Taro leaf blight - My 50-year part in its downfall

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Abbreviations

ACIAR	Australian Centre for International Agricultura Development
ACIL	Australian consulting company; now CARDNO ACIL
ADAP	Agricultural Development in the American Pacific
ADB	Asian Development Bank
AMC	Australian Managing Company
ANGAU	Australian New Guinea Administrative Unit
AusAID	Australian Agency for International Development (later, Australian AID)
BAF	Biosecurity Authority of Fiji
BARC	Bubia Agricultural Research Centre (Papua New Guinea)
BSIP	British Solomon Islands Protectorate
CBD	Convention on Biological Diversity
CDC	Commonwealth Development Corporation
CePaCT	Centre for Pacific Crops and Trees
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CIP	International Potato Institute
CIRAD	La Recherche Agronomique pour le Developpement
CMI	Commonwealth Mycological Institute
CRB	Coconut rhinoceros beetle
CRGA	Committee of Representatives of Governments and Administrations
CV	Cultivar
DAFF	Department of Agriculture, Forests and Fisheries (Western Samoa)
DAL	Department of Agriculture and Livestock
DDT	Dichlorodiphenyltrichloroethane
DFAT	Department of Foreign Affairs and Trade
DNA	Deoxyribonucleic acid
DSAP	Development of Sustainable Agriculture in the Pacific
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FSA	Food Support Association
FSM	Federated States of Micronesia
GDP	Gross domestic product
IITA	International Institute of Tropical Agriculture
INEA	International Network for Edible Aroids
IPGRI	International Plant Genetic Resources Institute (later, Bioversity International)
IPM	Integrated pest management
IRETA	Institute for research, Extension and Training in Agriculture
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IUCN	International Union for the Conservation of Nature
KGA	Kastom Gaden Association
KRS	Koronivia Research Station
LAES	Lowlands Agricultural Experiment Station
LRD	Land Resources Division
MAF	Ministry of Agriculture and Fisheries (Samoa)
MAFFM	Ministry of Agriculture, Forests, Fisheries and Meteorology (Western Samoa)
MAL	Ministry of Agriculture and Lands (later Livestock) (Solomon Islands)
MFAT	Ministry of Foreign Affairs and Trade (New Zealand)
NAQIA	National Agriculture Quarantine and Inspection Authority (Papua New Guinea)
NARI	National Agricultural Research Institute (Papua New Guinea)
NGO	Non-government organisation
ODA	Overseas Development Administration
OPRA	Oil Palm research Association Inc. (Papua New Guinea)
PRCRTC	Philippines Root Crop Research & Training Center
PHALPS	Pacific Heads of Agriculture and Livestock Production Services
PHAMA	The Pacific Horticultural and Agricultural Market Access Program
PhD	Doctor of Philosophy
PNG	Papua New Guinea
PRAP	Pacific Regional Agricultural Programme
PS	Permanent Secretary
PWD	Public Works Department
QUT	Queensland University of Technology
R&D	Research and development
RGC	Regional Germplasm Centre
RTMPP	Regional Technical Meeting on Plant Protection

SBD	Solomon Islands dollars
SDC	The Swiss Agency for Development and Cooperation
SPC	South Pacific Commission (now the Pacific Community)
SPYN	South Pacific Yam Network
TANSAO	Taro Network for Southeast Asia and Oceania
TaroGen	Taro Genetic Resource Network
TCP	Technical Cooperation Programme
TLB	Taro leaf blight
TR	Tropical race
UH	University of Hawaii
UK	United Kingdom
UNDP	United National Development Programme
UNITECH	University of Technology
UQ	University of Queensland
US	Under-Secretary
USDA	United States Development Agency
USP	University of the South Pacific
WSFSP	Western Samoa Farming System Project
WWII	World War II

Acknowledgements

I want to thank the people of the Pacific islands where I have spent much of my life. I hope that my interest in taro and my contribution to finding a solution to its foremost pathogen repays to some extent the kindnesses they have extended to me.

There are two people that I want to give special mention as they have made an impact on my life, and kept the search for a taro leaf blight solution alive over the years . One is Festus Haggai, from Ulawa, Solomon Islands, who I worked with at Dala Experimental Station and later Dodo Creek Research Stations. Festus had incredible patience and understanding and was ideal to lead the Government's land resource section, in charge of negotiating the return of plantations to communities. He had so much potential. Festus was tragically murdered in Honiara. The other person is Ivor Firman, a plant pathologist, who worked first in East Africa, then with the Government of Fiji, SPC, FAO and the EU. I enjoyed working with him in Fiji and treasured his friendship, albeit too briefly. Both died before their time, but are remembered.

There are many people who have read through my story and given comment, and even hope that it might be published, whatever the consequences! I should like to thank the following: Phyllis Fong, Mike Furlong, David Gollifer, David Guest, Liz Hodgkinson, Caroline Smith, Vincent Lebot, Luigi Guarino, and Peter Walton.

Finally, I would like to acknowledge Spike Milligan, novelist and creator of The Goon Show, whose wartime memoirs were an inspiration for me to write this story. I am not saying that my story could have become a script for the Show, although there were times when it got close, but because I have plagiarised part of the title of one of his books!

Abstract

This is a story of taro and its fungus-like pathogen, *Phytophthora colocasia*, the cause of a major leaf blight. It has parallels with a similar disease which struck down the Irish potato in Europe 100 years before. It is also about my part in its downfall, a journey of many twists and turns. But more than this, it is a story of development assistance in Pacific islands, and its role in alleviating vulnerability to invasive plant pests and pathogens.

My story begins in Solomon Islands, where I was sent to work on diseases of taro and cocoa in 1972, after completing university studies in the UK. At Dala Experimental Station, Malaita, I learnt the history of taro leaf blight, its entry into the South Pacific: first to Papua New Guinea before or during WWII and, after the war, its journey through Solomon Islands to all but its most southerly islands. Its impact was considerable and contributed to sweet potato becoming the main food crop staple, largely replacing taro.

Even so, farmers wanted to grow taro, notwithstanding its deadly pathogen. It remained a favoured food, and retained high status in local custom. Attempts were made to manage the taro leaf blight using fungicides, by manipulating cultivation techniques and by testing varieties for resistance, but without success. The only hope was to breed for resistance, but that was not a policy favoured at the time, and no one had done it before. But all that was about to change.

During a transit through Bangkok in 1975, seed was collected from wild taro to provide healthy plants for virus transmission tests for another serious taro disease we were researching; they were taken to the UK, grown in tissue culture, and forwarded as sterile plants to Solomon Islands a year later. There, at Dodo Creek Research Station, Guadalcanal, they were found, by chance, to be blight resistant and crossed with local cultivars; this initiated the first attempt to breed taro in Pacific island countries. Later, a regional UNDP/FAO/SPC root crops project supported the work with a volunteer plant breeder.

In 1983, I left Solomon Islands and joined a UNDP/FAO/SPC project in Fiji, working regionally on plant protection and root crops improvement. Work on taro leaf blight continued in Solomon Islands until 1984, stopped for 5 years, then started again under a second UNDP volunteer until1993, stopped once more, and then moved to NARI, Papua New Guinea. In Fiji, I worked with the Ministry of Agriculture breeding new taro varieties (but not for taro leaf blight as the disease does not occur there), carried out pest surveys regionally, and set up the region's first tissue culture lab at SPC to move root crop germplasm between countries. Completely by chance, we found taro of Micronesia were tolerant to leaf blight.

However, support to resolve taro leaf blight remained elusive, even after 1993 when blight entered Samoa for the first time, and within 6 months annihilated domestic supplies and export production. Five years lapsed before plant breeding was accepted as the only viable option. Together with ACIAR, I met with AusAID in 1997, and was asked to design a regional program, which became known as TaroGen. The focus was on breeding for blight resistance using Micronesian and Philippine cultivars in Samoa, and wild Bangkok hybrids in Papua New Guinea. Complementary projects from ACIAR supported virus-indexing to allow international movement of germplasm as well as DNA fingerprinting to establish a Pacific island core collection for conservation in the project's regional germplasm centre, enlarging the lab I had established previously. TaroGen began in August 1998. Unfortunately, its premature closure denied farmers access to blight-tolerant breeders' lines, leaving many as vulnerable today as Samoan farmers were in 1993.

In a final section, the story covers the preparedness of Pacific island countries to deal with major invasive pests. It compares taro leaf blight with more recent incursions of new forms of coconut rhinoceros beetle. It concludes that lessons have not been learnt how to deal with major invasive pests, and worse, the battle with taro leaf blight is far from over.

Early days – Solomon Islands

So how did I, a lad from England's potato-growing Fenland of East Anglia, come to be rushing to the rescue of a foodstuff that few Europeans have even heard of, to try to save it from a terrible leaf disease?

The story starts with a gifted biology teacher at my school, Mrs Lunn. She, although sadly nobody else, thought I was university material and encouraged me to apply to the University of North Staffordshire, Keele, then the newest and trendiest university in the country, and founded with a different ethos from other academic establishments at the time.

Mrs Lunn fired my interest in plants and all their ways, an interest which has lasted to this day and which enabled me to kick off an unusual and satisfying lifelong career, researching diseases of tropical crops, starting as plant pathologist to Solomon Islands, then a British protectorate[1].

At Keele, I did a joint degree in Biology and Geology, and fortunately for me, the professor of biology was Alan Gemmell, a well-known panel member of BBC Radio 4's Gardeners' Question Time, midday each Sunday for some 30 years. His excellence as a broadcaster was mirrored by his brilliance as a lecturer, and his course on plant diseases created a fascination in me for further study.

Lucky for me, I was awarded a grant by the Overseas Development Administration, UK, to do an MSc in plant pathology at Imperial College, Silwood Park, on the condition that I did 2 years' service overseas upon completion. However, at the end of the MSc, Bryan Wheeler, Senior Lecturer and course supervisor, asked if I would like to delay going overseas while doing a PhD.

For the next 3 years my life was devoted to powdery mildew of black currents and gooseberries, and how they survived the English winter. But by early 1972, I was ready to go! I had never been out of the UK before except once by land to Greece. I had never been in an aeroplane.

The chance to go to the South Pacific seemed an exciting opportunity and certainly more interesting than being in a research station in the UK working on well-investigated temperate crop diseases, which would have been my other option. To work on tropical diseases of taro, considered an orphan crop because it had attracted little attention from the world's scientists, would be a particular challenge, although I did not foresee it at the time as a task of nearly 50 years, and I would never come back to work in England.

Under the contract which I had with the BSIP, my annual starting salary was SBD1800, taxed, and a tax-free gratuity of £1,200 paid in the UK by the Overseas Development Administration. I thought I was well-off as the Solomon Island dollar was more valuable than

[1] The British Solomon Islands Protectorate was established in 1893, principally to control flows of labour, particularly from Malaita, to plantations in Queensland and Fiji, as well as the influx of guns. Initially, it applied to New Georgia, Malaita, Guadalcanal, Nggela and Makira. In 1897 and 1898, Rennell and Bellona, and the Santa Cruz islands of present day Temotu Province, were added. Finally, under the provisions of a Tripartite Convention of 1899 between Germany, the UK and the US, Choiseul, the Shortland Islands and Isabel (previously part of a German New Guinea Protectorate) were incorporated, an exchange for the UK surrendering all rights in Samoa to Germany. The BSIP remained in place until independence in July 1978.

that of the US, and especially as I had spent eight years living off student grants of £325-£1000 a year. For the final six months waiting for an overseas appointment I had been existing on £6.36 a week from Bracknell Labour Exchange! Hardly a princely sum even in those days.

Fig. 1 Map of Solomon Islands and nearby countries. Note the proximity of the Solomon Islands to Papua New Guinea. Bougainville island (top left corner), is the major part of the Autonomous Region of Bougainville of Papua New Guinea. It is only 9 km from Shortland Islands (arrow).

So, when the offer of a position as resident plant pathologist with the Ministry of Agriculture and Lands, Solomon Islands, arrived from ODA, I was ecstatic, although I have to admit now that I was not sure of its exact position, geographically (Fig. 1). Of course, I knew it was in the South Pacific, but not part of an archipelago, which runs from eastern Papua New Guinea. What I did know was that I would be attached to Dala Experimental Station on Malaita[2].

I arrived at Henderson Field airport, just outside Honiara, the country's capital, on the island of Guadalcanal and was met by Derek Taysum, Chief Research Officer. I stayed those first few nights at the Mendana Hotel in temporary prefabricated rooms no longer there, having made way for a car park. In the afternoon, I was whizzed, still jet-lagged (as it was not yet recognised), around town to see Point Cruz wharf, the botanical gardens, which seemed curiously to contain a prison, China Town to shop, the Hibiscus Motel to meet Mrs Blum the owner, as I would stay there in future when visiting Honiara (my pay scale did not rate the up-market Mendana), the Ministry of Agriculture and Lands to meet work colleagues, and Finance to sign forms. I also had to go to an agriculture store to discuss fungicides as they would be needed for plant disease control.

Most of the people met were from England or Australia. There seemed to be few Solomon Islanders in the offices or in town generally. There weren't many cars and trucks on the road either.

Derek was a good guide, and apart from the essential stops, I was introduced to the carnage of the Guadalcanal Campaign of World War II, the fighting on Edson's Ridge, the skirmishes around the Matanikau River where the US and Japanese faced each other for several weeks in September and October 1942, and the final Japanese defeat at the Battle for Henderson Field. There were also many sea battles, too many to recall, except for one during the Battle of Guadalcanal where so many ships and planes were sunk in the waters between that island and Ngella that the area became known as Iron Bottom Sound. It was hard to imagine the horror.

[2] The name was subsequently changed to Dala Research Station as some feared that 'Experimental' might convey that it was the station not the crops that was the experiment!

All this confirmed what I had been told at a week-long course on Solomon Islands at Farnham Castle International Briefing and Conference Centre in 1971 before I left the UK. In a lecture which asked what hobbies are suitable for gentlemen going to Solomon Islands, given by one of the resident staff, reading of the country's WWII history appeared high on the list. We were given the impression that not a lot else of importance had been written. Wives of the gentlemen involved themselves in 'good works', of course.

There was not a mention of Maasina Ruru (corrupted as Marching Rule), the name taken from the Are'are language meaning 'his brother', an anti-colonial movement of non-cooperation whereby Malaitans, and many in the adjacent islands of Guadalcanal and Makira, sought the right to control their own affairs[3]. It began towards the end of WWII and continued until the early 50s when the leaders were released from prison and some demands were met. It was a pivotable time leading to self-determination of Solomon Islands, but the Farnham briefing was silent on its existence!

Nevertheless, Sir John Gutch, former Governor of the Solomon Islands and High Commissioner for the Western Pacific (1955-1961), and Lady Gutch, were there to give an illustrated talk on what it was like to live in Solomon Islands in those days, and what one really did outside of work. Both were charming, and amusing, with Sir John confusing one town for another, and Lady Gutch, gently correcting him: "Oh no, darling, that's not Kirakira, that's Gizo!" Sir John would say "oh, yes, that's right, that's Gizo", chuckle, we would laugh, and he would carry on getting it wrong. There too was the congenial Francis Bugotu who had just completed his MA degree at the University of Lancaster. He and Mike Hamilton who had been involved in developing cooperatives gave more practical suggestions. Francis was to end a distinguished career as Secretary General of the South Pacific Commission, where we met once more several decades later.

Another big plus from Farnham was a briefing on the political situation in Solomon Islands. Yes, it was still a British Protectorate, but the 1960s saw changes that would progress rapidly to independence. A Legislative Council of 1960 became the Governing Council of 1970 with increased numbers of elected members (for the first time) from island constituencies, plus government officials[4].

By the end of two days after arriving in Honiara, I was glad to hear that Derek and I would be leaving for Malaita the following Monday. I was exhausted, and spent much of the weekend catching up on sleep.

Dala, taro and *Phytophthora* blights

At Dala, my job was to work on two *Phytophthora* water moulds: one on taro called taro leaf blight (Fig. 2), and the other on cocoa known as black pod. Under a microscope these two look like fungi, but scientists now know because of their DNA that they are closer to algae. They bear the name oomycetes. But that wasn't all I was supposed to involve myself in. Taro

[3] Solomon Islands Historical Encyclopaedia 1893-1978. http://www.solomonencyclopaedia.net/biogs/E000181b.htm

[4] Later, during my stay, GovCo morphed into the Legislative Assembly of 1974 with a new constitution, a Council of Ministers - Solomon Mamaloni, Chief Minister, another five elected members with ministerial portfolios, plus the Deputy-Governor, Attorney-General and Secretary of Finance. Self-government followed in 1976, and independence in 1978, with Peter Kenilorea as first Prime Minister. Solomon Islands is a constitutional monarchy, with Queen Elizabeth II as Head of State, represented by a Governor-General, based on the UK's Westminster system of government. It is a member of the Commonwealth of Nations.

also had intriguingly unique virus diseases, and there were pathogens of other tropical crops - sweet potato, cassava and yam, not to mention rice, coconuts and oil palm. All these crops as well as their pests were completely new to me.

Taro has sustained populations of the Pacific for thousands of years, grown for its nutritious corms and leaves. It's a starchy food, like the potato. But for most of its history in the Pacific islands it grew without taro leaf blight although, as we will find out, it is highly susceptible to it. Interestingly, my story of the *Phytophthora* blight of taro has some similarities to that on potato.

In the 1840s, *Phytophthora infestans* destroyed the potato crops of Europe and caused famines, and one hundred years later, events of a similar kind took place on the other side of the world, involving taro, the people who depended on it, and its blight, *Phytophthora colocasiae*.

Although the work that I was employed to do in Solomon Islands involved two look-alike pathogens they behaved quite differently, even though they both wreaked havoc on their respective hosts. Both love wind and rain to aid spore dispersal, and they both destroy their hosts at alarming speed. But they differ: the one on cocoa rots the pods containing the important beans - the source of chocolate - whereas the other on taro destroys the leaves (Figs. 2&3), and also the corms (Fig. 4). In their different ways they are both very dangerous: without leaves there can be no greens or starchy corms to eat (Figs. 5&6); without pods there would be no cocoa, a traded commodity worth billions. In different ways, both pathogens challenged people's food security.

Fig. 2 Taro leaf blight. The reaction on a very susceptible variety in Samoa (left); and the underside of a leaf of an equally susceptible variety in Malaita, Solomon Islands (right). The arrow is pointing to an area of white spotting at the margin of the infection where spores form at night. See also Fig. 7 for upper surface. Note, reddish droplets in the centre of the rot; this is sap that has oozed from the damaged leaf and congealed into hard pellets.

And Dala where I worked, what was that like? It was an ideal location for the job: it was isolated, a place to concentrate the mind, and it was wet, ideal for pathogens, but just as important it was relatively well equipped and, for the time, probably the best research station in the entire Pacific.

Fig. 3 The impact of taro leaf blight is to defoliate plants: they have 3 to 4 leaves instead of 6 to 7 on a healthy plant. The plant in the foreground is a blight-tolerant breeders' line, either the "Agriculture taro" from Solomon Islands or a Samoa variety, for comparison. It is a line bred for tolerance to taro leaf blight. The variety in the background with dark leaf stalks is a local susceptibility variety. (Field of Osanti Ludawane, Takwa, north Malaita, 2019. Image kindly provided by Pita Tikai, Kastom Gaden Association).

Fig. 4 A corm cut in half to show the hard dry rot caused by *Phytophthora colocasiae*, the cause of taro leaf blight**.** In Solomon Islands, the rot appears after harvest, presumably from spores infecting damaged corms as the young shoots or suckers are ripped off plants as they are pulled from the ground. Such symptoms have not been reported from other countries, and not all scientists agree that these rots occur. For instance, it has not been seen in Hawaii and recent surveys in Samoa of blight-tolerant taro suggest that it is rare or absent. The question of whether the leaf blight pathogen is corm-borne or not is important and needs to be resolved: it is of concern to biosecurity authorities in countries free from blight, but which import taro from countries where the disease occurs. Recent work by Plant and Food Research, Auckland, New Zealand, funded by ACIAR suggests that the blight-tolerant breeders' lines do not harbour infections in their corms. Another plus from the breeding TaroGen breeding program!

