

Taro Improvement and Development in Papua New Guinea - A Success Story



Asia-Pacific Association of Agricultural Research Institutions
c/o FAO Regional Office for Asia and the Pacific
Bangkok, Thailand

Taro Improvement and Development in Papua New Guinea - A Success Story

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Foreword

Taro (*Colocasia esculenta*) is a crop of prime economic importance, used as a major food in the Pacific Island Countries (PICs). In Papua New Guinea (PNG), taro is consumed by the majority of people whose livelihood is mainly dependent on subsistence agriculture. It is the second most important root staple crop after sweet potato in terms of consumption, and is ranked fourth root crop after sweet potato, yam and cassava in terms of production. PNG is currently ranked fourth highest taro producing nation in the world.

This success story illustrates as to how National Agricultural Research Institute (NARI) of PNG in collaboration with national, regional and international partners implemented a south Pacific regional project on taro conservation and utilization (TaroGen), and how the threat of taro leaf blight disease was successfully addressed by properly utilizing national capacity. So far, four high yielding leaf blight resistant taro varieties have been released to the farmers, which are widely adopted now. These successes also point out to the positive impact towards food security and income generation for rural farmers. Also, efforts have been made to conserve diverse germplasm in the Regional Germplasm Centre (RGC) in Fiji, and maintain a core collection representing major genetic diversity of the region.

The Asia-Pacific Association of Agricultural Research Institutions (APAARI), as its on going activity, brings out such successful case studies for the benefit of NARS in the Asia-Pacific region. It has brought out more than 40 such success stories covering diverse topics of concern to member NARS and other

partners. The major objective is to disseminate information and share technologies developed. It is felt that wider distribution of this publication will be useful particularly to the scientists in countries where taro is grown as a staple/major food crop or as a subsidiary crop.

We are extremely thankful to the authors for their efforts in synthesising information for this success story, to which some additions have been made by APAARI. Our thanks are also due to Dr. Raghunath Ghodake, Director General, NARI, for his keen interest and persistent efforts in getting the manuscript written for this publication. It is our expectation that APAARI members and all readers will find this publication both informative and useful.



R.S. Paroda
Executive Secretary

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I. Introduction

Taro (*Colocasia esculenta* (L.) Schott) is an ancient and important vegetatively propagated root crop species belonging to the monocotyledonous family Araceae. It is the fourteenth most consumed vegetable worldwide (Lebot and Aradhya 1991) and is grown primarily in humid tropical regions of the world. Taro is considered to have originated in the Indo-Malayan region from where it was dispersed to east and Southeast Asia, the Pacific Islands, Madagascar and Africa, and then introduced to the Caribbean and other parts of tropical America (Ivancic and Lebot 2000). Taro is considered to be a less adaptive crop because of its predominant vegetative propagation and its requirement for high fertility soil.

In the past, taro was relatively a much more important crop in Papua New Guinea (PNG) and the Pacific but production started to decline over recent times mainly because of pests and diseases. Consequently, many traditional varieties have been lost and replaced by more adaptive crops like sweet potato, cassava and maize. This success story illustrates how the National Agricultural Research Institute (NARI) of PNG implemented plant breeding strategies in a systematic fashion to address complex breeding objectives in a crop normally propagated vegetatively. It also reveals how the threat of taro leaf blight (TLB) disease was successfully confronted by properly utilizing national capacity, opportunities, potentials, research grants and collaboration/diverse partnership. It points out as to how such concerted efforts helped overcome production decline of taro by spread of promising varieties to the farmers through an effective R&D programme, largely networking the activities through a south Pacific regional project on taro conservation and utilization (TaroGen).

Economic and Cultural Importance

Taro is a crop of prime economic and cultural importance to the people of Pacific Island Countries (PICs). In PNG, taro is consumed by a majority of the population whose livelihood relies predominantly on subsistence farming.

In addition to its economic importance, taro has a long history of social and cultural attachment in PNG societies. This sentimental attachment to taro is evident also in other cultures within the Oceania and the Southeast Asian regions (Onwueme 1999). In PNG, taro is a prized commodity for traditional social activities such as compensation payments, bride price ceremonies and feasts. Its importance stems from the crop's unique taste, its early association with the people's culture and its high labour input requirements.

II. Production and Constraints

Taro is the second most important root staple crop after sweet potato in terms of consumption (Singh *et al.* 2006) and is ranked fourth root crop after sweet potato, yam and cassava in terms of its production by weight (Bourke and Vlassak 2004) with an estimated annual production of over 229,088 tonnes (Figure 1).

