to improved adaptation to climatic change and quality. - Improvement of farmers’ diversity via the distribution of selected genotypes. - Correspondence between consumers’ requirements and cultivars characteristics. - Improved scientific understanding of a taro genetics and drought adaptation. - 50 varieties distributed to 16 countries, 30 varieties distributed to 10 villages in each country, 16 lots of seeds exchanged internationally between 16 countries.</td>
<td>- molecular diversity measured and increased in farmers’ fields, - 16 TTS lots exchanged, - 30 Varieties accepted, - 12 Scientific publications, - 5 PhD theses defended, - 2 MSc theses defended.</td>
<td>- no major risk envisaged - the expertise existing in EU countries is such that there are no risks that these routine type analyses will not be done in time.</td>
</tr>
<tr>
<td>Activities</td>
<td>- Establishment of an international network of scientists and farmers to secure the future of widely grown orphan crops; - Distribution of allelic diversity of taro to strengthen taro breeding throughout the world; - Training of scientists and farmers in developing countries to taro breeding techniques; - Study the genetic diversity of traditional cultivars and progenies; - Evaluation of drought resistance of cultivars and progenies; - Understanding the relationships between the chemical characteristics of the corms, quality, and new products potential; - Optimisation of virus indexing procedures for taro species. - Selection of varieties chosen by farmers for their corm quality and adaptability to diverse farming systems and agro-ecological situations.</td>
<td>- 30 new varieties cultivated in farmers’ fields), - 16 TTS lots produced and exchanged between y countries, - successful distribution of allelic diversity measured in farmers fields with DNA markers, - 800 lead farmers involved.</td>
<td>- the scientific procedure is sufficiently independent to allow publications in due time, no risk are envisaged. - students to complete their work is a guarantee for deliverables.</td>
</tr>
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- Budget:
  - Internet platform,
  - Annual reports and meetings,
  - Budget:
- SPC log book and data base,
- NARS reports,
- Visible internet platform with loaded relevant information.
- 30 scientists participating to the international edible aroids network
- 160 villages benefiting from the project germplasm distribution
- NARS counts conducted in farmers’ fields
- 1000 samples analysed at the DNA level
- 140 cultivars analysed for their tolerance
- 1100 samples analysed for their chemical analysis
- 300 samples virus indexed
- International journals,
- PDF files shared and circulated,
- Universities data bases,
- Internet platform.
- Cities and students to complete their work is a guarantee for deliverables.
- all partners will sign a “code of conduct”;
- the action steering committee will be in place,
- there are no conditions outside the Beneficiary’s direct control that have to be met for the implementation of the planned activities.
- Farmers agree to collaborate by carrying out on-farm evaluation
- core sample and seed can be transferred safely complying with national plant quarantine regulations
- molecular analyses identify markets for drought tolerance to support breeding programme
13. **Remarks on the budget** *(please refer to Annex III – Budget for the action)*

► Modifications introduced to the budget included in the full application result from the following:

This project involves five partners from the “North”: SPC, CIRAD, Maribor, Madeira and DSMZ and one associate (Biodiversity Int.) and 15 partners from the “South” (Indonesia, Papua New Guinea, Nigeria, Ghana, the Philippines, Vanuatu, Kenya, South Africa, Madagascar, Cuba, Burkina Faso, Nicaragua, Costa Rica, India and Trinidad and Tobago).

The five partners from the “North” and the associate are conducting different scientific tasks:
- SPC is providing vitro plantlets,
- CIRAD is DNA fingerprinting,
- Maribor is analysing the physico-chemical characteristics,
- Madeira is measuring drought resistance,
- DSMZ is detecting viruses,

and the associate (Biodiversity Int.) is linking the project to major international initiatives on similar topics.

The fifteen countries from the “South” are all conducting exactly the same activities in their respective countries. As stated in the project document, they: “will receive 50 genotypes in vitro from SPC (three tubes of each) in order to increase the genetic diversity existing in their breeding programmes. Once received by the partner countries, these genotypes will be field propagated, evaluated and selected for on-farm experiments. Thirty genotypes (a selection of the best local and introduced genotypes) will be distributed to five farmers in 10 villages (total of 50 lead farmers in each country).”

All these partners are national research institutions already working on edible aroids and the EU contribution aims at supporting their activities. As they are all exactly conducting the same activities and participating, to the same international network, it is essential that, for fairness and good working spirit within the network, they receive the same EU contribution.

However, the Evaluation Committee of the EU has raised an important point (and weakness of the original budget proposal): *the on-farm research budget appears limited to ensure maximum impact on farmers and stakeholders.*

In order to address this point, budget for the 15 partners from the “South” contribution to the project (units in human resources) have been modified and their budget line allocated to “human resources” have been reduced as these were essentially focusing towards “on-station” activities. Accordingly their budget line allocated to “local transportation” has been increased so that scientists and technicians could get out from their research station and reach the 10 villages to be chosen at greater distances, to cover a better sampling of the various biotops. The scientists and technicians involved in the project will then be able to conduct and supervise on-farm experiments more frequently.

As a result of this budgetary transfer, it is expected that each of the 15 above-mentioned partners will spend around 5.5 months per year of project implementation undertaking field mission dedicated to on-farm research (15 partners * 5 years * 5.56 months = 417 months)

Budget from the partners from the “North” remains untouched, as there is no reason to modify it since there will be no change in their activities. The major budgets volumes (ie, South vs North) are also untouched. The total budget for the “South” is almost identical and the overall sum is the same.

These financial arrangements are responding to the EU queries, strengthening the 15 partners from the “South” activities and are in agreement with the original project proposal.