Fig. 5 Taro growing in patches cut from the bush in Solomon Islands. Here, three successive plots have been planted with the oldest near the trees at the back of the photograph. Plots are often separated by logs, or here a low fence. When plants are well-established with 5-6 leaves, the youngest are often taken and cooked for leafy greens. It is an important vegetable throughout Pacific island countries.

Fig. 6 Taro corms (centre) in two piles according to size in the Honiara market. The older leaf stalks and roots have been removed and the corms scraped. It is usual to leave the shoot attached to the corm to preserve self-life. Invariably, buyers will cut off the leaf stalks (which contain the growing point) retaining about a centimetre of corm at the base, and plant them. Elsewhere in the region, the leaf stalks are about 50 cm long, and depending on the country and traditional practices, several are tied together for ease of carrying to and from the market.

The Station was situated about 25 km north of Auki, the only town on the island of Malaita, the most populous island in the country. Dala was on an uplifted coral terrace, above the coastal strip north west of the island. It was established during the late 1950s by Dick Keevil and Ollie Torling of the BSIP Agricultural Department to determine the economic performance of selected perennial and annual crops on the Dala Soil Series, a fairly widespread soil type on Malaita and elsewhere in the country. Cocoa was the main crop of interest at the time and the first trials were established at Dala by Dick Keevil after his transfer to Solomon Islands from Ghana, West Africa, in 1958 , where he had been employed by the British Colonial Service from 1942.

The infrastructure at Dala was adequate for the tasks at hand. There was plenty of land under long-term lease, roads of gravel and grass, sheds for a Land Rover and tools and a small lab – a house as the PWD did not have plans for laboratories! As a small house it ranked lowly in PWD's classification of entitlements: we were allowed an internal toilet, but not a seat! Fortunately, royal visits never made it to Dala, just to Auki.

In 1972, a training centre was built on the Station land for farmer and extension staff courses, and there were houses for senior and junior staff.

The houses were PWD designed: three for senior staff and several more in a 'labour line' for local staff, heads of various crop divisions. Mine was on concrete pillars, mostly with Masonite walls, whereas the other two were on the ground and of more substantial brick; there were kitchens with gas stoves and kerosene fridges, which belched black fumes occasionally and for no reason or when needing new wicks. Removing the soot was a chore! Furniture was provided too. But if there was a lack of any comfort, it was overcome by verandas providing superb views of Dala Bay, wonderful drinking water straight down bamboo pipes off the mountains, four hours of electricity a day, from six o'clock to 10 at night, supplied from two Lister generators, and cool night sea breezes. Such blissful sleep!

And I had Patterson, a cook, trained by Carol Friend, wife of David, the Cocoa Agronomist, whose porridge and stews were renown, although the order served in a day did not always follow English convention for such fare.

Every day the Land Rover went on a mail run to Auki and collected whatever else was required from the stores, so we were kept well provisioned. And for personal transport up and down the coastal road and for moving around the station I bought a motor bike, an off-road model, suited to unsealed roads.

Keeping healthy was no problem either. If any of us, senior or junior staff or labourers, were ill there was always the Anglican Hospital of the Epiphany at Fauaabu, just down the road, with Sister Helen Barrett, a long-time resident of Solomon Islands in charge, assisted by colleagues, Sisters Helen and Pam. The hospital ran a leprosarium nearby. Yes, there were still lepers in the country, and very occasionally we would see people who had had elephantiasis, but both these diseases were near to being eradicated. The problem ones were tuberculosis and malaria. The latter required weekly doses of chloroquine. Mosquitoes were all too common, and there was never a week that went by without at least one of the Solomon Islands' officers or labourers off sick from an attack caused by *Plasmodium vivax* or *P. falciparum*.

Following its brief to assess crops of economic importance, Dala had assembled valuable collections of food, spice and tree crops. Its main function was to undertake research in keeping with the semi-subsistence smallholder agriculture of Solomon Islands. Its staff consisted of both expatriate and local scientists and there was firm support from local communities, many of which supplied the Station's staff needs.

As I arrived, David and Carol left to live at Dodo Creek Research Station outside Honiara. His task was to oversee trials at Black Post, an area of SIG-owned land near Dodo Creek, as part of plans to commercialise the Guadalcanal Plains. David Gollifer was General Crops Agronomist and Officer-in-Charge at Dala, and was already investigating diseases of taro, including taro leaf blight[5], as well as creating a foundation for the development of a spice industry in Solomon Islands built on extensive trials of many potential species.

Although isolated, we received constant flows of visitors, except royal ones. Malaita District Commissioners brought parties of foreign dignitaries to Dala, more often during the UK winter months, offering them a chance to leave Honiara for a day to see tropical crops in a very pleasant setting. Dala had become a flag-ship for rural development in Solomon Islands. But there were also many visitors interested in our research. Derek Taysum, Chief Research Officer came frequently, sometimes with Hector Davison, Director of MAL.

And there were overseas agriculture experts too, including, John Purseglove, the author of two famous books on tropical crops, (who collected wild banana); Robert Cunningham and Roger Smith, natural resource advisors at (the then) ODA; FAO resident representatives from Samoa; Roger Plumb and Andy Dabek , virologists from Rothamsted Experimental Station (now Rothamsted Research), Harpenden, who were backstopping research into taro viruses; Franklyn Martin, USDA, Puerto Rico (who collected yams), several visits from Frank Newhook, University of Auckland (who collaborated on taro and cocoa diseases), and Eric McKenzie, DSIR, New Zealand, who worked on a pathogen check list, all of whom were highly appreciative and supportive of the on-going work at the Station.

Taro leaf blight arrives

Papua New Guinea

Taro leaf blight first spread to Solomon Islands soon after WWII probably arriving in 1946. Scientist Jerry Packard, whose 1970s book *The Bougainville Taro Blight*[6], based on his master's thesis from the University of Hawaii, has done more than anyone to document the spread of the disease at this time. His searches through administration records and interviews of local growers have found evidence of epidemics of taro leaf blight in Papua New Guinea contributing to food shortages and early deaths immediately following the end of the Japanese occupation.

In early 1945, reports started to circulate within the post-war Australian New Guinea Administrative Unit (ANGAU) about a blight in Bougainville that was causing a dieback of

[5] Gollifer DE, JF Brown (1974) Phytophthora leaf blight of *Colocasia esculenta* in the British Solomon Islands. Papua New Guinea Agricultural Journal 25: 6-11.

[6] Packard JC (1975) *The Bougainville taro blight*. Pacific Islands Studies Program. University of Hawaii. Miscellaneous Work Papers.

taro, the like of which had never before been seen by farmers. Some reports by missionaries, however, maintained that it was known in 1942 or even before the war. How the disease got to Bougainville in the first place is unknown. Pere Kokoa, formerly plant pathologist with NARI, LAES, Keravat (and now with NAQIA), says the likelihood is that it arrived from Indonesia during WWII with the movement of plant materials, agreeing with Ed Trujillo that it came from Java to Papua New Guinea via the Philippines[7].

In any case, descriptions of the disease at the time leave no doubt that it was taro leaf blight. A member of the ANGAU wrote of a dark watery spot, increases in size, lesions showing concentric rings, large droplets of pale fluid on the damaged tissue, becoming deep red, leaves that rot away and lesions on the leaf stalks and, finally, plant collapse. Many crop failures were reported.

However, it was not until 1947 that it was identified officially by the Department of Agriculture, Stock and Fisheries, Papua New Guinea, and later confirmed by the Economic Botanist, Department of Agriculture, Fiji[8].

At this point, it is important to understand how taro leaf blight works – that is, its epidemiology. Spores form in the cool early morning as a white fuzz at the margins of brown spots (Fig. 7). This is significant: dew collects the spores from the spots and as it dribbles downwards over the leaf it releases them form secondary infections. Some dew with spores reaches the edge of the leaves and drips over the edge infecting younger leaves below. In this way, the disease ticks over often not doing much harm. Most of the spores are short-lived; they are fragile and by 10 am most if not all have shrivelled in the sun, and have died.

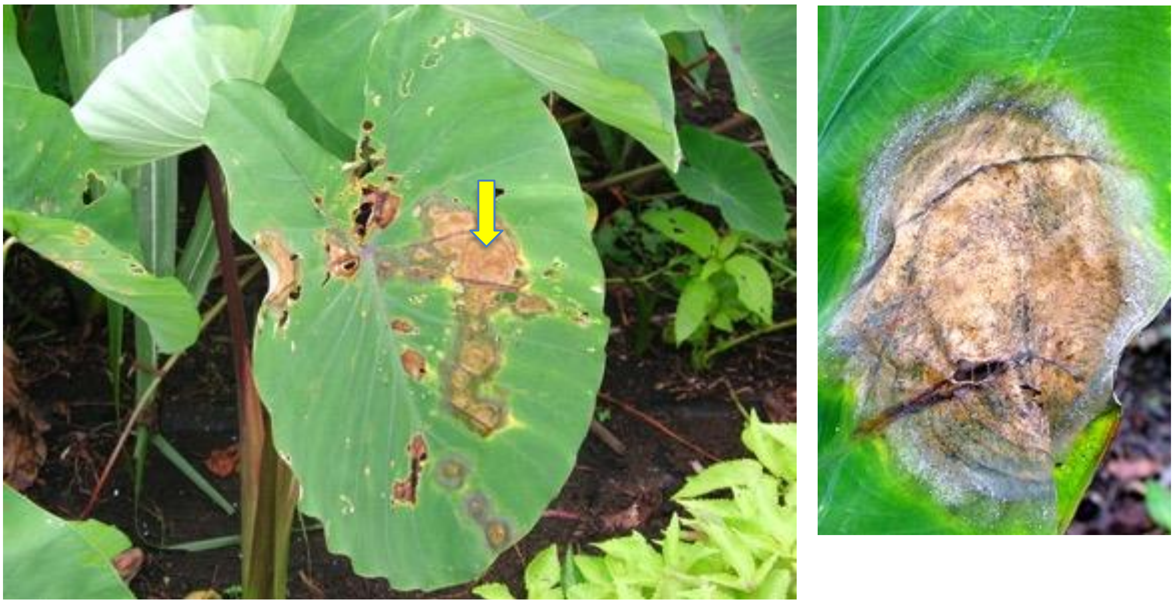

Fig. 7 Spores from the initial infection (arrowed) have dribbled down the leaf in rain or dew and caused secondary infections below (left). The spores develop at night-time appearing clearly as a white halo around the spots in the early morning, especially noticeable on the top of the leaf (right).

[7] Trujillo EE (1967) Diseases of the genus *Colocasia* in the Pacific area and their control. In *Proceedings of the International Symposium on Tropical Root Crops* (pp. 13–18.). St Augustine, Trinidad, 2–8 April 1967. St Augustine: Department of Crop Science, University of the West Indies.

[8] Captain BA O'Connor, ANGAU Entomologist, identified the disease from: Butler EJ, Kulkarni GS (1913) *Colocasia* blight caused by *Phytophthora colocasiae* Rac. Memoirs of the Department of Agriculture in India. Botanic Series 5, No. 4: 233-261.

However, under the right conditions, this slow ticking-over can explode into an epidemic. All it needs is three to four consecutive days of rain so that the spores remain alive from one day to the next, and there is wind to spread them. But there is more.

Phytophthoras and their relatives have a trick that is unique to their group. The contents of each rounds up into 15-20 tiny mobile spores, and when these are released each is capable of causing an infection. The original spores, carried by wind and rain, land on a leaf, burst open to discharge the swimming spores, which germinate within a few minutes, infect and rot the leaf. The effect is swift and dramatic. Within a few days every leaf hangs down dead or dying. You can smell the decay in a garden from a distance, especially in the still of the early morning.

In the 1940s, when the disease first struck Papua New Guinea and Solomon Islands the effect of an epidemic would have been frightening to growers. More frightening perhaps in cultures where spirits are capable of retribution for present or unknown past breaches of lore or custom.

It is very likely that the taro varieties would have been extremely susceptible to taro leaf blight. There is a reason for this. Taro leaf blight would have been what scientists call a 're-encounter disease'. This needs some explanation.

Taro and *Phytophthora* leaf blight probably evolved together in an evolutionary arms race with neither the one nor the other having the upper hand. Where this early association of taro and its blight occurred is unknown, but north-eastern India, south-western China, northern Thailand and Myanmar is possible as this is the likely area where the ancestor of taro originated[9]. Spread from here through Southeast Asia and Papua New Guinea to Australia was likely by seed dispersed by birds and small mammals. DNA analysis suggests that the wild populations that formed along the migration are genetically diverse, later providing varieties for domestication, selected for their starch, medicinal properties or as leafy greens.

However, somewhere along the way, taro and blight became separated, with each continuing to evolve separately. This may have occurred in Indonesia as we believe the island of New Guinea was free of the pathogen until the Second World War. But wherever it occurred, taro lost its tolerance to taro leaf blight, and when the two came together again, as occurred in the Pacific, the effect on taro was catastrophic. By then it had become extremely susceptible to the disease. Epidemics occurred, and the people who saw these for the first time would have been deeply shocked, and no doubt scared for their survival.

The effect on the Bougainville population is disputed, but it seems probable that there were unusually high death rates after the war and in the following years. How much these could be ascribed to trauma left over from the occupation and wartime experiences of the population combined with the psychological effect of a lack of taro is not clear. But there is evidence that it was impossible for most villages to return to subsistence after the war. Gardens and villages were abandoned due to Allied bombing of Japanese positions, or gardens were plundered by starving Japanese troops[10].

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[9] Mathews PJ (2014) On the trail of taro: An Exploration of Natural and Cultural history. Senri Ethnological Studies 88. National Museum of Ethnology, Senri Expo Park, Suita, Osaka, Japan. 429 pp.
[10] Wesley-Smith T,, Ogan E (1992) Copper class, and crisis: changing relations of production in Bougainville. The Contemporary Pacific 4(2). Honolulu, Hawaii.

Correspondence at the time from churches and the Department of District Services and Native Affairs in Papua New Guinea reported by Packard leave no doubt that there was malnutrition and in some cases starvation among the local populations too.

For Pacific islanders, taro was (and in many places remains) not just a staple crop like potato, rice or wheat in other parts of the world, but held a sacred, totemistic place in their culture. It could never be absent at significant events, feasts and the like. It was part of the fabric of society and prominent in rituals and ceremonies. If it was not grown, people felt the loss profoundly, and it translated into a feeling of enfeeblement, 'softness', and reduced stamina. The Papua New Guinea administration of the time recognised this situation.

And so, attempts to investigate the disease began in earnest in Bougainville in 1947, but due to lack of resources they faded and by the end of 1949 it was generally accepted by the administration, and more reluctantly by farmers, that a change of crop was the only practical solution. Taro no longer delivered sufficient food for the people of Bougainville, and sweet potato, and to a lesser extent cassava, other aroids such as giant taro, giant swamp taro and *Xanthosoma*, yams, became the staple foods.

Solomon Islands

Similar reports of crop failure to those of Bougainville were first reported from Shortland Islands in Solomon Islands in December 1946. The Shortlands are only a few kilometres from the southern coast of Bougainville (Fig. 1). Packard documents the Department of Agriculture's drastic remedy to destroy all taro on Shortland Islands in an attempt to eradicate the disease, with no new plantings for six months[11].

This solution may have been scientifically sound, but understandably it was not one wholeheartedly supported by growers; there was not only the obvious effect on food and nutritional security, but also the loss of treasured culturally important taro varieties.

In the event, the pathogen was not eradicated, and taro leaf blight gradually made its way through the archipelago, probably in wind-driven rain and/or on planting material, reaching Choiseul in 1948/49 and Malaita in the early 1950s[12]. It went on to Guadalcanal and Makira, but the more distant Temotu Province remained free from infection[13]. Today, only one island in that province has taro leaf blight, and that is the island of Tikopia. In the 1950s, people from Tikopia were resettled in the Russell Islands, north of Guadalcanal[14]. It is likely that people returning to Tikopia either to stay or visit took taro with its pathogen.

[11] Packard also reports that Shortland Islands' headmen and Catholic clergy suggested the disease was not new, although occasionally serious, in an attempt to protect their treasured varieties from being eradicated; this was not true, and most people there associated with Japanese occupation of the islands.
[12] Attributed to Frazer IL (1973) *To'ambaita Report*: A Study of Socio-Economic Change in North-West Malaita. Wellington, NZ: Department of Geography, Victoria University, by Akin DW (2013) Colonialism, Maasina Rule, and the Origins of Malaitan Kastom. Pacific Islands Monograph Series 26. Center for Pacific Islands Studies, School of Pacific and Asian Studies, University of Hawai'i. Manoa. University of Hawai'i Press Honolulu. 527 pp.
[13] Temotu Province is the most eastern part of the country, made up of the large island of Nendo, the Reef Islands and a number of small isolated islands, one of which is Tikopia, populated by people of Polynesia descent.
[14] Tikopia and other small islands were overcrowded, plus there was a severe cyclone in 1952, resulting in a resettlement scheme to Yandina where Levers Pacific Plantations Pty. Ltd., provided land. Later, in the 1960s people went to Makira. See Tikopia and Santa Anna Resettlement Scheme. Solomon Islands Historical Encyclopedia 1893-1978. http://www.solomonencyclopaedia.net/biogs/E000311b.htm.
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From this time until the Ministry of Agriculture and Lands took note of the disease in the late 60s, there is little known about the blight and its impact on taro in Solomon Islands. There was probably a loss of the most susceptible varieties, especially on the coast where the environment is more conducive to epidemics of the diseases than in the cooler inland areas.

However, population movements from the mountainous interior to the coast that accelerated after the war meant that taro could no longer support the people to the extent required. Population growth, poor soils, and taro leaf blight conspired to force a change of food crop. Sweet potato became the food crop staple of choice as had already occurred in Bougainville previously. In the agricultural census of the early 1970s sweet potato was found to be about 65% of the area given to root crops production[15].

Fungicides not plant breeding

The question in the early 1970s then was what could be done about the disease. Was it possible to turn things around and reinstate the crop to its former glory? It was a nutritionally important crop, one of high cultural significance, and only one of four major root crops where the leaves are also a major food, in the Pacific islands at least However, it was the fact that taro was increasingly in demand at major markets, for instance, those of Auki and Honiara, that caught the attention of decision makers. It was fast becoming an important commodity showing its potential as a commercial crop.

But there were drawbacks to the work we were charged to do. Senior administrators of the Ministry of Agriculture and Lands were certain that the only answer to taro leaf blight was to control it with fungicides. It was told to us clearly that that was to be the direction of research. Changing the ways people grew the crop, perhaps using wider spacing, or removing infected leaves – so-called cultural practices - were not to be entertained.

And certainly not taro breeding.

This was unfortunate as about this time there had been a breakthrough from the Caribbean which meant that breeding was a possibility. Researchers at the University of the West Indies had discovered that a single spray of gibberellic acid induced flowering[16]. Gibberellic acid is a naturally-occurring plant hormone that stimulates stem and root growth, and can break seed dormancy. To make taro flower, all that was needed was one spray at about two months, and flowers would appear in about a month to six weeks, pollen would form, allowing pollination and viable seed formation.

When David Gollifer and I explained the potential of this result to the Chief Research Officer and Director of Agriculture we were left in little doubt where the direction of research should be. If it was not fungicides then it would be difficult to support the need for a plant pathologist. So be it (Fig. 8)!

At Dala, some work had already been done by David and a consultant plant pathologist, the late John Brown of the University of New England, Armidale, before I arrived. They had used the fungicides available – copper and mancozeb – and found that the disease could be

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[15] Eele GJ (1978) 1974-1975 agricultural statistics survey: a sample survey of Solomon Islands smallholder agriculture. Ministry of Finance, Statistics Office. Ministry of Agriculture and Lands. 98 pp.

[16] Alamu S, McDavid CR (1978) Promotion of flowering in edible aroids by gibberellic acid. Tropical Agriculture (Trinidad) 55(1): 81-86.

managed up to a point, although it was totally uneconomic as applications were needed weekly and the gain was not substantial. With advice from Frank Newhook, who was visiting annually with John Cole his technician, we used a mist blower instead of a hydraulic knapsack sprayer to apply the same fungicides. Application were faster, and gains in terms of corm yields were substantially greater, but costs were even greater!