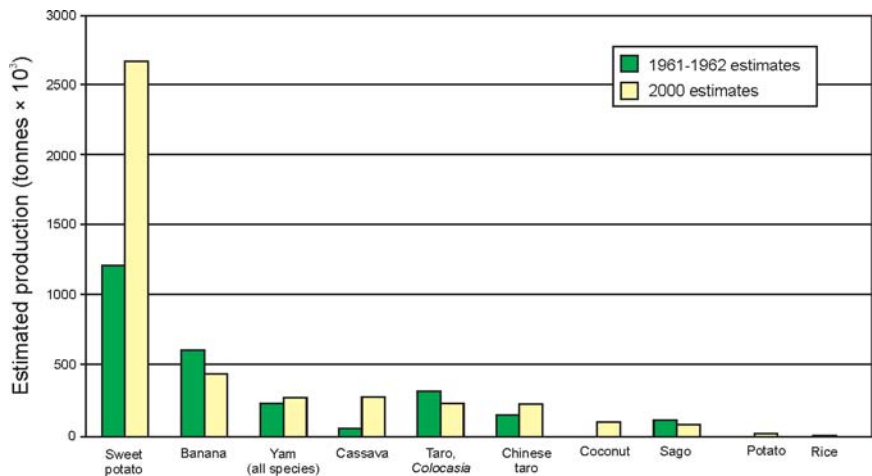


Figure 1. Comparison of the 1961-62 and 2000 estimates of production of ten staple food crops of PNG (Source: Bourke and Vlassak, 2004). Chinese taro being *Xanthosoma sagittifolium* and Taro being *Colocasia esculenta*

PNG is currently ranked fifth highest taro producing nation in the world (Figure 2) and has had a consistent record of highest taro production compared to its Pacific neighbors since 1990 according to FAO 2004 estimates (Figure 3).

Major constraints to taro production include diseases like TLB, pests as taro beetle, poor soil management practices and

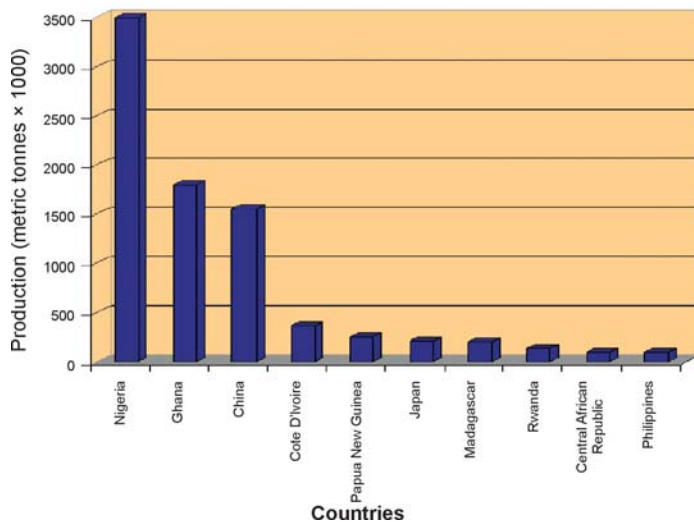


Figure 2. Taro production of ten top producing countries (Source: FAO, 2004)

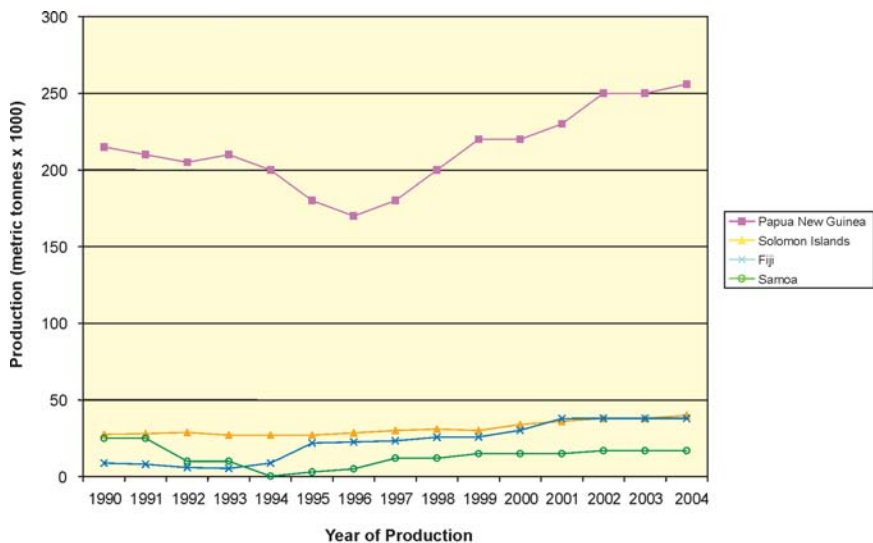


Figure 3. Taro production in predominant taro growing Pacific nations from 1990 to 2004 (Source: FAO, 2004)

declining fertility, lack of value addition to production and lack of efficient marketing systems. However, of the various constraints, TLB and taro beetle (Figure, 4 a and b) are of prime importance since the former can reduce yield by up to 50 percent and can also lead to poor quality of the corms (Paiki 1996; Sar *et al.* 1998) while the later can cause up to 95% crop loss due to damaged corms.