Fig. 8 Fungicides not plant breeding was the order of the day! Here the author, at a considerably younger age, demonstrates everything not to wear when applying a pesticide with a mistblower. Note the total lack of PPE (personal protective equipment). Plant breeding would have been so much safer!

Applications of fungicide every one to two weeks stopped leaf blight infections, and also prevented post-harvest rots. Control was excellent. But we were dealing with a subsistence crop only sold on local markets when there was surplus to household needs. Costs were far too great, never mind the problems inherent in using pesticides, which include supplies of chemicals, complicated application, maintenance of equipment, and the dangers to human health and the environment. Also, with copper treatments, two-spotted mite outbreaks occurred as the copper was, presumably, toxic to their natural enemies. We had exchanged one pest for another!

It was a missed opportunity not to get into plant breeding, but understandable in terms of the mantra of the time that pesticides were the panacea to managing pests and diseases, and them alone. After all, this was only a decade after Rachel Carson's Silent Spring[17], and the environmental movement was still in its infancy. Integrated pest management (or IPM) was not a phrase on the tip of anyone's tongue. Furthermore, the complacency that we showed to pesticides in those days is extraordinary by today's standards. My house was sprayed inside and out every six months with DDT, a program sanctioned by the WHO, and no one thought anything of it. The concern was more on the impact of the spraying on the number of cases of malaria – were they going up or down - and how to feed your cat butter to prevent it from being the program's collateral damage!

[17] Carson R (1962) Silent Spring. Houghton Mifflin.

So I carried on spraying taro against taro leaf blight, searched for the vectors of the taro virus diseases, *alomae* and *bobone*[18] with David, screened cocoa varieties for black pod and branch canker, and looked into a leaf blackening and dieback of yam that caused unusual symptoms. Yam growers would say the yams had been struck by lightning, so quickly the leaves were turned black in response to millions of spores deposited on their surfaces during heavy and prolonged rains, and then exposed to sunlight. The disease was novel and later investigated by one of Frank's students, Janet Winch, who visited Solomon Islands after we had moved to Dodo Creek[19].

There was also a major problem with imported oil palm seeds. One of the batches of seed sent from estates in West Africa to start the Commonwealth Development Corporation[20]-led industry on the Guadalcanal Plains arrived partly rotten. Unfortunately, I was sent seed and found *Fusarium oxysporum*, a fungus that is common everywhere, but which has strains causing wilt diseases to specific crops, one of which infects oil palms. There was no time to do tests. The question was whether to plant the seeds or destroy them. I was for destruction. The difficulty was that by the time of my discovery and its confirmation by CMI, Kew, the seeds had been planted in the nursery. To destroy the seeds meant destroying several hundred large polybags of soil. The fires used a lot of trees and were burning for weeks!

After two years I went on leave. It was time. But just before I did, I visited Papua New Guinea and toured with Dorothy Shaw who had been there as plant pathologist for 25 years! I was able to share with Dorothy what David and I had discovered in Solomon Islands[21]. The situation in PNG was exactly that of Solomon Islands: taro leaf blight and the virus diseases were everywhere, and taro could no longer sustain rapidly increasing populations in coastal areas: sweet potato was fast becoming the dominant subsistence food as had occurred in the highlands where it began replacing taro some 350 years previously[22].

My leave started in August 1974, and this is where serendipity played a part in my story. This is where virus and taro leaf blight research came together.

First piece of luck: Bangkok taro

I went back to England via Bangkok where I had a stopover. On the way from the airport to the city, I noticed taro was growing wild next to deep canals alongside the road. I had never seen anything like it. Even from the taxi I could see that it was flowering, and there were bright red fruits. If there were fruits, there were seeds!

If there were seeds, I mused, perhaps they would be healthy, as often seeds are a filter for viruses. If free of viruses, we could use them in transmission tests to find out which of the

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18 *Alomae* means 'taro dies' and *bobone* means 'plants grows small'; these are names given to diseases of taro in the Kwara'ae language, north Malaita. We know that both are caused by viruses, but still not sure which.

19 Winch JE, Newhook FJ, Jackson GVH, Cole JS (1984) Studies of *Colletotrichum gloeosporioides* disease on yam, *Dioscorea alata*, in Solomon Islands. Plant Pathology 33(4): 467-477.

20 Later the CDC Group plc., a development finance institution of the British Government.

21 Shaw DE, Plumb RT, Jackson GVH (1979) Virus diseases of taro (*Colocasia esculenta*) and *Xanthosoma* sp. in Papua New Guinea. Papua New Guinea Agricultural Journal 30: 71–97.

22 Bourke RM (2009). History of agriculture in Papua New Guinea. In Bourke R, Harwood T (eds.). Food and Agriculture in Papua New Guinea. Canberra: ANU Press, Canberra. doi:10.22459/fapng.08.2009. ISBN 978-1-921536-60-1.

viruses of taro in Solomon Islands - and there are many - were causing the diseases *alomae* and *bobone*. With that information might come the knowledge of which insects were spreading the diseases, and in turn the possibility of control.

This was an unexpected turn of events. I stopped the taxi where some women were clearing taro and water hyacinth from the canal and, with gestures and the help of the taxi driver, asked for a plant with flowers (Fig. 9). This was brought, and then another with fruits. I gave the perplexed women something for their troubles, took the seed to Bangkok, cleaned it from its fleshy pulp, and in the UK presented the seed to Roger Plumb at Rothamsted Research. Roger was helping us sort out the viruses and was as excited with the find as I. No one had reported on taro seed up till then, and neither he nor I knew how to grow them.

Fig. 9 Wild taro growing beside the road from the airport to Bangkok city in August 1974. Plants that were flowering were photographed, red ripe seed heads collected, and the seed placed in tissue culture at Rothamsted Research, and sent to Solomon Islands.

After a short stop in the UK, I went on to the University of California, Irvine, where I studied tissue culture with Ernie Ball and Joe Arditti, with support from the Commonwealth Foundation. Ernie was one of the pioneers of orchid tissue culture and with his help we showed it was possible to use shoot-tip culture techniques to produce healthy plants from those infected by *alomae*, the worst of the Solomon Islands' virus diseases. This was not the first time that tissue culture had been applied to taro to rid it of viruses; taro had been freed from *Taro dasheen mosaic virus* a year or so before in Florida, but it was a first to show that the technique worked on the lethal viruses of Solomon Islands. We also found that we could easily grow taro seed, but later found that it had been done previously in India, Japan, Hawaii, and also by David at Dala as reported in his Ph.D thesis[23]. David's success was

[23] Gollifer DE (1976) Factors affecting the production of taro, *Colocasia esculenta* in the Solomon Islands. Ph.D thesis, Reading University. 179 pp.

unknown to me at the time as a copy of his thesis never made its way to Solomon Islands, more's the pity.

Second piece of luck: It's bad - Dala closes

After six months, I was back at Dala in Solomon Islands with my tissue cultures but not with seed. That was still at Rothamsted being checked for viruses. But then things took an unexpected turn for the worse. The Under Secretary, Morris Vickers, wrote to me soon after arriving saying that the Government of the British Solomon Islands had decided to close Dala Research Station. I should proceed cautiously as he did not want protests to break out when local communities heard the news.

Instantly, I flew to Honiara to argue the case with the Permanent Secretary (Bob Finnimore), Head of Extension (Eric Mason), Entomologist (Jim Stapley), Administrative Officer (John Howarth) and Morris Vickers. David Friend the Cocoa Agronomist was at the meeting too. He still had large important spacing trials at Dala.

Only David and I spoke in support of staying the decision to close the station while the economics of it were better considered. I argued that if any research station was to be sacrificed it should be the one servicing international companies of the Guadalcanal Plains: Commonwealth Development Corporation - oil palms; Lever Pacific Plantations Pty. Ltd. (a subsidiary of Unilever) - coconuts and cocoa; and Mindoro International Corporation (which had bought Guadalcanal Plains Ltd.) - rice and cattle. Dala was doing work pertinent to 99% of the country's population.

These companies, in my view, were wealthy enough to take care of their own needs. And anyway, Lever Pacific Plantation was already in partnership with the Solomon Islands Government hosting the Joint Coconut Research Scheme in Yandina; CDC was establishing its own research unit; and Mindoro International Corp. had sold out to C. Brewer & Co, a company specialising in sugarcane and macadamia nuts in Hawaii - one of Hawaii's largest corporate landholders. After taking ownership of the rice company in Solomon Islands, Brewers Solomon Agriculture Ltd., as the local entity was called, established its own research division in 1975.

But there was to be no discussion, I was told; a decision had been made. It was immaterial that the cocoa trials were extensive - one alone was a10 acre spacing trial - and predicted to yield sufficient beans to run the station the following year and into the future. A grand gesture was expected, and Dala Research Station was to be offered. The country did not need two research stations.

We never understood the decision to close Dala, and to this day the reason remains a mystery. Poor relations between extension and research might have played a part: Eric Mason argued to leave the extension service untouched, and there was no one of his seniority to present an opposing view - the Chief of Research, Derek Taysum, was on leave. I had had a falling out with Bob Finnimore when he was District Commissioner, Malaita, and maybe that played a part in the thinking, but that is hard to imagine. We'll never know. There was no opposition from the ODA, UK; Roger Smith, the ODA Natural Resources Advisor at the time, washed his hands of the situation. I saw correspondence from him that said it was a matter for the British Solomon Islands Government. So we can only suppose the closure was done with his tacit approval.

Not only was Dala to be closed, but it was likely that the post of Chief Research Officer would be abolished and as well as that of Senior Agronomist. I am sure if I had been on leave, the position of plant pathologist would have gone too!

And so, Festus Haggai (who was managing tree crops research) and I packed up the station the best we could, saving much of the spice crops and root and tuber collections by giving out huge numbers of coconut baskets full of planting materials to missions, schools and farmers[24].

And so we headed for Guadalcanal. It was a sombre time.

I had the best part of my second 2-year contact still to run so I did the best I could to start over at Dodo Creek. Frank Newhook was scheduled to return and it seemed sensible to continue to the work on yam dieback and also sweet potato diseases. But I thought better than trying to pick up the work on taro or cocoa: it was logistically difficult and a constant reminder of Dala.

The decision to close Dala still rankles to this day. It was utter folly by people who had little idea of what they were doing, or they did, but did not bother. Feelings were so great that in 2014, David and I wrote the story of its closure for a UK journal[25]. I think we were generous in our telling.

Here is part of what we said.

> *Why did it happen when the Station was doing such valuable work? Even now, the actual reasons and the professed reasons remain hazy, but one has to remember that at the time, the previous system of administration based on colonial-style commissioners and district officers was being dismantled and the other, with locally elected representatives on the Westminster model was being erected. There was bound to be some confusion and as a result, some odd decision-making.*
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> *But more importantly, for our story, priority was given to large scale commercial agriculture on the Guadalcanal Plains with its extensive flat, fertile alluvial soils, and atypically low rainfall (for Solomon Islands), with a marked dry season. There were expanding oil palm plantations, irrigated rice fields, considerations of coconut and cocoa planting and cattle ranching. The Guadalcanal Plains were seen as a powerhouse of the economy, along with forestry and fisheries. To service these developments on the Guadalcanal Plains, Dodo Creek Research Station at Red Beach, about 10 km from Honiara, the capital, was built in 1972.*
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> *At Dodo there were modern labs and staff from various disciplines: soils, agronomy, entomology, and the office of the Chief Research Officer. There was a library, and*

[24] We did not save David's prize Granada nutmegs which were thought to have potential for Solomon Islands. They were not yet bearing. The trees were removed when the traditional landowner not knowing there potential used the *Leucaena* shade for cocoa. Who could blame him?
[25] Gollifer D, Jackson G (2014) The close of Dala Research Station, Solomon Islands. Tropical Agriculture Association 23, 64-66.

precious collections of insects going back decades. There was 24-hour electricity too. It was all very modern, but its interests were quite distinct from those of Dala.

When in 1975 the Ministry of Finance told all departments to rationalize and cut back spending this caused a dilemma for the Department of Agriculture and Lands. The word was that a 'grand gesture' was needed and that 'cheese paring' was not an option, although that was unlikely to have been a directive from Finance.

It is also important to know that the Director of Agriculture had retired and gone back to the UK, the Chief Research Officer was on leave, and the Officer in Charge/Agronomist at Dala had left during 1975, but was due to be replaced by another ODA Agronomist. This was significant as it left decision making to those in Honiara and Dodo Creek. The only senior staff person at Dala was me!

The head of the agriculture now PS had no expertise in agriculture – he was a former district commissioner - and the US who was the most senior technocrat had only recently arrived from the UK and consequently knew little about Dala and its excellence, or the needs of the country for that matter. Furthermore, I was not consulted as officer-in-charge of Dala. The agricultural extension service was to be preserved at all cost, as was Dodo Creek Research Station. Dala was thus offered up in the expectation that Finance would reject the idea as being preposterous, or so that was the story.

Unsurprisingly, it was accepted, and that was the end of Dala Research Station. Not only the research station, but also the positions of Chief Research Officer and Agronomist!

In 1976, the remaining senior staff members from Dala (Plant Pathologist, Station Manager and crop managers) were transferred to Dodo Creek Research Station on Guadalcanal together with files, records and as many of the collections as possible. All of the foreman and labourers, around 60, from neighbouring villages were dismissed. Dodo Creek Research Station had no land attached to it, but thanks to the generosity of the Catholic Church, land was made available at St Martins just down the road for remnants of the Dala collections and trials. [Later, all the files from Dala were lost when Dodo Creek was burned down during the so-called Ethnic Tension (1998-2003)].

So, was the loss of Dala important? Well, looking back from a vantage point of nearly 50 years, there is a great deal of evidence to suggest that it was.

First and foremost, the country would have a research station today. Although no one could have forecast the loss of Dodo Creek, the present situation is that there is no agriculture research station in the country, and very little research is possible as there are few staff with research expertise. If Dala had continued, it would not have been destroyed in the Ethnic Tension which saw fighting only on Guadalcanal.

True, there have been some attempts to resurrect agricultural research on Malaita and in other provinces since the closure of Dala. In the late 1970s the Government obtained a loan from ADB to do so, with field experiment stations mushrooming around the country. But it was really too many, too late, and they were always going to be too *expensive to maintain. In the event, they were mostly abandoned during the Ethnic Tension.*

It could be argued that Dala would have gone the same way, but evidence suggests differently. Malaita Province still holds the lease for Dala and it and the local people preserved the Training Centre, and that flourishes today. The present Government of Solomon Islands is trying to resurrect the field experiments stations; not only will it be costly, but also trained staff will be needed.

Secondly, ground-breaking research was done at Dala even though conditions were far from ideal. It was always possible to collaborate with centres of excellence elsewhere. Research into spice crops was done with support from the then Tropical Products Institute, London. Viruses of taro were investigated in collaboration with Rothamsted Experimental, UK, and two virus particles new to science were identified as well as their vectors. Work was also done to control taro leaf blight together with institutes in New Zealand and the UK, which laid the groundwork for successful breeding in the 1990s for resistance in Samoa and Papua New Guinea. And a similar collaborative strategy was developed for pests and diseases of cocoa, yam, sweetpotato and cassava. Unfortunately, much of this work stopped with Dala's closure as it was difficult to do it on the Guadalcanal Plains where the agro-ecological conditions were so different, and/or the pests and diseases were absent.

Thirdly, and importantly, the closure of Dala eliminated the work on minor cash crops, which are potentially so important to the semi-subsistence economy of Solomon Islands. Much work had been done on chillies and an embryonic industry was in the making, and other spices - cardamom, turmeric, ginger, nutmeg, allspice, cinnamon and cloves - were under investigation. All this stopped and, worse, the collections were lost. The citrus collections went the same way, although those of durian and rambutan were saved when, later, the Government employed a tree crops agronomist.

Fourthly, there is an economic consideration of having a research station on Malaita, a station that once employed over 60 staff and labourers from the surrounding villages. Malaita with a population of over 150,000 is the most populated island in the country. Since the Ethnic Tension, Malaitans are excluded as contract labour for the oil palm plantation on the Guadalcanal Plains, and the flow of remittances to Malaita has ceased. Likewise, they no longer come from Lever Solomon Ltd., Yandina where the commercial estates have been abandoned due to labour disputes.

Lastly, did the closure of Dala Research Station actually save money? Presumably it did in the immediate years after closure, but the more interesting question is what revenue did it sacrifice? The price of cocoa was unusually high in 1976, although it did decline thereafter. At the time we did the economic calculations and concluded that the savings would have been minimal over the years because of the volume of cocoa that the station was producing. In 1976, a 10 acre (4 ha) spacing trial was coming into bearing, and added to progeny and fertilizer trials already yielding, sales of dry beans would have made substantial additions to Government revenue, and would have paid labour costs, as well as infrastructure and vehicle maintenance. The expatriate costs were mostly borne by ODA. Revenue would also have come from the hybrid coconut trials established to determine the long-term effects of potash applications on palms growing on the Dala soils.

Whatever the reasons behind the closure of Dala Research Station, it is obvious that it was a hasty decision, made with considerable lack of foresight. It was a colossal blunder, one that has cost Solomon Islands far more than the paltry savings that were offered up at the time.

It also greatly hindered the work on taro leaf blight, my reason for being there in the first place.

Third piece of luck: We start to breed taro

Solomon Islands

Because of the move, when the Bangkok taro seeds finally arrived from Rothamsted Research, they came to Dodo Creek, not Dala. Not only was I trying to find out what to do – the station had no land for trials – but even if I wanted to work on taro it was now difficult. Apart from lack of land, it was not taro country: the Guadalcanal Plains have a long dry season mid-year when if taro grows at all, it does so poorly. We found that under stress it succumbed to a root rot disease, and also there were a lot of taro beetles that bored in the corms, making them inedible. Consequently, my interest in taro, taro leaf blight and virus transmissions faded, and I started to work on other things.

"What shall I do with the plants?", asked Moses Pelomo, my assistant research officer when the seedlings arrived in tissue culture. As I recall I suggested politely where they might be planted, or thrown away! But Moses took no notice of me, deflasked them, transferred the seedlings to our screenhouse and later planted them aside Ndodo Creek near our lab complex. Luckily, it was the wet season and they grew well. But there was more luck to be had. Moses had planted some local taro, a variety called Akalomamale (meaning the devil scratches!) beside the Bangkok seedlings and, as they matured, they became infected with taro leaf blight, but the Bangkok seedlings remained healthy.

We had resistant plants. Our interest in taro revived! This was an opportunity that could not be missed, and because we now had entomologist Jim Stapley as Chief Research Officer, who was also interested in taro, especially *Papuana* beetles, there was no impediment to breeding.

Land was found first at St Martin's Rural Training Centre & Chaplaincy, Tenaru, and later at St Joseph College nearby. It was cleared of used and unused mortar shells, hand grenades and other ordnance left from WWII, drains were dug, and funds obtained from the International Foundation for Science, Stockholm, for a screenhouse and a pickup truck, with the support of James Roni, Permanent Secretary.

However, there was a hitch. I had been taken to task for requesting funds from IFS without going through official channels, and I was not allowed to take delivery of the vehicle, even though it had been sought in James' name. Unfortunately, James had left MAL to take up work in the private sector, and it was now questioned why plant pathology should have its own vehicle. The truck should be made available to all research sections through the PWD. The impasse lasted some months, until a most unexpected event occurred.

Coconut seedlings in plastic bags in the nursery of Levers Pacific Plantations, Yandina, Russell Islands, started to rot at the junction between the base of the leaves and the seednut causing them to topple (Fig. 10). Identifications by Eric McKenzie found that a toadstool-forming fungus was the cause, *Marasmiellus cocophilus*. This was later confirmed by David Pegler from Kew Gardens, UK, who first described the fungus from Kenya and Tanzania, the only places in the world where it was known previously. What was alarming to those in Solomon Islands was that this fungus went by the name lethal bole rot, and scientific papers said it was capable of killing seedlings and mature palms.

This caused a huge concern as Levers was just about to plant their lands on the Guadalcanal Plains with hybrid coconuts and cocoa from seed gardens in Yandina. They were restrained from doing so by a SIG quarantine embargo to prevent the movement of *M. cocophillus* from Yandina to other islands of the country.

As plant pathologist, I had to immediately investigate the problem, and for that I needed a vehicle. The IFS Toyota truck was duly delivered to Dodo Creek Research Station, and my work now concerned coconuts as well as taro.

Fig. 10 Coconut seedling in the nursery at Levers Pacific Plantation, Yandina (left), were struck by a rare boll rot disease (right) only recorded previously from East Africa. Stems broke at the junction between petioles and top of the seednut. Such was the need to find a cure, a vehicle donated IFS for taro research was released to the plant pathology section.

On the taro front, the screenhouse was built at Dodo Creek Research Station, and seedlings were grown from crosses between the Bangkok taro and local varieties (Fig. 11) and transferred to Dala, Malaita, for testing against taro leaf blight (Fig. 12).

The first cross we made was Bangkok x Akalomamale, and from the single fruit we grew about 30 seedlings for evaluation[26]. Moses and I had no idea of the genetics of resistance to taro leaf blight. We would know that only by making the crosses, testing the progeny and by analysing the ratios we found.

Of the 30 plants at Dala, the majority were immune to infection, except for a few that showed spots on the older leaves. I cannot remember the numbers now, but it was small. The presence of a few susceptible plants meant that the genetics of resistance to taro leaf blight of Bangkok was probably more complex than we thought. More than a single dominant gene.

[26] Jackson GVH, Pelomo PM (1980) Breeding for resistance to diseases of taro, *Colocasia esculenta* in Solomon Islands. International Symposium on Taro and Cocoyam. Visayas State College of Agriculture, Baybay, Leyte. International Foundation for Science. Provisional Report 5: 287-298.

However, the pedigree of the hybrids was to cause yet another setback, which dampened our initial enthusiasm. FAO got wind of the work that we were doing and a senior plant protection officer in Rome was critical, and this was enough to stop the work.

Upon hearing about the breeding program, and that it was based on the resistance of a wild variety, FAO assumed that the resistance was most likely a single dominant gene, and this had potentially dangerous consequences. If resistant plants were bred using Bangkok and distributed to farmers there was a chance that over time the resistance would fail. This could happen if strains of blight present in the *Phytophthora* population grew at the expense of others. If that occurred and if farmers had become dependent on the new hybrid varieties, their failure from taro leaf blight might result in a food crisis, or so it was assumed.

Fig. 11 With IFS support, a screenhouse was built, crosses between the Bangkok variety and local cultivars made, and seedling grown, before being taken to Malaita for testing against taro leaf blight. The research staff in the photograph are (from the left): Davidson Tua, Ruth Liloqula, and Richard Ubua.

In theory, the criticism from FAO was valid, but it was unwarranted as there was no evidence for the type of resistance they feared in the Bangkok variety. We had shown in the first crosses that the ratios of immune to susceptible plants meant that there was probably more than one gene involved in taro leaf blight resistance, and as long as we did not use immune plants as parents we could use the Bangkok taro safely. Further, there is a test that can be done to check if immunity existed in the plants selected, and this is explained later. Nevertheless, FAO's view was a setback. We did not want to be accused of a disservice to humankind! A decision was made to stop breeding taro, unless we could sort out the matter.

At about this time, there was a sudden marked interest in root crops in the wider Pacific region. UNDP had accepted in principal to support a regional project to deal with constraints on the production and development of root crops in the Pacific. FAO with SPC arranged a five-week, nine country, pre-project appraisal mission throughout the region to gauge the status of root crop and needs. At the end of the mission, consultants and country representatives met in Fiji to discuss current research activities and national priorities[27].

Fig. 12 The first hybrids between the Bangkok and a Solomon Island variety were grown out on land previously occupied by Dala Research Station. Malaita Province had retained the lease of the former research station, and because of that the plant pathology section was able to keep staff there. The landowners were generous in their support, allowing land to be used for root crop experiments and showing interest in the work.

In a paper presented at the meeting, Keith Templeton and Michel Lambert from FAO and SPC, respectively, gave special mention of the work done on viruses of taro in Solomon Islands. Not only were the diseases serious for that country but held a risk for the region because of possibility of their transfer in infected plants. Their idea was to employ a virologist to continue the work, as well as to develop tissue culture to provide virus-indexed plants which would be healthy and, hopefully, resistant to the diseases. They saw the tissue culture aspects being done outside the region because of quarantine concerns, and the need for sophisticated equipment. It would provide an intermediate station for the future introduction of all root crops.

As we know, these aspects of their project design did not eventuate. The region had to wait for another decade and another UNDP/FAO project. Nevertheless, a regional root crop project, *Root Crops Development in the Pacific* (RAS/74/017), did begin, based first in Samoa, and later Fiji[28].

Rather ironically, Basil Williams, the team leader was keen to support taro breeding for taro leaf blight tolerance in Solomon Islands using the Bangkok variety, and under the project a UNDP volunteer, Zaheer Patel, who had previously worked as a maize breeder with Pioneer Seeds India Pvt. Ltd., was assigned to Solomon Islands. Basil did not take the view of FAO that the use of Bangkok would necessarily be detrimental and, anyway, there was no other

[27] SPC (1977) Regional meeting on the production of root crops (24-29 October 1975, Suva, Fiji). Technical Paper No. 174. South Pacific Commission, Noumea, New Caledonia.
[28] This project became Strengthening Plant Protection and Root Crops Development in the South Pacific (RAS/83/001) in 1983, based in Fiji.

choice. He designed a program to cross wild-type Bangkok to local varieties, just as we had done previously, and then back-cross the progeny continuously to favourite local varieties to improve their corm yield and quality. The same strategy was to be used successfully in Papua New Guinea later.

The hybrids Zaheer created had high blight resistance, but they were not immune. They also had runners which farmers do not find appealing, small corms and were acrid. Selections were made, leading to further backcrosses to improve their quality. This strategy worked well, but today there is only one survivor, LA16, known locally as ‘Agriculture taro’ (Fig. 13). It can still be found in people’s gardens around Takwa Catholic Mission, north Malaita. It has tolerance to taro leaf blight and is somewhat tolerant to the lethal virus disease, *alomae*. After 40 years, its resistance to taro leaf blight has not been broken.

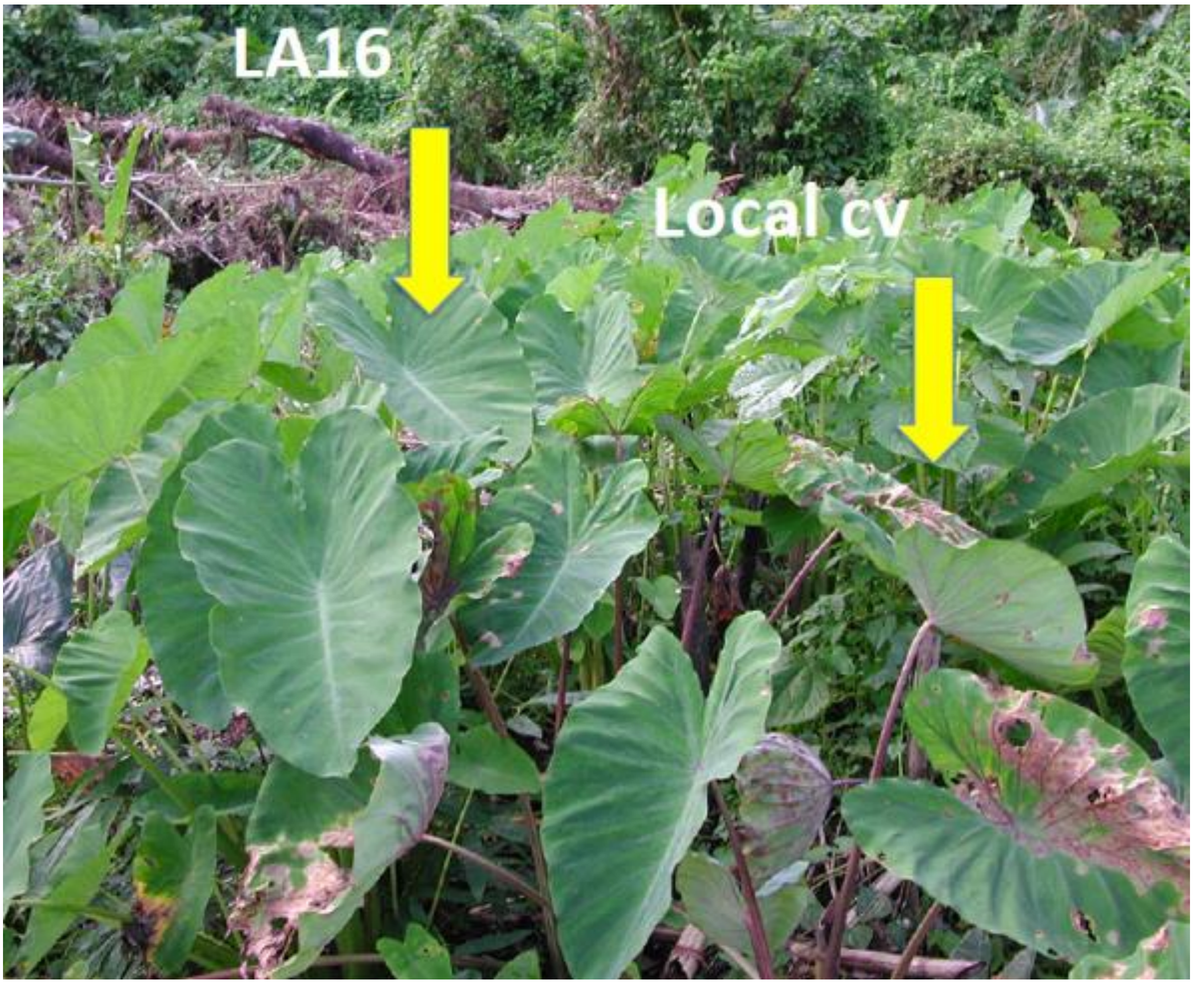

Fig. 13 A small plot of LA16, called “Agriculture taro” locally (with light green leaf stalks) planted next to the favourite susceptible taro, Akalomamale (purple leaf stalks). LA16 is not immune to taro leaf blight, but it is tolerant: leaves become infected as they age, but the amount of damage is small and unlikely to affect yield in any significant way.

But even at the time when Zaheer was still in Solomon Islands we realised that use of the Bangkok taro was not the answer. Not for the reason of FAO, but because it would take many years to breed out the wild-type characteristics, and we did not have that long. Zaheer had only four years in Solomon Islands before the end of the UNDP/FAO project. We needed tolerant cultivars (cultivated varieties), not wild types. We thought the best place to get them was India.

Unfortunately, this was a time before the ITPGRFA and the so called multi-lateral system which was a part of it[29]. Under the Treaty, signatories are obliged to share the plant genetic resources of the 40 crops that are listed. But in our day, there was no incentive for countries to share, and many didn't. They guarded their plant genetic resources closely. Although Genetic diversity in Indian taro was high, and we knew from the literature that scientists there had found what we were looking for. So it was decided that Zaheer should be funded to tour the country during his leave and collect. Arrangements were made and off he went, visiting the research stations where collections, and especially blight-tolerant cultivars, had been reported.

Zaheer was given permission to collect, a condition was that he should present the collection to the National Bureau of Plant Genetic Resources, Delhi, before leaving, so that the plants could be inspected and treated if that was required. This he did, but it was considered necessary to fumigate the plants against pests. Many did not survive the process, and the number of plants reaching Solomon Islands was modest, and did not include the varieties that we wanted, those that had been reported to have tolerance to leaf blight[30].

As a result, Zaheer did not use any of the Indian accessions in his breeding program and for the next two years concentrated on backcrossing to the best local cultivars, selecting against the wild characteristics of the Bangkok taro.

Bad luck!

Fiji, Solomon Islands and Papua New Guinea

I left Solomon Islands in 1983 and joined the FAO to work with Ivor Firman at SPC's Nabua offices in Fiji. Ivor and I had suggested that the regional UNDP/FAO root crops project that was still ongoing be amalgamated with a regional plant protection project that was in the pipeline; the idea eventuated ultimately with the support of the FAO Resident Representative in Samoa, Gideon Blumenfeld. The project became *Strengthening plant protection and root crops development in the South Pacific* (RAS/83/001).

Within the project, there was support for taro breeding and one of its several UNDP volunteers was sent to LAES, Keravat, Papua New Guinea. Unfortunately, nothing came of the work. When the project ended in 1987, the volunteer left and external funding ceased as it was difficult for the Department of Agriculture and Livestock to maintain taro breeding as a priority among its many other commitments. Consequently, taro breeding for tolerance to taro leaf blight was placed on the back burner.

Instead, I kept my hand in breeding taro at Koronivia Research Station, working with Param Sivan, Director of Research, MoA, and Makelesi Tavaiqia, agronomist. Param and Makelesi had already established a taro breeding program to produce new varieties for the market before I arrived. In fact, they had released Samoa Hybrid, a selection from about 20 seeds from an open-pollinated variety Samoa, a local favourite, and they had published on it in the

[29] The ITPGFA was adopted in 2001 to have fair and equitable sharing of plant genetic resources, and at the same time to respect farmer's rights. The notion being that sustainable use of plant genetic resources is fundamental for achieving food and nutrition security.
[30] In recent years, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuran, India, has played a very active role in INEA, the global taro network, and has participated in many exchanges of taro germplasm within the auspices of the ITPGRFA framework.

Fiji Journal of Agriculture[31]. Together with Jim Breen the UNDP/FAO project agronomist, we enlarged the program and made crosses among the top 10 taro of Fiji, grew 2400 seeds and selected nine of the best. Some of those are in the market today (Wararasa, Uro ni Vono and Maleka Dina). They are, however, almost certainly very susceptible to taro leaf blight.

We do not know how susceptible they are, or how the environmental conditions in Fiji will interact with the varieties of taro grown and taro leaf blight. We can't tell that until blight arrives. But we do know quite a bit about the genetic diversity of taro across the Pacific. We know, for instance, that as you move from Papua New Guinea eastwards across the Pacific the genetic diversity becomes less and less[32]. Taro in Samoa, for instance, are genetically similar, even though the varieties differ in colour, taste, size, and many other characteristics. We know, too, that taro in Samoa are very susceptible to taro leaf blight, we have seen that it is. As some of the taro in Fiji are the same as those in Samoa, we can assume that Fiji's taro are susceptible too, and that goes for any taro bred between them. Later, I will show how knowledge of the susceptibility of Fiji's taro to taro leaf blight was put beyond doubt. It occurred by chance.

Back in Solomon Islands, Zaheer left in 1984 to continue his career with Pioneer, and the program was abandoned. Five years later, in 1989, after Solomon Islands had requested UNDP/FAO for another volunteer, Anton Ivancic arrived from Slovenia. He continued the work at Dodo Creek assisted by Helen Tsatsia, the present Acting Director of Research.

Anton's strategy was different from that of Zaheer: he is a population breeder. Instead of backcrossing Bangkok and its progeny to local selections, he collected whatever varieties he could and made as many crosses as possible between them and screened the 'population' for blight and other characteristics thought important to farmers. He did this for several generations and would certainly have been successful in developing hybrids with blight resistance and other acceptable qualities had he continued.

Anton left Solomon Islands at the end of 1993 and, sadly, none of his taro progenies survived him. He went directly from Solomon Islands to Papua New Guinea, joining the National Agricultural Research Institute, Lae, as taro breeder. At NARI, he worked with Tom Okpul, now a senior lecturer at UNITECH Biotechnology Centre, Lae, and together they assembled a taro population containing Bangkok, Bangkok hybrids from Solomon Islands, three blight-resistant local 'wild' types from Papua New Guinea, and more than 50 favoured local cultivars, including the popular Numkowec. Before Anton left in 1995 to take up a senior position in genetics and planting breeding at the University of Maribor, Slovenia, one cycle of breeding had been completed, and a second was on the way from which three lines were released in 2001. Anton and Tom had established an important foundation that would serve the country well in the future.

Tom managed to keep the breeding program going during the early years of NARI when the future of the Institute was uncertain, and resources slim. However, it was difficult at that time to create the momentum needed to succeed in a reasonable time; success would only be achieved with a realisation that breeding was long term and to be successful this stop-go approach due to short-term funding would never get the job done.

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[31] Sivan P, Tavaiqia M (1984) First taro variety developed from breeding programme released for commercial production in Fiji. Fiji Agricultural Journal, 46:1-4.
[32] Lebot V, Aradhya KM (1991) Isozyme variation in taro (*Colocasia esculenta* (L.) Schott) from Asia and Oceania. Euphytica 56: 55-66

Unexpectedly, long-term funding was to come, but not in a way that was envisaged, and not from events in Papua New Guinea or Solomon Islands, but from far away in Samoa.

It was luck in one sense, but very bad luck in another.

Blight spreads: Samoa

In June 1993, taro leaf blight spread to American Samoa and then Samoa, most likely originating from Hawaii. How it got to American Samoa is hard to know. An unauthorised plant, perhaps, brought into the country? It is way too far for spores to travel in wind-blown rain from Hawaii to American Samoa and remain alive. But it would be possible for spores to reach Samoa from American Samoa, a distance of only 165 km in the direction of the prevailing southeast trade winds.

It was particularly wet that June, and the disease was devastating. A useful account of the outbreak is given by Julia Brunt, Danny Hunter and Charles Delp together with a useful bibliography, which now needs to be brought up to date[33].

The epidemic that occurred in Samoa gave an inkling what it must have been like for plants and farmers 50 years earlier in Papua New Guinea and Solomon Islands, except that the psychological effects on the population may have been different as Samoan farmers understood the cause of the problem. By contrast, a lack of information had Bougainville farmers grasping for explanations, with lack of faith, wrath of ancestors, sprays of DDT, diesel or ash discharged from airplanes or volcanic eruptions, suggested as causes of the disease.

How important is it?

I went to Samoa shortly after the outbreak of the disease in October 1993 on behalf of the AusAID/IDSS Western Samoa Farming System Project. This project had been established to assist cocoa development before it was derailed to deal with taro leaf blight. Trevor Clarke and Eddie Chan the cocoa specialists with the Project weren't plant pathologists or familiar with taro, so I was asked to report on the situation and provide recommendations.

One of the first things that struck me was the divergence of opinions about the outbreak. People could not agree on the seriousness of the situation, which meant finding a solution and putting it into practice was going to be a challenge. This was not entirely unexpected. Even before I got to Samoa, I had called the AusAID natural resources advisor in Sydney and said how serious I thought the outbreak was. After all, taro was 20% of agricultural exports valued at Tala16 million by the World Bank. The response I got was unexpected. It was that the situation was exaggerated, like several other so-called serious pest outbreaks in the region over the years, and this one would be the same. This outbreak won't come to much, and would be over soon: "Ask me this time next year and there will be no disease". I replied: "Yes, that's probably true, as there won't be any taro!"

[33] Brunt J, Hunter D, Delp C (2001) A bibliography of taro leaf blight. AusAID/SPC Taro Generic Resources, Conservation and Utilisation. Secretariat of the Pacific Community, Noumea, New Caledonia. 96pp.

In Samoa, there were also differences of opinion about the seriousness of the situation. It was difficult for some to realise what kind of disease they were dealing with. This is what I wrote in my report[34]:

> *Some maintain that now that the breadfruit season has begun, and there is a good crop this year, food will be plentiful for the next 2 months at least. There are also supplies of banana, plantain, and ta'amu* [Alocasia]. *In the immediate future, taro production will fall as growers abandon the crop, especially in the higher rainfall areas where disease control may be difficult. A plateau will be reached: supplies will be maintained by commercial producers, and by smallholders on Upolu and Savai'i where the disease is either absent or where damage is minimal. In these areas, the new control strategies are likely to make an impact* (p.18).