Figure 4. (a). Taro leaves damaged by Taro Leaf Blight, **(b)** Taro corms damaged by Taro Beetle

Taro leaf blight has been present in the Pacific region since the early 1900s (Carpenter 1920). It is a disease highly adapted to the wet humid environment of the region and is a major constraint for taro production particularly in the Pacific Island countries. The most recent introduction of the disease was to the Samoan islands in 1993 but it has been present in PNG since the Second World War. In Samoa, over 90% of taro plantations were under the local cultivar Niue, the choice for commercial production. The disease spread rapidly, severely affecting all local cultivars and within a few months TLB reached epidemic proportions. As a result, Samoa lost an export market estimated to be worth around US\$ 4 million per year, with a similar decline in domestic supplies. TLB continues to be a major constraint in PNG, and many other countries, including Fiji, Vanuatu, Tonga, Cook Islands and Niue, which remain vulnerable to this devastating disease.

III. Research and Development

Taro research and development has been a priority programme with the Pacific Island Countries (PICs) and assumes great importance as taro is a staple food crop of this region. Hence, well planned research efforts were focused, directed towards improvement of agronomic traits and resistance to pests and diseases by breeding. These research initiatives in time, could, provide a practical method for controlling TLB and also could help control, alleviate the declining trend in taro production (Okpul *et al.* 1997). There have been several attempts to improve the crop genetically, beginning in PNG and other PICs in late 1970s. The programmes have been aimed either at improving cultivars for commercial productivity or for TLB resistance. To date there have been five breeding programmes in the south Pacific region with essentially similar objectives, but with little collaboration between them. The net result has been the release of very few varieties for improved yield and, also with TLB resistance with relatively little impact on production. The low output of the programme initially was also due to inconsistent funding, staff changes, political disturbances and lack of collaboration. To overcome these problems, a network was established among PICs interested in taro improvement supported by Australian Agency for International Development (AusAID) and Australian Centre for International Agricultural Research (ACIAR) which funded the 'Taro Genetic Resources: Conservation and Utilization Project' (TaroGen). The project re-activated the PNG breeding programme, after a long dormant period, and linked it closely with the other Pacific programmes by means of transfer of breeding material. To further link Oceania with Southeast Asia programmes, another network, 'Taro Network for Southeast Asia and Oceania'

(TANSO) was established (Lebot 1997). This networking through collaborative research has brought out rich dividends with notable results/achievements in less than a decade.

TaroGen Project (Taro Genetic Resources: Conservation and Utilization)

The TaroGen project, supported by AusAID and ACIAR involved an alliance of PNG's NARI, the Secretariat of the Pacific Community (SPC), PNG University of Technology (UniTech), University of the South Pacific in Samoa (USP), Horticultural Research Organization in New Zealand (Hort Research), University of Queensland, Australia (UQ), Queensland University of Technology, Australia (QUT) and Bioversity International, formerly the International Plant Genetic Resources Institute (IPGRI). As a network, AusAID and ACIAR funded the project while SPC implemented and managed the project. Taro germplasm was collected by south Pacific NARS (primarily PNG, NARI) and the Southeast Asia NARS from TANSO project, Taro Network for Southeast Asia and Oceania. IPGRI assisted the NARS in morphological characterization of the germplasm while UQ and UniTech assisted in molecular characterization using DNA fingerprinting. Once the germplasm was rationalized, a core collection was collectively established by NARS, UQ and IPGRI and was virus indexed by QUT and UniTech before it was transferred to the SPC Regional Germplasm Centre (RGC) in Fiji. The breeding programmes were established at NARI, PNG and USP, Samoa while Hort Research assisted in developing pathology techniques and TLB screening. Overall, the project activities were aimed at assembling, conserving and utilizing taro genetic resources for breeding and crop improvement, and assisting farmers to improve food security and rural incomes. The TaroGen strategy was based on a networking among PICs, universities and research institutions, and regional and international organizations. (Figure 5).