Other people I met held a different view. This was the view of the AusAID/IDSS Western Samoa Farming System Project:

> *As the wet season sets in, the area under taro will contract rapidly as farmers stop replanting, perhaps to 80% of present levels in the next 6 months. The bulk of the remaining production will be done by commercial growers who have the resources to control the disease with fungicides. The majority of smallholders will be forced through reason of food security to seek alternative crops to make good the loss of taro for home consumption. Unless alternative crops are sought immediately, some growers may be faced with severe food shortages beginning early next year.*
> *In either case, the impact of the disease will have major social and economic consequences, a fact already being discussed in newspaper editorials: food shortages will occur, there will be a downturn in local business as consumers have less to spend, unemployment will increase, foreign exchange earnings will plummet, and food import bills will escalate. Should a cyclone occur in the next 4 months …* (p.18)

The situation was confused because of a lack of any detailed monitoring: knowledge of that was happening was based on anecdotes and hearsay. There was no data on the number of taro farmers who had stopped production and, if they had, whether it was localised or country-wide. And for those continuing to grow taro, what help was needed. Equally important, and unknown, was whether farmers who were no longer growing taro, were diversifying into other crops, and if so, which ones, and whether they had sufficient planting material.

In the event, the economic repercussions *were* severe: before the blight, taro was the main agricultural export of Samoa, but within 18 months, production fell from 0.4 million tonnes per year to less than 5 tonnes, and the export value from US$3.5 million to a few thousand dollars[35]. Only those growers who could afford fungicides continued to grow the crop. The remainder turned to ta'amu, taro palagi (*Xanthosoma*), cassava, banana, breadfruit and even

[34] Jackson GVH (1993) Study of taro leaf blight in Western Samoa. A report prepared for the Australian International Development Assistance Bureau. Canberra, Australia. 62 pp.

[35] Various estimates of the value of taro export for this time exist. The Government put the value in 1989 at Tala7.5 million, a figure the World Bank considered to be less than half the true value because of under-reporting. Its estimate was Tala16.4 million. For the same year, home consumption was valued at Tala 25 million and domestic sales at Tala15.8 million. The conversion rate Tala to USD was *c*.2.5 at the time.

sweet potato, a less favoured crop. The situation at that time was later explored by Andrew MacGregor in his report for IUCN[36].

Arguing for a breeding program

During this October visit, I had not only to assess the opinions concerning the disease and its likely impact in Samoa, but also to consult with other taro breeding programs in the Pacific (PNG and Solomon Islands), other agencies (ACIAR, EU, FAO, Forum Secretariat, SPC, USP, UNDP, USDA), development assistance projects (US Commercial Agricultural Development Project, USP Alafua), and report on actions taken so far to control the disease outbreak locally.

I said there was only one approach to solving taro leaf blight where epidemics are common: use fungicides as a stop-gap measure, and at the same time start breeding varieties with resistance. This was obviously a long-term venture of uncertain success as no one had done it before, but there was no practical alternative.

Fungicides were never going to be a long-term solution for taro leaf blight in Samoa: they were too expensive, rainfall was too high, and all but commercial farmers were not experienced in their application.

I favoured giving support to the breeding programs of Solomon Islands or Papua New Guinea. By assisting them, Samoa would access seed to screen. This could have been accomplished quickly and provided Samoan farmers with plants to test; later, if Samoa was keen to breed taro this could have been done knowing what was involved and assembling adequate resources. Seed was important because it would filter out chance virus infections. No taro virus was known to be seedborne.

My concern at the time was that Samoa would immediately begin breeding taro with whatever plants were available, such was the urgency of the situation, and this would establish yet another taro breeding program in the region, and one that might make unsafe taro introductions as well as lack the resources required long-term. Although the need for a breeding program in Samoa was understandable, there were already taro breeding programs in Fiji, Solomon Islands and Papua New Guinea, with little or no coordination between them, and none of them appeared sustainable. The counter argument was that Samoa had bred taro in the past. In the 1970s, Jill Wilson was part of USP's research and extension institute, IRETA, working in a large USDA program supporting the newly-established agricultural campus. Jill was a crop breeder by profession, having previously worked at IITA, Nigeria, breeding, yam and later *Xanthosoma* in the Cameroon. Unfortunately, when she left USP the program was abandoned. There was no plant breeder to continue the work.

My report to the WSFSP stated that breeding for taro leaf blight resistance was necessary and urgent, but the program should consider sustainability from the outset; and there was need for an expert plant breeder. I thought the best thing to do under the circumstances was for funds

[36] McGregor A with Peter Kaoh, Laisene Tuioti Mariner, Padma Narsey Lal and Mary Taylor (2011) *Assessing the social and economic value of germplasm and crop improvement as a climate change adaptation strategy: Samoa and Vanuatu case studies.* A background case study prepared for IUCN's report, *Climate Change Adaptation in the Pacific: Making Informed Choices,* prepared for the Australian Department of Climate Change and Energy Efficiency (DCCEE), IUCN, Suva, Fiji.

to be made available to bring the three taro programs together with authorities in Samoa to develop a comprehensive plan for the region to be presented to the SPC CRGA and then donors. Potentially four ill-coordinated and poorly resourced taro breeding activities all doing essentially the same work in the region was not the best way forward.

I made another suggestion. I was concerned about the despair that this outbreak had caused in Samoa, no matter that some people felt the impact would not last long. I suggested that members of DAFF and representatives from the Ministry of Women Affairs travel to Pohnpei, FSM, and see the taro there. I had found by chance that the taro there were tolerant to the disease – I will explain how later. They should cook the taro in different ways as they would at home and of course rate them for taste and texture. If possible samples should be brought back to Samoa.

If the taro in Pohnpei were satisfactory, it might be welcome news that plants exist that can beat the blight. They could be multiplied and given out to farmers, and even form the basis of a breeding program. I was told later that indeed a delegation did visit Pohnpei and the result was positive. Pohnpei taro came to Samoa.

But I was not the only person giving advice, and the opinions of some others did not tally with mine! Cultural control was under consideration by FAO.

FAO goes for leaf pruning

FAO under a TCP project, *Assistance for the control of taro leaf blight*, sent Tonie Putter, Plant Production and Protection Division, Rome, to Samoa in October 1993. He spent much of the time showing people how taro leaf blight operated at night so they could appreciate the life cycle of this *Phytophthora* species.

The nocturnal behaviour of this fungus-like organism was important and suggested that the disease could be controlled by leaf pruning. Tonie had studied taro leaf blight at Vudal Agricultural College, New Britain, Papua New Guinea (now Papua New Guinea University of Natural Resources and Environment), for his master's degree. So he knew the *Phytophthora* well. He was also a student of JE Van der Plank, a world-famous plant disease epidemiologist, to whom he dedicated his thesis.

In 1963, in a seminal book *Plant Diseases: Epidemics and Control* by Van der Plank[37] revolutionised our understanding of epidemiology and plant breeding approaches to contain disease epidemics. He coined the words 'vertical' and 'horizontal' to describe the resistance of plants developed by plant breeders.

Vertical resistance is the resistance of pedigree breeding of the Mendelian kind: it is either present or absent. It is usually based on a single gene (often termed R-genes) and is vulnerable to the appearance of new races of a pathogen.

Horizontal resistance is field resistance and multi-gene in character. It is also incomplete resistance, varying over a range of environments but, importantly, it is less likely to break down. It is the resistance that exists in crops to most pathogens, otherwise they could not be grown successfully. The many genes involved determine a complex of minor characteristics

[37] Van der Plank JE (1963) *Plant diseases: epidemics and control*. Academic Press. New York. 349 pp.

which together create resistance or slow the rate of infection, especially at the start of an attack.

Van der Plank showed the importance of rogueing or leaf pruning to slow the rate of infection of a pathogen and to delay the onset of an epidemic. It does this by lowering the amount of the pathogen in the environment, especially the number of spores. By delaying or lowering rates of infection, it is possible to reach crop maturity and produce a satisfactory crop. Essentially, this is what fungicides do.

Tonie was trying to demonstrate this feature of epidemics of taro leaf blight to make people in Samoa aware of this important point of 'cultural control'. It's a misnomer really: it would be better to call it 'cultivation control' or 'environmental control', changing the conditions around the crop to reduce the disease without the need of pesticides.

Tonie had shown the importance of pruning infected leaves, that is lowering the amount of disease in the crop, during his studies in Papua New Guinea. In the relatively low rainfall of Vudal, he could turn the disease on and off by removing the blighted leaves (or cutting out infected bits and leaving the healthy rest). It was a nice demonstration of cultural control, and it would have been a wonderfully simple solution to Samoa's blight problem that farmers could have implemented straight away, but it has limitations: it depends on the amount of rainfall. What is possible in rainfall of 2000 mm a year at Vudal is not going to work in Samoa with rainfall of 3500 mm. You just cannot keep up with the ability of the blight to produce spores that infect leaves soon after they appear. We had shown this in trials at Dala where rainfall was similar to that of Samoa. Pruning twice a week ended up with plants with few leaves and, consequently, low yields.

So, if leaf pruning was not the answer, what was? We have been saying breeding for tolerance to the disease was the only answer, but how and where to get the parental lines to start the breeding program?

If we had known better and had greater resources and time, our breeding approach in Solomon Islands, Papua New Guinea and perhaps Samoa would have been different. We would have crossed local taro cultivars and screened hundreds of thousands of seedlings, hoping to assemble the minor genes of horizontal resistance in a few of the progeny. Those minor genes would likely be present but scattered among the varieties.

What we needed to do was reassemble the genetic makeup of taro before taro split with taro leaf blight, thousands of years ago.

But we did not really understand this possibility. It was not until much later when I met Raoul Robinson, and studied Raoul's 1987 book *Plant Pathosystems*[38] that I understood our lost opportunity. His 1996 book *Return to Resistance*[39] says it all and is very easy to understand as he has written it for students and non-scientists. I will return to Raoul and his impact on our understanding of taro leaf blight later.

What we wanted at the time were cultivars with better resistance than anything that was then grown. We were concerned about the resistance of Bangkok; it might be vertical and might

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[38] Robinson RA (1987) Plant pathosystems. Springer-Verlag, Berlin, Heidelberg, New York. 184 pp.
[39] Robinson RA (1993) Return to resistance. agAccess, Davis, California. 480 pp.

break down, and we did not want to start with susceptible taro as we did not understand its potential. Even if we had understood, we would have been concerned that positive results would have taken many generations of breeding.

But where to go for tolerant taro? We had tried India, so where next?

Fourth piece of luck: Micronesian taro are tolerant

This is a digression, but it is important to explain how I got to know of taro that were tolerant to taro leaf blight, and probably quite different genetically from those in the South Pacific. Just to repeat, I am using the word ‘tolerant’ to mean that the plants get infected, but the damage is relatively small, and yields are acceptable. This is distinct from ‘resistance’, which is often used to convey immunity, where plants are free from infection.

The tolerant taro were in the north Pacific, in Pohnpei, Federated States of Micronesia. It’s another story of chance, and this is how it happened.

I return to 1983 and my departure from Solomon Islands and arrival in Fiji to work with the regional UNDP/FAO project on root crops and plant protection. One of the things I had to do under the project was to set up a tissue culture lab at SPC. Luckily, I had met George Stride who, before he left Fiji and FAO, was tasked with designing a regional plant protection project (the one that we later amalgamated with the on-going UNDP/FAO root crops program). George came to Solomon Islands in about 1981 to discuss the new project. On the way to the airport, I suggested casually the need to move root crop genetic resources into the region from the CGIAR international research stations, as well as sharing the good varieties of the region between countries.

George and FAO liked the idea, and so in 1984, the first tissue culture lab in the Pacific was established. There was not a lot of funds for the activity as it was a new and no one knew if it would be successful or not. The ‘lab’ was about the size of a broom cupboard! It was the forerunner of the Regional Germplasm Centre and the current CePaCT lab but, of course, nothing like the size or complexity. Nevertheless, it was the start of tissue culture in the region. It held collections of sweet potato, cassava and banana from CIP, IITA, CIAT, and Pacific taro, cassava and yams tested for viruses by Alan Brunt and Olwen Stone, Horticultural Research International, Littlehampton, England (previously Glasshouse Crops Research Institute), and Brian Harrison, Scottish Crop Research Institute, Invergowrie, Dundee, Scotland. To do much of the lab work I had a technician, Samila Devi Lal, who made up the media, and who could see meristems, remove and culture them, far better than I. And I would like to mention the assistance we had from Fiji quarantine, now Biosecurity Authority of Fiji, which allowed us to bring germplasm of many kinds into the country, and expedited its distribution around the region.

BAF kindly allowed us space in their new quarantine houses at KRS and we filled them with pathogen-tested varieties of all the major root crops for distribution to countries that had difficulty handling tissue cultures. There they were under the care of Hasmat Ali.

Importantly, Param Sivan at KRS agreed to share Fiji taro with other countries. After they were tested for viruses and found to be free, I sent 10 varieties in tissue culture to the College of Micronesia-Land Grant, Pohnpei. The State had only a few varieties and wanted to test others. A few months later, during the frequent trips I was making to Micronesia on pest surveys, I stopped over to see how the taro were doing. Jackson Phillip and Reuben Dayritt met me at the airport. Jackson said, “ We are pleased you have come; we have tried to keep the taro alive for your visit!”

What on earth did he mean?

It was soon obvious. The taro were defoliated by taro leaf blight, leaves and petioles were infected and only the youngest emerging leaves were still intact. Local varieties at the station and in farmers’ fields were fine; they had a few spots but nothing they could not cope with; certainly the disease was not harming production and, in a rainfall of 5000 mm a year and the high temperatures of a country not far from the equator, that was extraordinary. There was only one conclusion: the varieties of Pohnpei had a natural tolerance to taro leaf blight (Fig. 14).

As sad as it was to see the Fiji taro melting from taro leaf blight, it was exciting to know that there were cultivars in the Pacific island region that were unaffected by it. What about in other States of FSM, and in Palau, where I was also working? Palau had taro leaf blight, but farmers did not complain about it. It was not a crippling disease. Taro were grown close together in the swamps of Palau and had a similar tolerance to those in FSM. Actually, farmers were more concerned with *Pythium* rots and, to combat these, we were encouraging traditional rotations which included lengthy fallows.

Later, varieties were collected from Palau and also proved a useful source of tolerant taro for the breeding program in Samoa

Fig. 14 Cultivar Toantal growing in Pohnpei, Federated States of Micronesia. This variety was tolerant to taro leaf blight even under very high rainfall and temperature conditions which defoliated Fiji introductions. This variety and other Pohnpei varieties – Kosrae, Pastora and Pwetpwet – were introduced to Samoa and used in the breeding program, along with a variety from the Philippines and one from Palau.

So now we knew the mechanics of breeding taro, the strategy to use and where to go for multi-gene horizontal resistance. We did not know the genetic diversity of the potential breeding lines at that time, but we suspected the Micronesian taro were not local; perhaps they had been brought from Japan by people who established farms there many years earlier and after the local taro had been struck down by taro leaf blight when it first arrived in the 1920s.

The wasted years

Meetings galore! USP, Samoa; University of Cenderwasih, Indonesia; UNITECH, PNG

The pieces of a breeding strategy were coming together: we knew how to make taro flower and the mechanics of breeding; we knew about horizontal resistance; and we knew where to obtain the parental plants we needed; further, the Government of Samoa was supportive. All we needed were funds!

As so often happens in the region when events occur of great significance, finding solutions comes slowly. Part of the problem is that collaboration, coordination and communication is poor. And so it was with overcoming the Samoa taro leaf blight outbreak. In November 1993, a month after my visit to Samoa, SPC called a regional seminar on taro leaf blight in Samoa to determine what needed to be done. We met at the Alafua Campus of USP.

Twelve countries met with universities and development assistance agencies - USDA, EC, UNDP, USP/IRETA, ADAP, and representatives from MFAT (The New Zealand Aid Programme) and AusAID (Australia) – and I found myself back in Samoa, this time representing ACIAR. The meeting (Taro Seminar I) went over all the control measures, contingency plans, surveillance systems, community awareness programs, and training in pest and disease identification. Bob Macfarlane and I presented an Emergency Response Plan in case the disease spread, and specialist groups made a draft workplan with outputs and a schedule of activities.

The report from the breeding group elicited most discussion. The problem, as mentioned above, was how to help the programs in Solomon Islands and Papua New Guinea and in the process help Samoa. It was a matter of coordination and getting agreements. Solomon Islands and Papua New Guinea wished to assist Samoa, but if their programs needed broadening to do this, they would need donor assistance. But Samoa wanted its own program as it saw the problem of viruses restricting the movement of germplasm from other countries. Remember Solomon Islands and Papua New Guinea had the serious diseases, *alomae* and *bobone*, which were not present in Samoa. After much discussion, another meeting was scheduled for March 1994, at which a panel of experts would develop a strategy and a project proposal. It was a case of kicking the can down the road!

But to the surprise of us all, another breeding program sprang up immediately after the meeting. This time it was in Hawaii.

Ed Trujillo, plant pathologist, University of Hawaii, attended the Samoa meeting and, upon hearing about the tolerance of the FSM taro, went straightaway to Palau where taro is grown in large coastal swamps (Fig. 15). There he collected several cultivars and took them back to the University and produced hybrids between Maui Lehua and one of the Palau cultivars. Three of the best were patented, much to the consternation of indigenous Hawaiians who considered themselves relatives of taro, as stated in the Hawaiian Creation Chant. Such was the objection that the University later withdrew the patent.

More regional meetings followed. In November 1994, a symposium was held in Irian Jaya organised by UNITECH and DAL, Papua New Guinea, and the University of Cenderwasih, Manokwari, Indonesia. Networking was now seen as the way forward. Semisi Pone, SPC's Plant Protection Officer focused on a regional taro leaf blight network for scientists to collaborate and share information on the disease, and Ramanatha Rao, Senior Scientist, IPGRI, the International Plant Genetic Resources Institute (later, Bioversity International), was keen on collecting, conserving and sharing taro genetic resources. ACIAR had provided IPGRI with funds to investigate a genetic resources network and I had been asked to see what countries thought of the idea and to put forward suggestions how it might operate. I was also there to prepare the Proceedings! [40]

Fig. 15 Palau has many taro varieties. Those shown here are growing in a swamp at Ollei village, Babeldaob, planted close together in small plots. Leaves are invariably infected by taro leaf blight, but when screened by Ed Trujillo at the University of Hawaii, several varieties were found tolerant to the disease. One, variety Ngeruuch, code named P10, was sent to Samoa and used in the breeding program.

[40] The Second Taro Symposium (1996). Proceedings of an international meeting held at the Faculty of Agriculture, Cenderawasih University, Manokwari, Indonesia, 23-24 November 1994. Editors: Jackson GVH, Wagih ME. Cenderwasih University and Papua New Guinea University of Technology. 147 pp.

Unfortunately, few Pacific island countries attended the symposium, it was primarily a meeting between the universities of Cenderwasih and UNITECH; nevertheless, it was an important meeting as it brought us up-to-date with taro breeding at PNG DAL's Bubia Agricultural Research Centre[41], led by Anton Ivancic. This was the only active taro breeding program at that time.

Anton's work was important because at the outset he investigated reasons why flowers fail to form or form but fail to produce viable seed. He and the team at BARC assembled a population that included Solomon Islands hybrids, the Bangkok variety, PNG wild types and elite cultivars, grown under ideal conditions to stimulate large number of flowers, viable pollen, receptive female parts and good seed set. They demonstrated that recurrent mass selection was a breeding strategy that had the potential to create varieties with high yield, acceptable eating qualities, and tolerance to a range of diseases.

This was not the final meeting; that came in June the following year. Taro Seminar II was hosted by UNITECH, Lae, with support from DAL, IPGRI and SPC. There were 11 Pacific island countries, and several research and development organisations (CIRAD, Hort-Research (later, Plant & Food Research, New Zealand), FAO, ACIAR, UQ, UH). The same topics were discussed as there was nothing new to say - no one was doing anything except BARC! Nevertheless, it was good to revisit the recommendations of the Cenderwasih meeting where few Pacific island countries had been present.

The Lae meeting had three objectives: i) to share recent information on taro, especially that concerning pests, and to encourage further work; ii) to view taro breeding in Papua New Guinea and discuss ways of supporting the program so that it might benefit all Pacific island countries; and iii) to consider establishing a regional root crops network for the conservation and use of genetic resources, and how it might be done.