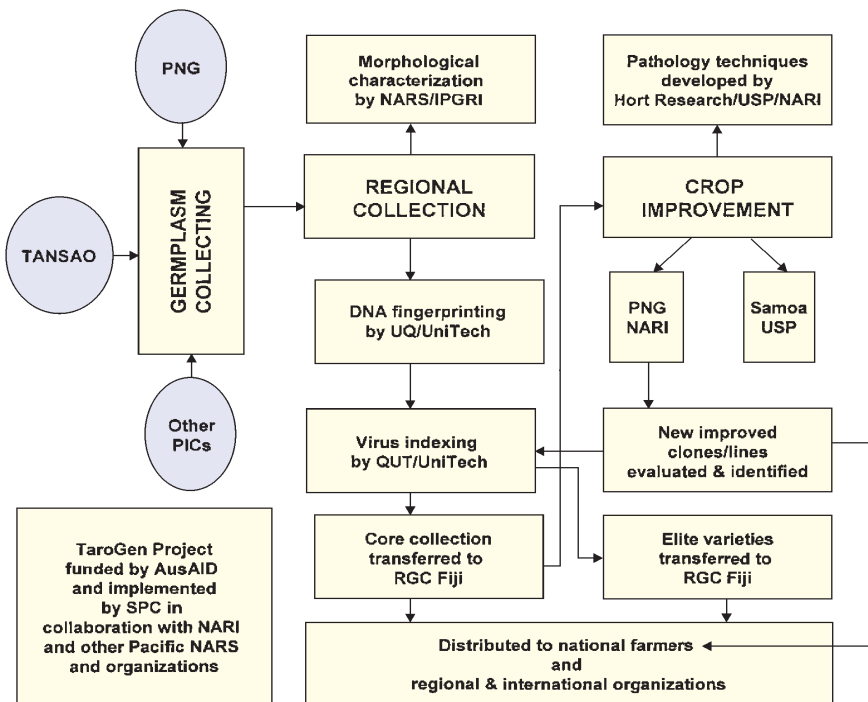


Figure 5. Role of TaroGen partners in networking for taro conservation and utilization in the Pacific

Significant Achievements of TaroGen

More than 850 taro accessions were collected over fifteen provinces of PNG under the coordination of TaroGen (Table 1 and Figure 6). The germplasm was characterized morphologically by using selected IPGRI descriptors, and molecular markers. Complete database for passport and morphological characterization is available. A core sample of 20% collection was established on the basis of morphological characterization, and 10% using molecular characterization (Figure 7). The 20% core collection was transferred to Regional Germplasm Centre (RGC) Fiji, and is



Figure 7. (a). Taro core collection, **(b).** Field view of taro growing in Bubia, Morobe Province

being maintained *in vitro* as tissue culture. The 10% core collection was transferred to Vudal University for maintaining a duplicate set as a complementary conservation strategy. In addition more than 100 exotic cultivars were acquired under TANSOA project from Southeast Asia and Oceania. These cultivars are being maintained in tissue culture at UniTech.

The crop improvement output of this project culminated in the development of improved taro varieties with high yield, yield-stability across broad agro-ecological sites, resistance to TLB and good eating quality. TaroGen project was inceptioned when NARI breeding was in early stages of Cycle 2. The first cycle of selection in the PNG breeding programme was conducted at one location (Bubia) on a population generated by mating TLB-resistant wild and partly domesticated accessions with local agronomically-preferred cultivars. Under the technical directions of the project, NARI rejuvenated breeding programme by redefining breeding objectives and strategies. The main breeding objectives were to develop high yield TLB resistant varieties with good quality. Population breeding strategy using modified recurrent selection approach was adopted to accumulate incremental genetic gains over cycles. The programme focused on incorporating horizontal resistance (considered more durable form of resistance and is accumulated over cycles) to TLB. Using the strategy outlined in Figure 8, NARI released four new TLB-resistant NARI taro (NT) varieties under the names NT 01, NT 02, NT 03 and NT 04 (Table 2).

The development of these high yielding varieties of taro, thus helped dissipating the threat of TLB. Under trials, these varieties (Figure 9) perform well in farmers' fields giving over 50% higher yields than standard popular check varieties like Numkowec.

The yield of these lines is considered sustainable over time, since these varieties are derived from genetic improvement, and are not environment-specific or enhanced by agronomic practices.