Anton was still in Papua New Guinea but left soon afterwards, returning to Slovenia. Fortunately, he was soon back in the Pacific islands breeding taro but, unfortunately, not for blight resistance. Vincent Lebot, CIRAD, found funds for him to work in Vanuatu. He took his vacations there and also in New Caledonia. He took taro seed from his Papua New Guinea program as the basis for the work. Bangkok genes were moved from country to country!

At the Lae meeting, I presented the report for ACIAR and IPGRI on forming a taro and yam genetic resources network that I had been working on the previous year[42]. The idea broached at the Cenderwasih meeting had gained traction. Instead of concentrating on breeding, we should try a different approach to attract donor funding: taro leaf blight had the potential to erode genetic resources which might be needed in future breeding programs in Solomon Islands, Papua New Guinea and Samoa. Further, these same genetic resources were needed to overcome the vulnerability of many other Pacific island countries, and those in other regions of the world, that were yet free from the taro leaf blight and other diseases of the crop. Now was the time to collect and use. A network was required to do this.

The priority was to collect and conserve; plant breeding would develop as a use of the conserved collections.

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41 Later, BARC became the headquarters of NARI, the National Agricultural Research Institute.

42 Jackson GVH (1994) Taro and yam genetic resources in the Pacific and Asia. A report prepared form the Australian Centre for International Agricultural Research and the International Plant Genetic Resources Institute. ANUTECH Pty Ltd. Canberra, ACT 0200. 69 pp.

As much as it felt like we were going around in circles, we all agreed to the establishment of the taro (and yam) network to be implemented through a regional organisation; it would establish a germplasm centre for conservation, support sharing and, hopefully, use the genetic resources for breeding.

Interestingly, at the Lae meeting, we heard from Vincent Lebot of a similar network, TANSAO, the *Taro Network for Southeast Asia and Oceania*, for the first time, for which EU funding was promised. Apart from countries of Southeast Asia, Papua New Guinea and Vanuatu were members. The aim of the program was to explore the genepools of the Pacific and Asia, establish an *in vitro* collection in Indonesia, index selections in Holland, and to share. It was not primarily concerned with taro leaf blight or plant breeding; it was to conserve diversity, and was based on Vincent's PhD results showing that diversity of taro decreased from west to east across the Pacific. Taro varieties might look different but really they were genetically similar in the Pacific at least, and were vulnerable. Samoa had found this to its cost: all the taro in the country were equally susceptible to taro leaf blight.

SPC took the Lae workplan and activities to the 9th RTMPP, Fiji, February 1996, and obtained a recommendation to seek support for the network, a view that was later endorsed by the 12th PHALPS the following March in Cook Islands. The recommendation stated:

> *That PHALPS gives high priority support to the development objectives of establishing a Reginal Root Crops Network and that this be conveyed to AusAID and other donors. Once a commitment in principle is obtained for a long-term project, it is recommended that an approach be made to FAO to assist with the formulation and other activities in the action plan produced by the Taro Seminar II in Lae.*

The meeting of the Committee of Representatives of Governments and Administrations, the governing body of SPC, endorsed the recommendation, which was subsequently ratified by the South Pacific Conference in October 1996.

But a year went by and there was still no progress.

More visits to Samoa

1995 was the last regional meeting, but I continued to visit Samoa, for the WSFSP. There were two more visits, in July 1996 and October 1997, both were arranged through IDSS, the International Development Support Services Pty Ltd, Melbourne.

The first visit reviewed the situation - again. After the blight appeared in 1993, farmers immediately diversified into other food crops and this conversion had been completed within two years. Amazingly, food security had been re-established in the country, based primarily on crops of *Alocasia* and support through remittances from family members living overseas. However, the need to get back into taro production was a heart-felt priority of everyone I talked to.

My report recommended that research on fungicides be concluded as soon as possible - phosphorous acid, with or without the addition of copper, was giving good control, but only for about 200 commercial farmers; for the majority, it was too expensive. It was time to concentrate on selection and breeding with FSM, Palau, and also Philippine varieties that had been sent to USP Alafua by Jose Pardales, PRCTRC, Philippines in 1994. The FSM varieties came later, as did several varieties from Palau, which had been collected by Ed Trujillo, tested at the University of Hawaii for blight-resistance, and sent to American Samoa from where they reached Samoa. They were grown in quarantine at USP Alafua in 1996, and tested twice for viruses by Mike Pearson, University of Auckland. Those with symptoms of rhabdovirus were discarded.

A plan for a participatory selection and breeding program involving MAFFM, USP and farmers was designed. Param Sivam had returned to USP Alafua in 1995 after completing his Ph.D studies in Brisbane, and was key to the program. He started to work with the varieties available: Philippines (PSB-G2), FSM (Pastora, Pwetpwet, Kosrae, Toantal) and Palau (many) either in the field under multiplication or in open quarantine at USP awaiting release.

The idea of a breeders' club at USP was suggested for the first time after discussions with Raoul Robinson who had outlined the concept in his 1996 book. Raoul's assistance at this time and later was instrumental in helping me develop an appropriate breeding strategy. He would send long emails describing the mechanics of horizontal resistance and how it should be applied to taro with taro leaf blight.

I had first met Raoul in 1985 when I was with the UNDP/FAO plant protection and root crops project. He, Steve O'Hair from the University of Florida, and I visited the taro breeding programs of Solomon Islands and Papua New Guinea. We had stayed in touch since that time.

The plan was that breeding was to be centred at USP Alafua, with Param, who would also help establish a similar program at Nu'u Crop Development Centre, MAFFM, and train staff to ensure sustainability over the long term. Funds were made available through the WSFSP.

My second visit in 1997 came at the end of the WSFSP and had been scheduled to monitor progress on the taro breeding strategic plan that had been agreed the year before. Unfortunately, MAFFM's efforts to breed taro failed for a number of reasons. It was difficult as there was no one who had plant breeding experience, and also there were staff movements that interfered with continuity of the program. More success was achieved at USP Alafua where crosses had been made between local varieties and introductions from the Philippines and Micronesia. Seed had been collected sometime before my visit.

However, USP's continued involvement in taro breeding was in doubt, as Param was scheduled to depart USP in December 1997. Fortunately, Danny Hunter, previously agricultural officer, Ministry of Agriculture and Fisheries, Maldives, joined USP Alafua in 1996 as plant pathologist and was keen to take part in the program. But rather than trying to breed taro at Nu'u as well as USP Alafua, it was agreed that breeding for taro leaf blight tolerance would be centred at USP Alafua, and that MAFFM would concentrate on the testing and multiplication of tolerant cultivars from the Philippines and Micronesia, and getting them to farmers as quickly as possible. Let farmers be the judge.

Fifth piece of luck: TaroGen

Between my first and second visits to Samoa for the WSFSP in 1996 and 1997, there was a surprising turn of events. This is the story of how funding was finally achieved to deal with taro leaf blight. To quote Churchill, "Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning"!

I knew Paul Ferrar, Research Program Coordinator, Crop Sciences, ACIAR; we used to keep each other up-to-date on agricultural research in the Pacific islands through lengthy phone conversations. In early 1997, Paul told me of ACIAR's intentions to respond to IPGRI's concern about the loss of taro genetic resources due to taro leaf blight and competition from other root crops, sweet potato and cassava in particular. A project on DNA fingerprinting the region's taro was forecast and, from that, a core sample would be developed, representative of the genetic diversity of the crop in the Pacific islands. UQ would be the Australian commissioned organisation with Ian Godwin as project leader.

Paul was also in discussions with Rob Harding at QUT on international movement of taro. If taro was to be collected, DNA fingerprinted and a core sample identified, then there was need for conservation and sharing. Rob's project would produce virus indexing procedures to ensure sharing would be done safely. The work would be done in collaboration with SPC, enlarging the small tissue culture lab that I had set up to conserve the taro varieties.
I said to Paul that with ACIAR's commitment to these two projects, it should be possible to leverage funds for a project to breed taro for tolerance to leaf blight[43]. Would he come to AusAID to support the case. I felt that my association with the problem over the last four years was sufficient to act on behalf of the region. I had previously discussed needs with Pacific island countries, donors, including AusAID, and my reports had always been sent to SPC and widely circulated. My views on the need to breed for resistance were well known.

On a windy, cold day in May 1997, we met in the foyer at 62 Northbourne Avenue, Canberra, and went to see the head of the Pacific regional division. Paul described ACIAR's position and future intentions, and I laid out the need and how to deal with taro leaf blight, and then we left. There was little discussion. We sat in the café in the foyer mulling after our meeting. We were hopeful, but not wildly so; we knew it was going to be a costly program.

Two days later, I got a phone call from AusAID that they had $A2 million that might be put to solving taro leaf blight; could I write a project design document? The work was to be done in conjunction with SPC and IPGRI and in consultation with Pacific island governments.

I went to Fiji, Papua New Guinea, Solomon Islands, Samoa, Tonga and Vanuatu, and in each country visited departments of agriculture, health and economic planning. After the visits, I spoke with the heads of research of Pacific island countries, taking advantage of a regional fruit fly meeting.

The draft Project Design Document was put out to tender by AusAID, and ACIL won the contract for a 4-year $A2.3 million program, which we called TaroGen – *Taro Genetic Resources: Conservation and Utilisation*. The program brought together a team with considerable expertise (Fig. 16): IPGRI (Ramnath Rao), Hort-Research (Bob Fullerton), the universities of USP Alafua (Danny Hunter), QUT (Rob Harding), UQ (Ian Godwin), and eight Pacific island countries, and SPC. Simon Field was AMC Director (he had led a soils project in Fiji previously, funded by ACIAR); Param was Team Leader; Mary Taylor, Tissue Culture Specialist; Davinder Singh and Tom Okpul, PNG Plant Breeders; and I was Director of Research. Apart from AusAID, funding came from ACIAR and MFAT.

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[43] The two ACIAR projects were amalgamated into *Virus indexing and DNA fingerprinting for the international movement and conservation of taro germplasm,* with Ian Godwin as team leader.

The objectives of the project were: i) describe and conserve the majority of taro genetic resources in the region; ii) support leaf blight breeding programs; and iii) to develop an infrastructure to backstop the implementing agencies.

TaroGen commenced in June 1998. In August, we held a technical meeting on plant breeding strategies at SPC in Fiji. Raoul Robinson was the consultant plant breeder. We took the recommendations of the meeting to the TaroGen Planning Workshop, 3-4 September 1998, held at HortResearch, Auckland, New Zealand, following a meeting of the FAO Heads of Agriculture for the Pacific island countries[44].

At the Planning Workshop, countries agreed to exchange taro germplasm of the Pacific islands under a Code of Conduct. The members of TaroGen – the Pacific Island countries as well as regional and international organisations and research institutes - associated with the project were obliged under the Agreement to share their taro genetic resources for research purposes.

Fig. 16 Some members of the TaroGen team meeting in Samoa after the start of the project to discuss breeding strategies. From the left: Param Sivan, Team Leader; Danny Hunter (University of the South Pacific, Alafua); Davinder Singh (PNG Plant Breeder); and the author (Director of Research).

The outcome was the re-activation of the long-dormant taro leaf blight resistance breeding programs of Papua New Guinea and Samoa, and linkage of these to programs developing a regional core collection of Pacific island taro and as well as those finding ways to safely share both traditional cultivars and breeders' lines. Importantly, TaroGen was linked to TANSAO, the Southeast Asia taro network. The importance of this became obvious some years later, when TANSAO lines from South and Southeast Asia were needed for incorporation into the Samoa breeding lines to widen their genetic diversity.

[44] The meeting was facilitated by Dr Andreas Tarnutzer, Zurich, a specialist in project design, planning and monitoring. Andreas was team leader of an SDC project in Sikkim, India where I worked with him for a number of years.

Move fast, and breed things!

So much was achieved in such a short time under TaroGen: by 2001, 2400 taro accessions had been collected, described morphologically and DNA fingerprinted, and a core sample of 220 accessions identified, representing the broad diversity of taro in the region[45]; a new Regional Germplasm Centre was set up in SPC (which later became CePaCT), and the core sample conserved[46]; surveys for six viruses were made and indexing methods developed; and several cycles of breeding carried out in Samoa and Papua New Guinea. Within four years of the project's inception, taro was being grown by Samoan farmers without the need for fungicides.

In Papua New Guinea, Davinder Singh and Tom Okpul continued the population breeding started by Anton Ivancic, using Bangkok genes and local varieties and cultivars. Interestingly, Davinder and Tom worked out the genetics of the Bangkok resistance and it was based on one dominant gene and one or more recessives[47]. It was a pity that FAO had made such a fuss over the use of the wild Bangkok taro several years earlier! A lab method to determine resistance to taro leaf blight had been devised by Bob Fullerton ad Joy Tyson. By 2003, four new lines with blight resistance and acceptable taste were released.

In Samoa, at USP Alafua, Danny Hunter with assistance from Charles Delp, a Peace Corp volunteer with the crops section, established TIP, the *Taro Improvement Program*, in 1999 that took Param's hybrids through further cycles. Under TIP a *Taro Breeders' Club* was set up in March of that year, with students and farmers producing new lines, and about 30 farmers evaluating whatever USP produced.

MAFFM also played a vital part in the program with Pelenato Fonoti evaluating the Philippine line (PSB-G2) and Micronesian cultivars Pwetepwet, Pastora and Toantal) for his master's degree at USP between 1996 and 1998. It was found that farmers in Samoa were taking to the varieties from FSM, Palau and the Philippines[48].

TIP made good progress with farmers selecting several progeny from each generation to enter the next cycle for crossing. The selections from each generation were sent to SPC where they were established in tissue culture and indexed by QUT for viruses.

NGOs also played a part in TaroGen, with KGA Solomon Islands and FSA Vanuatu producing important information on *in situ* conservation, expanding knowledge on the complexities of irrigated taro production and reporting on traditional ways of naming varieties.

The pace of work was truly amazing, but then everyone on the team knew what was required: they knew taro and were experts in their respective fields. The team met often, and collaboration was outstanding. We all realised that we had little time to succeed, and this kept the momentum going. There had always been a feeling of reluctance among donors to get

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[45] This was achieved even with having to re-collect in Solomon Islands, as the first collection held at Fote, Malaita, was lost during the Ethnic Tension due to disease when the officers in charge abandoned the station, and a second collection from Guadalcanal maintained at St Joseph's School, Tenaru, was lost from similar reasons.

[46] This collection later became a world collection and has attracted support in perpetuity from the Crops Trust.

[47] Singh D, Okpul T, Gunua T, Hunter D (2001) Inheritance of resistance to leaf blight in taro cultivar 'Bangkok'. JOSPSA 8: 22-25.

[48] Brunt, Hunter, Delp (2001) op. cit., p.3-9.

involved in plant breeding because of the inherent long-term nature of the work and the uncertainty of success.

We were right to be concerned: after only two years, in November 2000, AusAID called for a major review of the project[49].

The result of the review was potentially catastrophic for taro research in the region and food security in particular. We considered that it was likely that the project would succeed in conserving a representative collection of Pacific taro, and produce blight tolerant varieties that could be shared safely, but it was unlikely that farmers across the region would benefit. The difficulties involved in getting germplasm of any kind through government agencies to the farming community in Pacific island countries has always been underestimated by regional organisations and donors. Logistically it is difficult and very expensive, and mostly avoided by donors, expecting it to be a country concern.

And that has turned out to be the case for new blight tolerant taro varieties.

A failure to comprehend: TaroGen reviewed

TaroGen was unique; there had never been anything like it previously. It was a model of how countries could work together to solve common agricultural research problems, and do it quickly. Yes, there had been large EU-funded research project previously - PRAP and later DSAP - but these were programs that bundled individual national projects under an umbrella of collegiality for administrative efficiency; for the most part they did not tackle truly regional problems collaboratively. Each country had its own separate project.

Why did AusAID review the project in 2000 after two years when a review was scheduled after four years? We don't know. Perhaps it was the old concern about plant breeding and the length of time to get results. We were not told explicitly, but led to believe it was because of sustainability that there was need for major changes, and donor withdrawal.

The Review said the following:

… the project has made some good progress. The project has:

- Collected a broad range of germplasm
- Produced positive preliminary results from the breeding programs in PNG and Samoa
- Helped develop a relationship between farmers, extension officers and research in Samoa that involves farmers in the breeding program and provides an effective means of distributing improved taro varieties
- Laid the foundation for the conservation and exchange of genetic material in the Region.

[49] Mid Term Review. Taro Genetic Resources: Conservation and Utilisation Project (TaroGen). AusAID Pacific Regional Program. November 2000. 121pp.

… but the criticisms were serious:

- The project was hindered by a poor design
- There was an apparent lack of funds for basic operating costs
- Neither the executing agency nor the project's coordinating body play a meaningful role in the preparation or approval of work programs … nor … in the management of the project
- Sustainability is at risk … measures need to be taken to increase the role of SPC, NARI and USP as counterpart agencies.

A six-month extension was suggested, instead of the four years requested by ACIL. By the end of the project, after four and a half years, TaroGen would be transferred to SPC management for a further two years, with increased responsibilities for USP and NARI. By then, all taro would have been conserved and indexed for viruses, further breeding cycles would have been completed in Papua New Guinea and Samoa, and exchange and distribution of taro taken place within the region.

Param left TaroGen at the end of 2002 after the extension. Mary stayed on, continuing in the role of RGC Advisor, and then manager of SPC's plant genetic resources, rebranded as CePaCT, the Centre of Pacific Crops and Trees, with a new building at SPC's Narere campus. Davinder left Papua New Guinea in 2003 (the Review considered this necessary to ensure sustainability) and Danny left USP in 2000.

But before I left TaroGen, I went to Solomon Islands in January 2002, and together with Jean Galo, Research Officer, MAL, described the taro that had been collected in Choiseul, Malaita and Ndendo Island (often referred to as Santa Cruz) in Temotu Province. It was now safe to go to Solomon Islands as the Ethnic Tension had died down. We took a random 20% of the collections, adding varieties of special interest, and these were taken by Mary to the University of Queensland, Brisbane, where they were DNA fingerprinted and placed in tissue culture. Later, they were passed to Rob Harding nearby at the University of Technology for virus indexing. Finally, they went to SPC CePaCT for conservation, joining similar national collections from other Pacific island countries, and elsewhere in the world. Funding for the conservation of the taro collection comes from the Crop Trust (established by Bioversity International to conserve 25 important crops from those listed in the ITPGRFA).

Unfortunately, the Guadalcanal collection was a causality of the Ethnic Tension, and none remained to be described and conserved.

My final task was to assist Rob Harding's ACIAR project to carry out a survey of Pacific islands in 2003 to determine the locations of the many taro viruses. What a wonderful finale. Either with Peter Revill, the post-doc on the project, or with Rob, I visited American Samoa, Fiji, Papua New Guinea, New Caledonia, Tonga, Samoa, Solomon Islands, and Vanuatu. Samples were collected, dried over calcium chloride and taken back to Australia for analysis. The results were later written up in Australasian Plant Pathology[50].

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[50] Revill PA, Jackson GVH, Hafner GJ, Yang I, Maino MK, Dowling ML, Devitt LG, Dai LC, Harding RM (2005) Incidence and distribution of viruses of taro (*Colocasia esculenta*) in Pacific Islands countries. Australian Plant Pathology 34: 327-331.

The end of TaroGen

It is not my intention to be critical, there's no reason now, the passage of time has eroded feelings. But I need to point out the repercussions from the events that occurred. There are lessons to learn, and comparisons with recent pest incursions to make.

SPC did take over TaroGen in 2002. By then, the ACIAR projects on viruses and DNA fingerprinting had completed their work, HortResearch had succeeded in developing a lab method for differentiating blight-tolerant breeders' lines, and IPGRI's input on collecting and conservation was over. All that SPC had to do was channel funds to the breeding programs with 2-years' funding from AusAID, and this it did. It also held the 3rd Taro Seminar in 2003 obtaining funds from a number of donors[51]. A fitting finish to TaroGen.