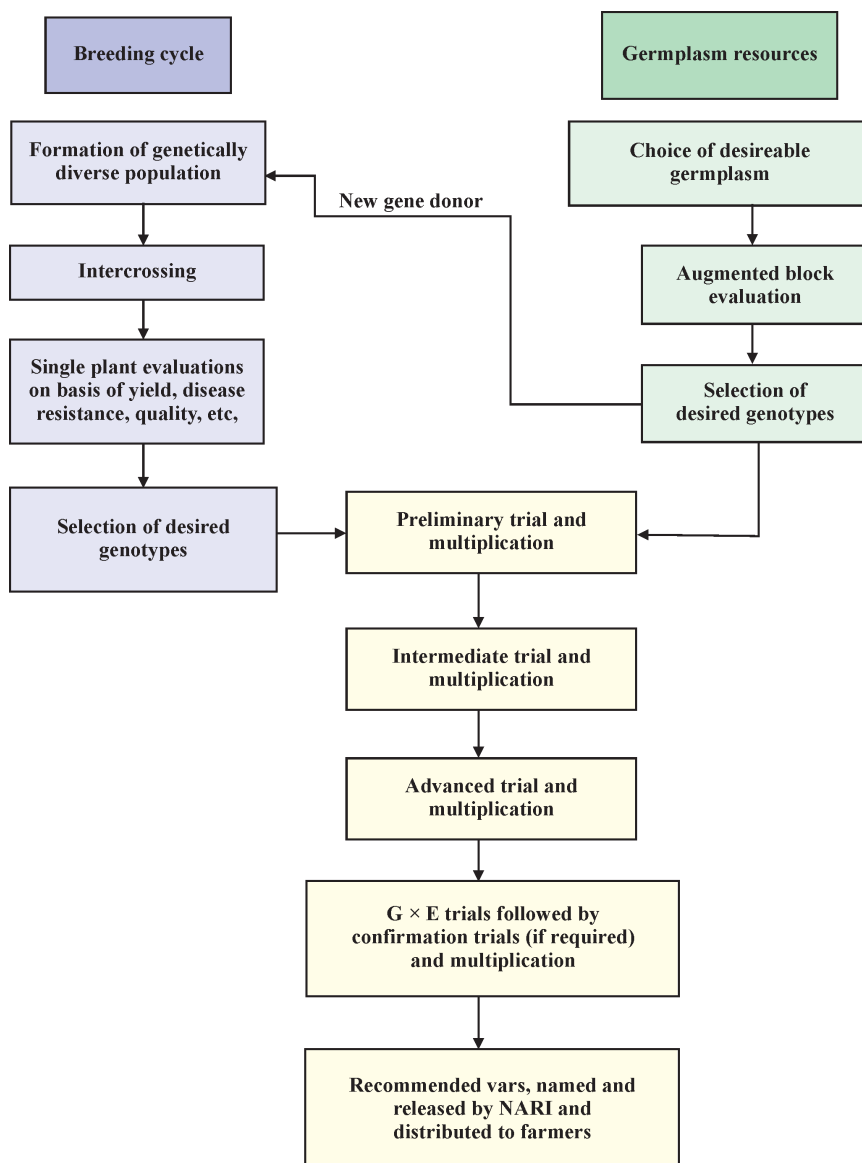


Figure 8. Schematic representation of evaluation, development and release process for promising taro varieties

Table 2. Salient features of the four released taro varieties compared to one of the popular cultivars 'Numkowec'

Trait	Variety				Numkowec
	NT 01	NT 02	NT 03	NT 04	
Yield (t/ha)	10.49	7.68	7.65	11.1	5.89
Average corm weight (g)	525	380	380	570	300
Yield stability	Stable	Stable	Unstable	Stable	Stable
Taro Leaf Blight (TLB)	Resistant	Resistant	Resistant	Resistant	Susceptible
Taro Beetle	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible
Eating quality	Good	Good	Good	Good	Good
Maturity (c.month)	6	6	6	7	6
Sucker production	3-4	2-3	5-6	6-7	6-8
Growth habit	Erect	Erect	Erect	Erect	Erect
Plant height	Tall	Medium	Tall	Tall	Medium
Leaf lamina	Light green	Dark green	Dark green	Dark green	Dark green
Petiole colour	Light green	Purple green	Purple	Purple	Light green
Petiole junction	Purple	Purple	Purple	Purple	Purple
Flowering	Rare	Rare	Frequent	Rare	Frequent
Corm shape	Cylindrical	Elliptical	Conical	Elliptical conical	Elliptical
Corm skin	Smooth	Smooth	Smooth	Smooth	Smooth
Flesh colour	Pink	Pink	Pink	Pink	Pink
Corm dry matter (%)	35	41	41	37	38

Source: Singh *et al.* (2006)