SPC does not have a pool of funds of its own making, it relies totally on donor funding, apart for small contributions from Pacific island members. Transferring the project to SPC was not a guarantee of sustainability: it was still going to require funding, either funds from ACIAR, AusAID (AusAID was absorbed back into DFAT in 2013 as Australian Aid) or other donors. Additionally, SPC did not have staff who were agronomists or plant breeders; and, crucially, it lacked the expertise to administer a broad technical project of this kind, as was also seen a decade later with the implementation of the EU-funded International Network for Edible Aroids (INEA).

However, to SPC's great credit, it kept the Samoa taro breeding program going after the Project's 2-year extension under its management. Tolo Iosefa, a graduate research associate under the PRAP farming system sub-project, joined USP Alafua and took charge of the program, moving it from USP Alafua to MAF. In 2003/2004, Tolo visited Vanuatu and together with Vincent Lebot selected TANSAO lines mainly from Malaysia, to broaden the genetic diversity of the Samoan breeding program (Vincent Lebot, pers. com., 9 October 2020). The Malaysian varieties were of exceptionally good taste and with waxy leaves that repelled water droplets (and perhaps other properties) were tolerant to taro leaf blight. In this way, the program incorporate genes from the Asian genepool. Tolo did an exceptional job, without the backstopping of a qualified plant breeder, except for only occasional sharing of experiences with Vincent Lebot in Vanuatu. He continued to operate the program until its closure in 2020.

Also, to the credit of NARI, it found funds to keep the breeding program going in Papua New Guinea; new lines have been produced, community assessments carried out, and distributions made.

No part of TaroGen remains active now, but there is an extensive literature from the results of the program[52]. So, we might conclude that this is the end of the taro leaf blight saga. But, unfortunately, that would be wrong.

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[51] Third taro symposium. Edited by Guarino L, Taylor M, Osborn T (2003) Report of a meeting (technical). Secretary of the Pacific Community. 242 pp.
[52] Singh D, Jackson G, Hunter D, Fullerton R, Lebot V, Taylor M, Iosefa T, Okpul Tom, Tyson J (2012) Taro Leaf Blight—A Threat to Food Security. Agriculture 2: 182-203.

Is there more still to do?

Fifty years is a long time to solve one crop disease, but I suppose it's not surprising it has taken a while. After all, taro leaf blight is caused by a *Phytophthora* – a word that translates from the Greek as 'plant-destroyer'. The important task for me, and I hope for others, is to look back through all those years to find out if there are any lessons to learn. There's no doubt there will be other outbreaks of pests and diseases, so is the region ready? But before we come to that, and before we pat ourselves on the back as some papers and reports seem to have done, we should ask if we have finished with taro leaf blight, or whether further work is required.

I think there are several needs: we should be careful when writing about the history of taro leaf blight; we should review the breeding programs of Papua New Guinea and Samoa, detailing what occurred, the achievements as well as the difficulties, and look at present needs; and above anything else, it is critical to make the breeders' lines accessible to farmers in the Pacific.

Just the facts!

I would like to see a moratorium on people voicing unsubstantiated opinions on the taro leaf blight saga in the Pacific. It is a serious disease which has had serious consequences; it should not be hijacked by specious attempts to link it, for instance, to climate change or the need to collect, use and conserve taro genetic resources, regardless of the importance of these issues. Uncorroborated views undermine the successful efforts of regional collaboration, including the generosity of countries, such as donations of germplasm by the Federated States of Micronesia, Palau and the Philippines at the time of the epidemic in Samoa in 1993.

In response to that outbreak, there was no region-wide collecting for the taro breeding programs of Papua New Guinea or Samoa; we knew exactly where to go for the parents that were needed: they came from Micronesia and the Philippines, or we used wild Bangkok and its hybrids, which were part of the already-established breeding program in Papua New Guinea.

It is true that collecting was done in the Pacific under TaroGen to produce a core collection. However, it was done in case there were further outbreaks of taro leaf blight in this blight-susceptible genepool. The Pacific core and that assembled from the Asian genepool by TANSAO were later conserved in a purpose-built germplasm centre established by TaroGen, and later expanded by SPC to become CePaCT. The cores of those collections now need to be assessed by the same molecular markers and an Asia-Pacific combined core identified.

In a recent article, we hear that botanical expeditions were launched to gather wild relatives of taro from their centres of origin, and used "in a 10-year breeding cycle process to produce TLB-resistant varieties and replant the fallow fields of Samoa", and in the process to "distribute to countries worldwide affected by the blight, aiding in staving off potential famines and economic crises"[53]. It's not that these accounts have no basis in fact, but they exaggerate the truth greatly.

[53] Alexandra S, Jamora N, Smale Melinda, Ghanem M (2020) The tale of taro blight: a global effort to safeguard the genetic diversity of taro in the Pacific. Food Security: https://doi.org/10.1007/s12571-020-01039-6.

Distribute blight-tolerant lines to growers

One of the main risks to TaroGen achieving its objectives, according to the 2000 Review, can be found under the heading 'Improved taro varieties are not distributed to farmers in the Region' in the section 5.3 Risks[54].

Leaving aside the fact this risk might seem to have been premature after only 2 years of breeding, having identified it, the Review made no realistic suggestions how it might be avoided, except:

"… to increase the awareness of the breeding program and help support the RGC to establish a role in the distribution of taro germplasm in the Region. This role may simple be to provide national agencies (or projects) within countries with improved lines. If these options are not satisfactory, AusAID should consider the merit of funding a project specifically to propagate and distribute improved lines within the Region".

The identification of this risk was indeed prescient. Twenty years after the beginning of TaroGen, SPC's CePaCT (previously the RCG) is still dealing with the problem of getting its taro accessions (and other root crops) to farmers. The reason is simple: SPC can deliver its crop accessions to government agencies and NGOs, and does so with commendable efficiency, but leaves it to the countries to carry out evaluations and distributions to farmers. The result is that none reach them, or only an insufficient few. Not only are farmers left vulnerable to taro leaf blight, but also SPC's collections are not evaluated.

Whether or not SPC requested AusAID to consider the merit of funding a project specifically to propagate and distribute the improved lines, I don't know, but I expect not.

In 2018, for the first time, taro tolerant to leaf blight were provided to farmers, other than those who were members of the TIP Samoa. Six thousand plants of two Samoan breeders' lines were distributed in Fiji. This is about half a hectare of taro when planted at spacings of 1 to 1.5 m.

Apart from Fiji, no other country has attempted to distribute blight-tolerant taro, even though they have been available through SPC for 15 years. In 2009, for instance, cycle 2 and 3 lines from Samoa were sent to six Pacific island countries, and others were supplied in the following years, but none reached farmers[55].

Why aren't leaf blight-tolerant taro grown by farmers in countries vulnerable to the disease?

It cannot be because their importance is unknown. What happened in Samoa in June 1993 is known universally across the Pacific. There is even a Wikipedia site about how taro leaf blight was able to "ravage Samoa's taro"[56]. Furthermore, there can be no doubt that there is a willingness to deal with the disease. There is a fear it may spread. As a consequence, three countries (Cook Islands, Fiji and Tonga) are trying to breed blight-tolerant taro, proving their concern should the pathogen spread once more (see page 51).

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[54] Mid term review op. cit., p.10.

[55] Jackson G, Walton P (2017). The fate of CePaCT germplasm in the Pacific islands: 2009-2015. Pacific Agriculture Policy Project. 54 pp.

[56] Taro leaf blight – Wikipedia. https://en.wikipedia.org/wiki/Taro_leaf_blight

We are left with only one conclusion: that the logistics and costs involved in making farmers aware of the importance of growing at least a few tolerant plants, and then introducing, quarantining, multiplying, distributing the plants, and then monitoring the results are too great for most Pacific island economies. It is a very expensive exercise, clearly shown by Andrew McGregor's report[57].

Of course, there is no guarantee that farmers will hold on to the blight-tolerant taro in case the blight arrives, even if they are distributed. Convincing them to do so may be difficult because most farmers have never seen blight and the devastation it can cause so it will be difficult for them to imagine the impact.

It is a situation not dissimilar to preparing for climate change: people in the Pacific have to be convinced that it's likely to happen, and large amounts of money are needed to adapt and mitigate the possibility it will occur, money that most governments don't have.

Fiji has most to lose, of all the countries of the region, if taro leaf blight were to be introduced. It has a taro industry that is valued at around F$117 million, of which exports are put at F$23 million. The country has not moved to protect that industry from the disease. The new taro leaf blight tolerant taro have not reached farmers, except for a few mentioned that are part of its Fiji Taro Industry Plan 2017[58].

Fig. 17 The vulnerability of taro in Pacific island countries. The image show a taro from Vanuatu introduced to Samoa in order to improve the quality of corms of the breeders' lines. This and other varieties were found to be extremely susceptible, just as susceptible as those grown in Samoa and struck down by the disease in June 1993. A reminder of the destructive nature of taro leaf blight and the need to distribute taro leaf blight-tolerant breeders' lines to farmers as soon as possible.

But Fiji is not alone: Cook Islands, French Polynesia, New Caledonia, Niue, Tonga, Vanuatu, Wallis and Futuna are as yet free of the disease, but vulnerable (Fig. 17).

Crucially, there has been little or no research on ways that root crops move between farming communities in Pacific island countries. It is likely to differ between locations, and this information is needed before large distributions are made. Modelling to discover the most efficient ways to organise them is essential.

[57] Ibid. p. 34.
[58] The strategic 5-year plant for the economically and environmentally sustainable Fiji taro industry.

Fiji took over the export market from Samoa, only to become more vulnerable to taro leaf blight by increasing the area of taro grown; so when taro leaf blight epidemics occur in Fiji (as they inevitably will), the extreme susceptibility of the export variety, Tausala ni Samoa and all other varieties in the country, will usher in a disaster similar to that which occurred in Samoa in 1993. Varieties Tausala ni Samoa in Fiji and Niue in Samoa are the same, grown for the New Zealand market which has become accustomed to its culinary characteristics and shelf-life, although, traditionally, it is not the most favoured taro in either country.

Perhaps only another outbreak of taro leaf blight in the Pacific islands will result in the breeders' lines being distributed. If that's the case, then it will be a sorry day.

Pacific island countries are not the only ones that have difficulty in getting improved taro to farmers. At the start of INEA in 2010, 16 countries throughout the world received 50 accessions from SPC, many from the Samoa and Papua New Guinea breeding programs. None of these countries have reported successful distributions to farmers, although some are carrying out on-station evaluations. This is regrettable as recipients in West Africa received consignments immediately after taro leaf blight epidemics occurred on the continent for the first time in 2010.

My visit to Nigeria in 2012 showed that the Samoan lines were performing just the same as they were in Samoa in regard to taro leaf blight tolerance, and I am certain they will continue to do so. That they have not been given to farmers is a great pity. The more so as taro is the crop of the poor, and even though the Pacific varieties might not be favoured over the eddoes types grown in West Africa[59], they might suffice as a stop-gap until hybridised with local varieties.

As mentioned above, the TaroGen Review identified the risk of not getting the new lines to farmers, but either did not understand the difficulty, or did not want to come to terms with what it would involve. All it said was there should be more awareness or, if that did not work, then AusAID should consider alternative strategies. Neither of these suggestions was particularly helpful!

Countries and SPC need to confront the problem, and seek donor assistance.

Obviously, distribution should have been funded as an extension of TaroGen, as many of us expected at the time. We will never know why TaroGen was terminated so abruptly. No one has ever said that it was not a successful program, even with a poor design! Possibly, the decision was just part of countries and donors' reticence to invest in food crop staples which are mostly produced in the subsistence economy. For DFAT, for instance, economic integration with larger more advanced Pacific-rim countries has been the centrepiece of its aid delivery in the Pacific region, in line with the Australian Government's aid-for-trade policy and its focus on investment in private sector development.

[59] Eddoes differ from the Pacific dasheen (thought to be a corruption of the expression, de Chine – from China), having smaller central corms and many surrounding cormels; dasheens have a large central corm and many suckers arising from it.

Review taro breeding in the Pacific

Breeding strategies?

There's a need to understand what has been done by taro breeders in the last 20-30 years as it is not clear. We need to know if the correct strategy was used and whether it would be useful to continue breeding, perhaps incorporating tolerance to climate change putting into effect the work done by the University of Madeira with INEA support. A protocol to screen taro for drought tolerance now exists[60,61].

The TaroGen 2000 Review did have something to say about the breeding approach used, but only to show how difficult it is for people who are not well versed in plant breeding to understand the appropriate approach to a disease such as taro leaf blight, the nature of which has the potential to cause sudden and explosive epidemics. The report states the following:

> *The team was surprised at the emphasis on establishing multigenic (horizontal) resistance to TLB. The recurrent selection program provides a good long-term approach to providing new varieties, but it can be slow. If varieties with single gene (vertical) resistance could be released faster, then this approach could improve food security sooner without substantial risk to an industry, as long as further lines were released. A combination of both approaches would be optimal.*

We know that vertical resistance is not the strategy to follow. It might be fast, or faster than creating horizontal resistance, but that's not the point: it is insecure. It can break down as it selects individuals with the genetic capability of overcoming host resistance. Speed is not of the essence here, although as TaroGen showed even horizontal resistance can achieve success in a remarkably short time with good advice and a good source of tolerant cultivars.

To be clear, vertical resistance could, theoretically, be used if the pathogen population is stable (David Guest, per. comm., May 2020). However, results from the analysis among *P. colocasiae* isolates from South and Southeast Asia using enzyme and molecular markers showed that there was considerable variation both within and between countries, although links to pathogenicity were not established[62,63]. Furthermore, mating types do exist, with the so-called A1 strain restricted to Hainan Island, China, and northern India, and the A2 strain in those countries as well as many Pacific islands and Southeast Asia. If the A1 strain were to spread to the Pacific and hybridise with local strains there is the potential for more virulent forms of the oomycete in which case vertical resistance based on a single dominant gene might not be sufficient protection[64]. In that case, the situation could become similar to potato late blight caused by *Phytophthora infestans* in Europe[65].

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[60] Ganança JFT, Freitas JGF, Nóbrega HGM, Rodrigues V, Antunes G, … Lebot V (2015). Screening of elite and local taro (*Colocasia esculenta*) cultivars for drought tolerance. Procedia Environmental Sciences 29:41- 42.

[61] Ganança JFT, Freitas JGF, Nóbrega HGM, Rodrigues V, Antunes G, … Lebot V (2017). Screening for Drought tolerance in thirty three taro cultivars. Hotulae Botanicae Horti Agrobotanici Cluj-Napoca 45(2). DOI:10.15835/nbha45210950.

[62] Lebot V, Herail C, Gunua T, Pardales J, Prana M, Thongjiem M, Viet M (2003) Isozyme and RAPD variation among *Phytophthora colocasiae* isolates from South-east Asia and the Pacific. Plant Pathology 52: 303-313.

[63] Mishra AK, Sharma K, Misra RS (2010) Isozyme and PCR-based genotyping of epidemic *Phytophthora colocasiae* associated with taro leaf blight. Archives Of Phytopathology and Plant Protection 43(14): 1367-1380.

[64] Tyson JL, Fullerton RA (2007) Mating type of *Phytophthora colocasiae* from the Pacific region, India and South-east Asia. Australasian Plant Disease Notes 2: 111-112.

[65] Late blight is considered an increasing problem in Europe, with more aggressive strains, likely related to the presence of both A1 and A2 mating types (see ProMED posts: http://www.promedmail.org).

Thus, a combination of both approaches is not what is wanted. In fact, the concern in Papua New Guinea, but not in Samoa, has always been that vertical resistance is present in the breeding populations, and should be removed. The TaroGen Taro Breeding Workshop (Suva, Fiji, 26-28 August 1998) discussed this problem and concluded that before new cultivars are released they should be self-pollinated, and any that show Mendelian ratios for resistance to taro leaf blight should be discarded[66]. This has not been done for the released lines from the PNG breeding program. It is needed.

Another reason for a review is that taro breeding is being carried out in other countries in the region. In 2014, a project began with support of the AusAID International Climate Change Adaptation Initiative (and the 3rd call of ITPGRFA) to produce lines in Cook Islands, Fiji and Tonga with tolerance to blight. SPC was implementing agency with support from the Samoa taro breeding program.

A meeting in Santo, Vanuatu, in mid-2014, brought the project partners together to discuss the strategy. They formed a breeders' network. Each country would introduce the Samoan tolerant taro leaf blight varieties from SPC as tissue cultures and create hybrids between them and their favoured taro cultivars. Seedlings would be raised for evaluation by growers, and the best would be evaluated for blight tolerance.

But there was a problem. These three countries do not have taro leaf blight, and so they cannot make selections that are tolerant to the disease. The solution was to send a few of the progeny to Samoa for testing.

However, this strategy is not only unwieldy, but also unlikely to work. As Raoul Robinson says in *Return to Resistance*:

> *… when breeding plants for horizontal resistance it is necessary to select for all desirable variables at one time* (page 89).

In other words, you need a large population and within that you select for all the characteristics that are favoured by farmers, including taro leaf blight tolerance in this instance, and you do it all at the same time. That means it is very difficult to breed for horizontal resistance in the absence of the pathogen. By selecting only 20-30 plants from each country for screening in Samoa is not likely to be enough. Selections need to be made from thousands of seedlings.

Horizontal resistance breeding is called population breeding or recurrent mass selection – the resistance of the biometrician. It deals with polygenes, and it deals with large numbers of plants. It is unlikely that all the qualities that are sought are going to be present in 20-30 plants, especially if they have not been evaluated for the foremost characteristic required – tolerance to taro leaf blight.
So, what can you do instead?

Obviously, the first thing to do is distribute Samoa's tolerant lines to farmers. That's the most urgent task (see below). And then try something novel: develop a partnership with farmers creating a participatory selection program based on Samoan taro seed.

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[66] AusAID/SPC Taro genetic resources: conservation and utilisation. Taro breeding workshop. Suva, Fiji, 26-28 August 1998. Secretariat of the Pacific Community, Noumea, New Caledonia.

The breeding program in Samoa has reach its 9th cycle, and most seedlings have high tolerance to taro leaf blight[67]. So, take seeds from Samoa and screen them with farmers in the three countries. In that way, farmers could select plants suitable for their unique circumstances: good eating qualities and adaptation to local environments. It is also likely that the selections would have blight resistance far higher than crosses between Samoan blight-tolerant varieties and very susceptible varieties of Cook Islands, Fiji and Tonga. As far as I know no one has tried to do this, but they should.

Much more important, however, would be to use the screening method for drought devised in Portugal for the Pacific, and to use that to select parents from the Pacific and Asian genepools. It would mean looking at the potential of hybridisation with eddoes (*Colocasia esculenta* var. *antiquorum*), many of which appear more drought tolerant than Pacific dasheen varieties.

Assess genetic diversity

There is need to confirm that there has been an increase in genetic diversity as a result of breeding for taro leaf blight resistance. The SPC taro breeding program in Samoa has incorporated genetic materials from outside the Pacific region, primarily aimed at developing new lines with resistance to taro leaf blight. As we have seen, those growing at the time of the blight outbreak in 1993 had a very narrow genetic diversity, and hence there was considerable vulnerability to the epidemic. New sources of resistance came from Micronesia and the Philippines, and later from introgression of selections from the TANSAO collection of Southeast Asia.

This very successful program has given rise to lines that have been distributed within and beyond the Pacific. However, in programs elsewhere with other crops that have been primarily focused on the introduction of pest and disease resistance traits, there have been a number of instances where this has led to considerable narrowing of the genetic diversity of the crop population. The population mean has shifted, yet overall diversity has become or remains low (Ian Godwin, pers. comm., 2017). For example, this was the case with the Australian public and private sorghum breeding programs in the 1970-90s, when the primary focus was on the introgression of midge resistance from Indian and African sources.

Ian goes on to say, there is need to check whether this is also the case with the lines produced in the Samoa breeding program. The application of DNA fingerprinting to the lines will enable a reference to be established against which the genetic diversity of taro grown in Samoa prior to the taro leaf blight epidemic could be estimated. This will give valuable information on whether the current Samoan taro lines have increased in their genetic diversity and, hence, are less likely to be genetically vulnerable to a new pest or disease incursion. Similar interests exists in investigating the released lines from the breeding program in Papua New Guinea.