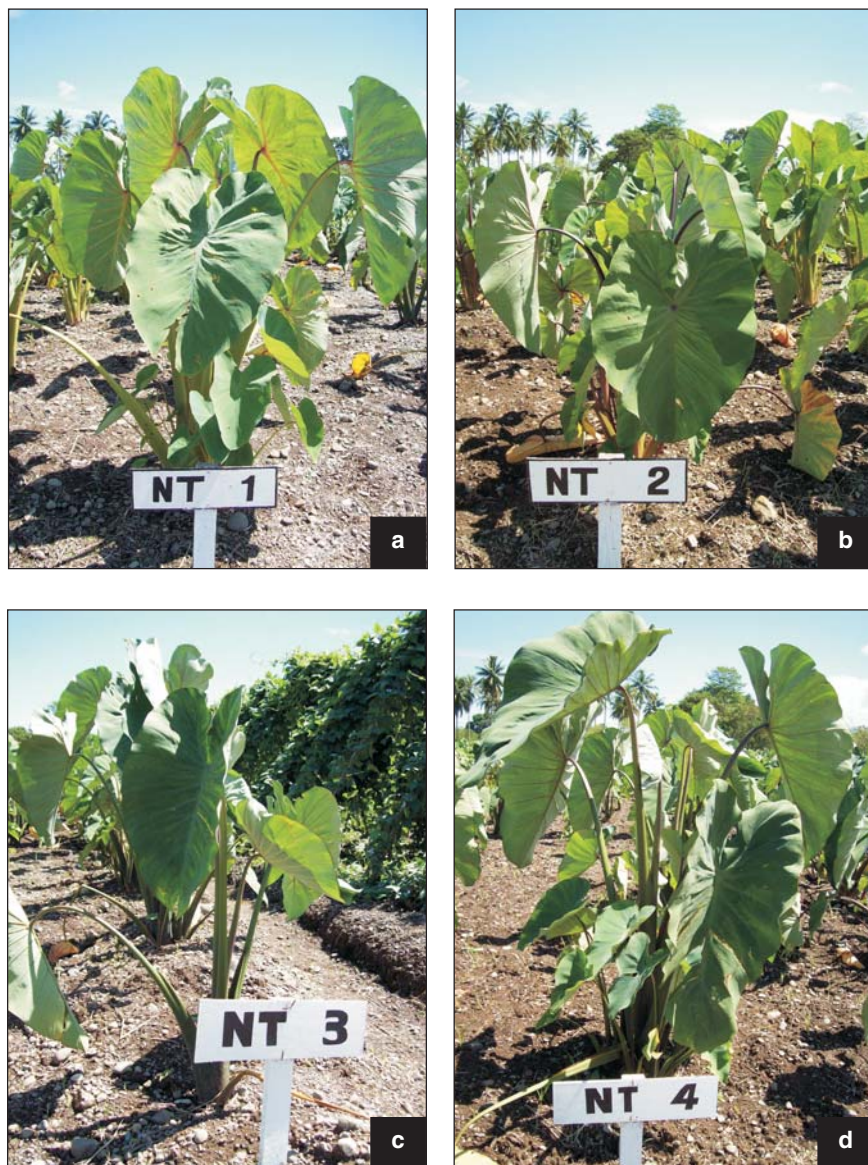


Figure 9. (a). NARI Taro 01, (b). NARI Taro 02, (c). NARI Taro 03, (d). NARI Taro 04

The TLB resistance will also be durable since it is based on horizontal resistance breeding strategy relying on multiple genes against the pathogen. These NARI-developed TLB resistant cultivars have since been highly adopted and intercropped in the farms/gardens of rural communities in PNG.

Multiplication and Distribution of Planting Material: Promoting Awareness

The planting materials for the four released taro varieties were disseminated to farmers during NARI open days, agriculture shows and through collaboration with NGOs and other organizations involved in agriculture extension and rural development such as the Lutheran Development Service (LDS) and Morobe Provincial Department of Agriculture and Livestock. Planting material was multiplied extensively on-station and at each site of the multi-location trial, with more than 10,000 clones propagated for each released variety during 2003-2005. Planting materials were multiplied through normal vegetative propagation through bulking and also using mini-sett technique (Singh *et al.* 2001). The distribution of material was coordinated by a National Taro Improvement Coordinating Committee comprised of members from national extension agencies, NGO networks, schools and churches. The best means for distribution of material was via field days at different NARI research stations and at local provincial agricultural shows (Figure 10 a,b,c). The demand for planting material has been high and to meet this need a challenge. However, adequate material has been distributed throughout the country. Further distribution relies upon the assumption that following harvesting of this material, farmers will share planting material with other farmers and disseminate it in their communities. The above success could be realized through effective participating role of scientists, extension workers and farmers and the awareness generated by NARI, PNG at the grassroot level among farming communities.



Figure 10. (a,b,c). Promotion and impact of new taro varieties released by NARI, at village/provincial level, field days and agricultural shows

IV. Impact and Adoption of New Released Varieties

The improved taro varieties developed by NARI have been widely adopted nationally as a result of mass scale distribution of material and awareness/promotion campaign, and already there are indications of the positive impact achieved towards food security and income generation for rural farmers. A pilot impact assessment study was undertaken in the Morobe province to estimate adoption of new varieties and the likely positive impact on farmers' livelihoods (Guaf and Komolong 2006). The survey showed a high occurrence/cultivation of the newly released varieties in the farmers' fields in five major districts (Figures 11 and 12). The study indicated that most farmers were satisfied and

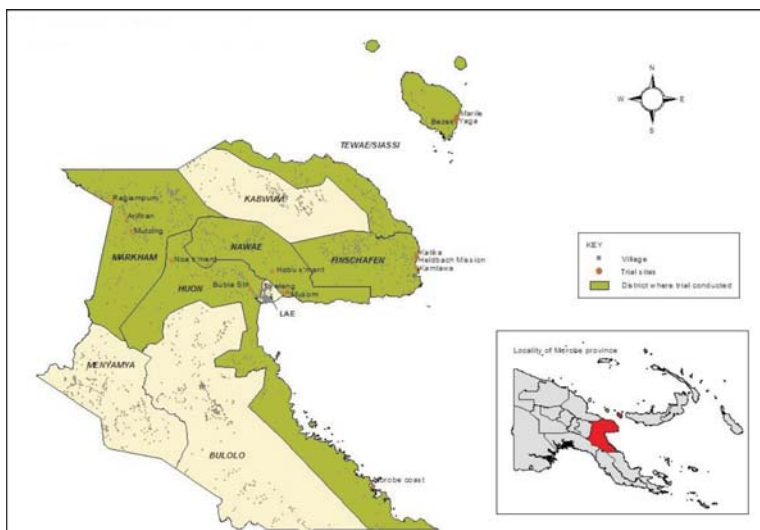


Figure 11. Distribution and spread of the improved taro varieties in the five districts of Morobe Province, Papua New Guinea

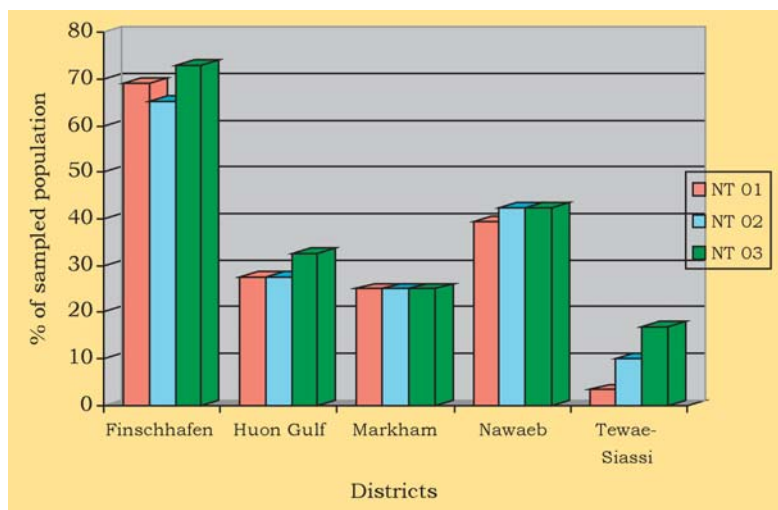


Figure 12. Estimated occurrence and proportions of NT varieties in farmers' fields in each of the five districts of Morobe Province (Source: Guaf and Komolong 2006)

impressed with the performance of the three improved varieties (NT 01, NT 02 and NT 03) with their tolerance to TLB disease and higher corm yield per plant in comparison to the local varieties (Table 3).

Table 3. Farmers' perceived impact (% of farmers) of NARI taro varieties on livelihoods of people in the five districts of Morobe Province of Papua New Guinea

Perceived Impact on Livelihoods	Districts				
	Finch-hafen	Huon Gulf	Markham	Nawaeb	Tewae-Siassi
Improved food supply	84.60	42.50	35.70	30.30	16.70
Income generation	30.80	7.50	17.90	27.30	16.70
Less fertilizer use	0.00	2.50	3.60	3.00	3.30
Less fungicide use	3.80	0.00	0.00	3.00	3.30

Source: Guaf and Komolong (2006)

Farmers interviewed were impressed with vigorous plant growth of the hybrids and expressed willingness to cultivate these varieties as a supplement to their daily diets and as promising source for income generation (Guaf and Komolong 2006).

The farmers sampled in the survey indicated that apart from TLB resistance, the other main advantages of new varieties were for self-consumption, diversification, cash income, revenue generation and use during special occasions like bride price ceremonies and feasting. These advantages were mainly associated with bigger corm size and higher yield of these varieties compared to local varieties.

V. Success Factors in Networking

The success of TaroGen lied behind the intensification of PGR network activities through crop improvement, long-term maintenance of national and regional germplasm collections – accessions maintained at different locations, and appropriate national PGR policies. Strengthened collaboration under TaroGen allowed wide access to the regional taro diversity and at the same time avoiding duplication of efforts by resource poor countries. Also countries within the Pacific are very diverse in their PGR set up both structurally and functionally and none is self-sufficient, thus countries need to share and exchange genetic resources both within and outside the region. Therefore, TaroGen utilized these collections, strengthened national programmes and stimulated collaboration amongst them. Under TaroGen, countries agreed to share their PGR and the products from crop improvement programmes under the common memoranda of understanding (MOU)

TaroGen encouraged the need-based strengthening of national R&D systems and awareness/success achieved can be highlighted as follows: Developing close relationships with government and non-government organizations, including community development organizations, farmers' networks, lead farmers and agricultural companies, religious institutions, schools, universities, national agencies, and regional and international organizations; Strengthening the interface between farmers and breeders for enhanced PGR utilization, specifically in building farmers' participation in the identification of priorities, germplasm evaluation and improvement to include participatory plant breeding (PPB) and wisely implementing it. Overall successes achieved through the TaroGen project are given in the Box.

Successes achieved through TaroGen Project

- Development of a regional strategy to collect and describe taro which resulted in a database of over 2,000 taro accessions;
- Technical assistance from UQ and IPGRI scientists in analysis of morphological and molecular data which allowed the identification of 220 taro accessions as a core collection, representative of the broad diversity of taro in the region;
- Assistance provided to SPC to establish the Regional Germplasm Centre as a centre of excellence for research on conservation methods and germplasm distribution;
- Regional NGOs, PMN and FSA, providing important information on the *in situ* conservation of taro which illustrated that on-farm conservation of taro is a feasible method for some countries;
- Advances in taro virus characterization and diagnostics by scientists at QUT which now allow the safe international transfer of taro germplasm;
- Crop improvement programmes established at NARI and USP-Alafua which have resulted in the production and distribution of leaf blight resistant taro varieties to farmers;
- Enhanced skills and capacity of many Pacific Island scientists through on-going monitoring with scientists of international repute. This included the completion of 10 postgraduate programmes; and
- Finally, through its many diverse activities and collaborations the Project has significantly added to the body of knowledge that exists on taro conservation and improvement as evident from the publications produced.

Source: D. Hunter and M. Taylor (2007) TaroGen: Networking and learning for taro conservation and improvement.

Also, the TaroGen website includes vast information on all aspects of the project components/activities on taro conservation and improvement, and the publications (<http://www.spc.int/tarogen/>). Other useful websites are of the SPC Regional Germplasm Centre (<http://spc.int/rgc>) and of the Pacific Agricultural Research Network, PAPGREN (<http://spc.int/pgr>).

VI. Future Strategies

Strengthening Inter-regional Collaboration

The future of a successful breeding programme and germplasm enhancement relies on the germplasm available and its proper utilization. Very diverse germplasm is available in southeast Asia compared to the Pacific germplasm. Additional variability lies in the Indian subcontinent, Indo-China, South America and Africa. The future strategy should be to develop inter-regional collaboration to enrich this germplasm from different regions to further diversify the existing germplasm diversity and conserve taro collection in an inter-regional germplasm centre. Use of this centre for exchange of material for crop improvement needs will strengthen the capacities of the national taro breeding programmes in the regions.

There is no doubt that collaboration and regional networking for crop improvement research has been and continues to be beneficial, as per needs of the countries/NARS in the various regions and realizing the difficulties they face in operating or maintaining effective research programme commensurate with their infrastructure and facilities. Hence, NARS in the Pacific should continue their collaborative crop improvement activities through a regional network by developing and implementing regional-networking projects via SPC, PAPGREN (Pacific Agricultural Plant Genetic Resources Network) and other regional and international agencies particularly GCDT, FAO, ACIAR, NZ aid, to overcome several constraints. Thus, there is a need to have partnership arrangements for countries to share expertise, facilities and genetic materials. Regional networking can be used to more readily and efficiently, seek and obtain technical assistance,

secure funding on a regional basis and build capacity, thereby strengthening ongoing R&D programmes.

The TLB constraint has been systematically addressed by NARI scientists using breeding and plant protection approaches. The disease was one of the biggest challenges to achieve high yield and producing quality corms for marketing. With this problem out of the way, taro farmers now stand to earn considerable income from the produce and sale of their crop. Future concerns in this connection might target emerging issues of specific market needs. This would again require a new strategy in combining development of relevant varieties with the preferred comparative advantage given availability of post harvest techniques and knowledge required to give maximum satisfaction to farmers. In this context, future efforts need to focus on 'Linking Farmers to Market', and database has to be developed on marketable products, commodities with NARI and other institutes. Also, facilities and approach with more role of extension and rural agencies needs to be streamlined and farmers' cooperatives developed to bring more benefits of saleable produce to farmers.

VII. Epilogue

Taro is an important staple food crop of the Pacific Island Countries (PICs). Over the past few decades, NARI, PNG has been systematically pursuing R&D initiatives for improving this crop through national, regional and international cooperation and collaboration.

The outcome of the TaroGen project in PNG in producing high yielding TLB resistant taro varieties in five years is no doubt an exceptional achievement in such a short period, for any conventional breeding programme. Farmers now have access to new TLB resistant taro cultivars. The new cultivars are helping to create income-generating opportunities for women and men in the region and build effective partnerships and networking. The research achievements significantly highlight the benefits of a well-organized collaborative partnership of international, regional and national organizations and governmental, and non-governmental organizations. Overall, the taro breeding programme and the TaroGen project has addressed a major food security threat by enabling the release of new constraint-free varieties and collection of germplasm for the PICs that would be well beyond the resource capacity of any individual country to address alone.

The success of the project relied on the development of the collaborative partnership and efficient use of available funds, resources and expertise. Within that, the key ingredient for the success was the networking and proper implementation of the project by NARI and the regional implementing agency, SPC. No doubt there are many challenges for future breeding to address more production constraints as discussed but a systematic approach to identify specific projects within a breeding programme

and sustained funding can help to address these challenges and at the same time help in the identification of new opportunities with focus on conservation and use of taro genetic diversity and create a positive impact for this important underutilized crop.

In providing benefits to the farmers, communities growing this crop for local consumption and market, the R&D efforts have been well geared to meet the millennium development goals (MGDs), for better livelihoods – generating more income to farmers, attaining food security, addressing malnutrition and poverty reduction.

It is strongly felt that wider dissemination of this publication by the Asia-Pacific Association of Agricultural Research Institutions (APAARI), will be useful to all countries/member NARS in this region where taro is cultivated as a food crop.

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