[67] The program was terminated in 2020 with the retirement of Tolo Iosefa from MAFF; however, expertise remans to obtain seed from the last cycle.

Are there other ‘taro leaf blights’?

We can agree or disagree whether the fight against taro leaf blight in the region is over or not. But shouldn’t we be looking to see if there are other ‘taro leaf blights’ out there waiting to spread, or waiting on the horizon to enter the region?

And, if there are any, is the region better prepared to tackle them? Will the problems that come – and surely they will sooner than later – be dealt with more efficiently and in a timelier fashion than taro leaf blight? Here are some examples of potential crop pest problems:

- Fall armyworm, *Spodoptera frugiperda* – in PNG, early 2020
- Cassava mealybug, *Phenococcus manihot* – not in the region but in Indonesia
- Coconut false scale, *Aspidiotus rigidus* – not in the region, but in the Philippines
- Citrus greening *(huanglongbing)* - the disease is in Papua New Guinea, and the insect vector, *Diaphorina citri*, is there, as well as American Samoa and Samoa
- Papaya mealybug, *Paracoccus marginatus* – in the region
- Bogia coconut syndrome, and associated diseases in bananas – in Papua New Guinea, and now in Solomon Islands, in banana
- Coconut rhinoceros beetle, *Oryctes rhinoceros* (G) – in Guam, Palau, Papua New Guinea, Solomon Islands and New Caledonia
- Cassava bacterial blight, *Xanthomonas axonopodis* pv*. manihotis* – in Micronesia and Solomon Islands
- Banana wilt, *Fusarium oxysporum* f.sp *cubense* (TR4) – not yet in the region, but in Australia

Quite a list, and we could add more. For this exercise, we want a pest that arrived in the region at least five years ago and is causing a major problem. *Oryctes rhinoceros* beetle strain G is a fitting candidate (Fig. 18).

Coconut rhinoceros beetle

This variant of the coconut rhinoceros beetle (CRB) was first recorded in Guam in 2007. Over the next few years it spread to Port Moresby, Papua New Guinea (2010); Oahu, Hawaii, US (2013); Palau (2014) and Honiara, Solomon Islands (2014)[68]. Spread probably occurred in ships and planes whilst loading cargo, especially at night as CRB is attracted to lights.

Surprisingly, tests done in Guam showed that a virus, *Oryctes rhinoceros nudivirus* (OrNV), which has been used since the 1970s to bring outbreaks under control in many parts of Southeast Asia, did not kill the beetle. In 2014, AgResearch Ltd., one of New Zealand Government’s research entities, with extensive experience of CRB, and the source of OrNV used in the Guam trials, was engaged by the University of Guam to investigate the situation. The findings suggested that “the Guam CRB is less susceptible than other Pacific populations to OrNV infection”[69].

[68] Many reports and papers give 2015, but observations by the author in September 2015 suggest that it was well established by then, and its long life cycle would suggest an earlier arrival, but exactly when is unknown.
[69] Marshall SDG (2014) Entomopathogenic virus for biological control of coconut rhinoceros beetle on Guam. Final Report for the University of Guam. RE400/2014/537. 35 pp.

Follow-up work by AgResearch Ltd. maintained that the Guam or G-strain beetles could be distinguished from beetles descended from the original introductions to Fiji, Samoa, Tonga and elsewhere in the Pacific (the so-called Pacific P or S strain) based on differences in the mitochondrial COI gene[70]. The P strain is still considered to be susceptible to OrNV infection whereas the G strain is not[71].

Fig. 18 Adult female *Oryctes rhinoceros*. The horn of the male is larger. The length of this beetle is 4.3 cm, others can be larger. The beetle bores through the base of the fronds into the crown to macerate still folded leaves and feed on the juices. Usually, the palms are not killed, except when number are high and the growing point is damaged. (Image kindly provided by Mani Mua, Pacific Community, Sigatoka Research Station, Fiji).

It was also said that the G-strain is less attracted to an aggregation pheromone, and capable of greater aggression[72] - meaning damage to coconut palms was greater than that made by the P strain, and in many cases killed the palms[73].

2015 was the first time that CRB had been seen in Solomon Islands, and there was concern for both coconut and oil palm industries as well as the livelihood and food security of rural communities. In the absence of natural enemies, the beetle ran rampant (Figs. 19-23). Other Pacific island countries were similarly alarmed: the G-strain might herald a time before OrNV was discovered and suppressed populations, the single most effective biological control treatment.

Immediately, Biosecurity Solomon Islands sought supplementary funding from the SIG, but it was not forthcoming. However, BSI did its best as did the research and extension divisions to fight the invasion using MAL recurrent budget allocations, and funding from an FAO TCP. The project primarily funded work to introduce the two most successful control methods *Metarhizium anisopliae* and OrNV, initiate a campaign to publicise cultural control methods and a study to see how domestic quarantine might be implemented. In the end only the work on pathogen introduction and some work on publicity was done. There were also visits by AgResearch Ltd. to Solomon Islands and several OrNV isolates from the institute's collections were tested[74].

70 Somewhat confusingly, S and P are both used in reports and other literature for the same beetles: S for susceptible; meaning susceptible to OrNV, and P for Pacific referring to the beetle.

71 Marshall SDG, Moore A, Vaqalo M, Noble A, Jackson TA (2017) A new haplotype of the coconut rhinoceros beetle, *Oryctes rhinoceros*, has escaped biological control by *Oryctes rhinoceros nudivirus* and is invading Pacific Islands. Journal of Invertebrate Pathology 149: 127-134.

72 SPC LRD Pest Alert: https://www.spc.int/sites/default/files/wordpresscontent/wp-content/uploads/2017/08/Pest-Alert-52-Coconut-Rhino-Beetle2016-spc-lrd.pdf.

73 The adult beetles do the damage to palms by boring into the growing point to feed on the juices of the young leaves; this damages the leaves and can be seen when they grow out of the crown and expand with parts missing. With many beetles attacking at one time as occurred in Solomon Islands, because there was no virus or other natural controls, the chances of death of the palms was increased, especially if the growing point (the shoot) was damaged. On a coconut or oil palm the shoots is at the top of the palm.

74 Sulav Paudel S, Mansfield S, Villamizar LF, Jackson TA, Marshall SDG (2021) Can Biological Control Overcome the Threat From Newly Invasive Coconut Rhinoceros Beetle Populations (Coleoptera: Scarabaeidae)? A Review. *Annals of the Entomological Society of America,* XX(X), 2021, 1–10. doi: 10.1093/aesa/saaa057.

Two isolates showed promise. Unfortunately, the virus lab became contaminated with fungus and had to be reorganised. More requests were made for Government funding, but they were declined. Offers of assistance were made by a sub-regional IPM project after seeing the damage in September 2017, but it did not lead to the projects' involvement at this time[75].

GPPOL, the oil palm company on the Guadalcanal Plains, was made aware of the presence of CRB as soon as it was discovered in Honiara. There was concern that windrowed palms in replant areas presented CRB with breeding sites. In response, the company imported and released a commercial *Metarhizium* preparation from Malaysia and brought in pheromone traps in order to monitor beetle populations[76].

Nevertheless, the windrowed palms became severely infested in the replant estates[77]. It mattered little that a ground legume (*Pueraria phaseoloides*) was covering the rotting trunks, which elsewhere has been considered beneficial in reducing accessibility of adult beetles to potential breeding sites (Figs. 21&23). In 2017, the company resorted to breaking up the windrowed palms, collecting the larvae, and safeguarding adjacent young palms with Furadan granules in the base of fronds.

Meetings between governments, palm industries in Solomon Islands and Papua New Guinea, regional agricultural organisations and research institutes, began in earnest in September 2017 (Papua New Guinea) and again in February 2018 (Solomon Islands) to develop management practices for estates and smallholders, and to stop CRB spreading further within Solomon Islands as well as to other Pacific island countries.

The February 2018 meeting announced that The New Zealand Aid Programme would commit funds to AgResearch Ltd. for 3 years to produce an IPM plan bringing together control methods into a single package - staff training in sanitation (mostly getting rid of breeding sites), improved agricultural practices, introduction of *Metarhizium* to artificial breeding sites and pheromone trapping - to limit impact of the G-strain, and to develop a CRB network of R&D personnel, both in Solomon Islands and nearby countries. Later, in 2019, the NZAID agreed to long-term funding on management solutions based on biological control as part of an IPM strategy.

Australia also committed to long-term assistance. Late in 2018, a second phase of the ACIAR IPM project started and after discussions with Fiji, Papua New Guinea, Samoa, Solomon Islands and Tonga, work began on more fundamental aspects of the beetle invasion, first, to understand what the differences between the mitochondrial DNA of G and P strains might mean biologically, and, second, to investigate G-strain (and other strain) responses to OrNV.

[75] PC/2010/090 *Strengthening integrated crop management research in the Pacific islands in support of sustainable intensification of high-value crop production*, funded by ACIAR and implemented by UQ in collaboration with SPC. Phase II (HORT/2016/185 began in 2018

[76] Bob Macfarlane, pers. comm., July 2020.

[77] In 2016, GPPOL, Guadalcanal Plains Palm Oil Ltd., were reporting handpicking 9000 larvae per ha per month from windrowed trunks in replant areas, and, in 2017, 12000 adults from pheromone traps from four of its estates, before numbers declined.

Fig. 19 Extreme damage to mature coconut palms by *Oryctes rhinoceros* near Honiara, Guadalcanal in June 2017. Typical symptoms when populations of beetle are high.

Fig. 20 Truncated fronds with missing wedge-shaped areas are typical symptoms of coconut fronds damaged by *Oryctes rhinoceros*. The damage is done as the beetles bore into the crowns to feed on the shoots. This was a ‘hotspot’ area west of Honiara, and produced large populations of larvae from rotting palms (see Fig. 20)

Fig. 21 Larvae of *Oryctes rhinoceros* at different development stages in rotten coconut trunk (left), and mostly mature larvae (right). After the trunks die they rot quickly and become preferential breeding sites for *Oryctes rhinoceros.* Both standing and fallen palms are infested equally.

Fig. 22 Two-year-old oil palm seedling attacked by *Oryctes rhinoceros* causing similar symptoms as occur on coconuts (left). The beetles bore through the base of the fronds to enter the crown (right). The low mound-like object behind the central palm is an old windrowed oil palm covered in the ground legume, *Pueraria phaseoloides*. These rotting trunks are excellent breeding sites for the beetles.

Fig. 23 As with coconuts, rotting oil palm trunks are excellent breeding sites for the beetles. Large numbers of larvae occur at all stages of development (left). The larvae of *Oryctes rhinoceros* larvae are typically C-shaped (right)

A year later, Australia also provided funds for SPC, through a coconut livelihoods project to investigate *inter alia* management options for both CRB strains G and P.

In addition, PHAMA, an Australian Aid initiative, co-funded by The New Zealand Aid Programme, which had supported a technical coordinator in Solomon Islands from 2017, also provided funds in 2019 for an overall CRB Project Coordinator based in Honiara, a person experienced in guiding complex international programs. The result was a Biosecurity Emergency Coordination Centre within MAL.

However, these initiatives, welcomed as they were, could not prevent further spread of the beetle. By 2019, all large islands of Solomon Islands were infested, and the beetle appeared for the first time in New Caledonia and Vanuatu (where attempts are being made to eradicate it). Tragically, few Pacific island countries are now free from infestation by this beetle, whether it is the original (Pacific S or P strain) or strains newly recognised[78].

What lessons can be learned?

The CRB outbreak has much in common with the taro leaf blight epidemic in Samoa in 1993. They are both events of major economic importance, so a comparison of the two is justified to see if the region is better able to deal with alien pest invasions 25 years on. Are there any lessons to learn?

What's luck got to do with it?

I have suggested that luck played a part in the success of the taro leaf blight story, as if it was crucial to its success. Whether it was or was not is open to interpretation. It is not something that I can prove one way or the other. What is luck anyway? It is the spin we put on experiences - positive or negative - that occur seemingly at random. The more unlikely they seem, the more likely, some will say, that it was luck!

In my case, events happened; mostly, they were positive, although the closure of Dala was certainly negative, and I was left to deal with them in the best way that I knew how.
It was a chance event to go to Thailand and see taro alongside the road with ripe fruits, and for workers to be on hand to haul the plants to my waiting taxi; for Moses to plant out seedlings from the Thai taro and show they had blight resistance; to send Fiji taro to Pohnpei to find they were susceptible, and, by contrast, Micronesian taro were tolerant to blight; and, perhaps greatest of all, that AusAID had a couple of million as if it was waiting for someone to come along and help spend it!

As a scientist, I can't believe that the events were anything other than random happenings, nothing more, nothing less. I certainly don't want to believe that they were connected with anything outside the laws of nature, anything of supernatural origin. Just random events.

Nevertheless, they were important because of what we made of them. Whether they occurred through deep conscious thought or a sudden "aha! moment" due to a rush of realisation thrust into daylight from the deep recess of the mind is immaterial. Each event took us to a new

[78] It is now known from the work of UQ that there are at least three strains of beetles in the region: i) G; ii) S or P, and iii) PNG. Apart from being in Papua New Guinea, the latter has been detected in Solomon Islands, Vanuatu and also in Samoa. In New Caledonia, strain G is present.

level, and a realisation that if we continued to plod away, we would succeed eventually to beat the blight. Perhaps I would like to think that "chance favours individualised action" as it has been put, because I behave in a certain way![79]

Whatever the case, the "lucky" events certainly helped to concentrate the mind.

Can we find similar events with CRB? Possibly, although not to the same extent. It is still early days. However, it was certainly bad luck that, like taro leaf blight, CRB invaded unopposed, at about the time oil palms were being replanted so that by 2017/18 a massive population was breeding in the old windrowed palms. But once the situation was realised it created an emergency: funds were made available by MFAT for AgResearch and by New Britain Oil Palm Co. for OPRA, its research wing, and activities to control the beetle began in earnest. This was lucky.

It was also serendipitous that at this time DFAT (Australian Aid) funds through ACIAR became available for the start of UQ's regional IPM project (HORT/2016/185), which set to work checking the beetle strains of Solomon Islands and elsewhere in the region, and searching for virus infection. In the process a much clearer picture of the ecological consequences of the new wave of invasive beetles became available, and the virus-resistance of the G-strain was challenged by the discovery that an OrNV isolate, similar to one from Philippines, was now in Solomon Islands[80].

The result confirmed earlier findings by AgResearch Ltd. - first, in Guam that G-strain beetles are not resistant to OrNV and, second, in Palau, that OrNV occurs in G-strain beetles in the wild[81,82]. However, there is no evidence, as yet, that infection leads to early death or reduced fecundity, or that it will bring the infestation under control. Tests still need to be done.

However, UQ has also shown that differences between beetles depending on their mitochondrial genes (G, S/P or PNG) cannot be linked to biological differences between them. The usefulness of these mitochondrial genes is limited to informing about their movement into and through the region. When the different haplotypes (G, S/P and PNG) are interbreeding, it is more likely that the nuclear genes will determine biological differences, for example resistance or susceptibility to virus[83].

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[79] Austin JH (1979) The varieties of chance in scientific research. Medical Hypotheses 5: 737-742. Austin differentiates four kinds of luck, resulting from: i) an accident; ii) general exploratory behaviour, iii) sagacity; iv) personalised action. The personality traits for iv) "depend on distinctive, hobbies, personal life styles, and activities peculiar to you as an individual, especially when they operate in domains seemingly far removed from the area of the discovery". He refers to this as 'altamirage' – "the facility of encountering unexpected good luck as a result of highly individualised action".

[80] Etebari K, Filipović Igor, Rašić G, Devine GJ, Tsatsia H, Furlong M (2020) Complete genome sequence of *Oryctes rhinoceros nudivirus* isolated from the coconut rhinoceros beetle in Solomon Islands. Virus Research 278.

[81] Marshall SDG (2014), op. cit.

[82] Marshall SDG, *et al*. (2017), op. cit.

[83] Etebari K, Hereward J, Ahoafi EM, Tautu R, Tsatsia H, Jackson GV, Furlong MJ (in preparation) Genetic structure of the Coconut Rhinoceros Beetle *(Oryctes rhinoceros)* population and the incidence of its biocontrol agent *(Oryctes rhinoceros nudivirus)* in the South Pacific Islands. Current Research in Insect Science.

Preparing for the inevitable

Is the region prepared for further transboundary pest invasions?

Taro leaf blight hit the Samoan islands without warning in 1993. It struck American Samoa first, and then in no time arrived in Samoa 165 km to the west. There was no monitoring for the disease, even though taro was the number one agricultural export of Samoa and the disease was known to be in the region. Similarly, Pacific island countries were not monitoring for CRB strain G which was known to be on the move. Placing pheromone traps at ports of entry might have been useful, as well as encouraging people to report unusual coconut symptoms in countries thought to be yet free from the beetle.

Not only was there no monitoring but no detailed contingency plans were available for either pest in case they breached biosecurity barriers and eradication was a possibility[84]. It is well recognised that in terms of costs, it is best to prevent invasive alien species from entering, establishing and spreading than attempting eradication, containment and control. But to be effective there is need for adequate legislation, identification services, supplies of materials on hand (chemicals, spray machines, vehicles), agreed job descriptions for those taking part in action programs, training and practice. These come at a cost, and it is often difficult to get funds for such preparedness. The measure of success for such schemes is a non-event, and that is hard to get excited about!

But how useful would such plans be for taro leaf blight or CRB where risk of invasion was high? They might be useful if eradication was a possibility, for example, if a fruit fly species was intercepted, identified quickly and pheromone trapping was known to be effective, but for a disease with the multiplication potential of taro leaf blight, there would be little chance of eradication after it had entered and established, especially if host plants were susceptible and environmental conditions conducive to rapid spread. Similarly, for CRB, eradication attempts would probably have been futile, even if the beetle had been spotted earlier in Solomon Islands. The number of beetles entering the country would likely have been low, perhaps a single egg-carrying female; small populations creating little damage would be difficult to notice at first, only slowly increasing over the months until symptoms became obvious. At that time, eradication would have been a forlorn hope.

There is anecdotal evidence that the S or P strain was in a remote part of Solomon Islands for several years before it was reported. It is also likely that the G strain was in Honiara for several generations, at least 3-4 years, before it was discovered[85].

Probably the most that can be done under such circumstances is to develop emergency response plans, build well-resourced biosecurity systems, train all agriculture staff to identify the most important pests with invasive potential, establish ways of getting fast and reliable identifications made and to have relevant information on management close at hand. In fact, several countries in the region – Fiji, Samoa, Solomon Islands and Tonga – are doing just that.

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[84] Generic contingency plans had been drafted by SPC, and were used to advise the first steps of the Solomon Island response – a delimiting survey – but were not written for *Oryctes rhinoceros* specifically.

[85] Bob MacFarlane, pers. com., July 2020.

Information on the region's pests is being packaged into fact sheets for mobile devices, and staff encouraged to consult them[86]. Additionally, plant health clinics are being rolled out by extension services – following a model initiated by CABI under its Global Plant Clinic program for Africa, Asia and Latin America, and expanded under Plantwise - potentially, providing a system for detecting alien pests. Further, WhatsApp groups have been established in these countries to identify pests rapidly from photographs sent by extension officers. The problem with all these sensible suggestions is that it costs money to deal with incursions once they have occurred, and rarely are funds made available in a timely manner.

At the very moment that I write this, the fall armyworm has begun its invasion of Australia. It first made it to the islands of Saibai and Erub, in the Torres Strait on about 12 February 2020, and a few days later was spotted on the mainland at Bamaga on the tip of Cape York. By 25 February, it was 1000 km to the south in Georgetown, and recorded in northern Western Australia. It is now in Papua New Guinea, and from there it will likely make its way to other Pacific island countries. Countries should set pheromone traps to monitor the armyworm in order to map hot-spots of the invasion and determine which crops are most damaged; they should also advise communities how they should respond. It is likely this will only happen if there is donor assistance.

Reacting to major pest outbreaks

Now let us turn to events after both taro leaf blight and CRB became established, when thoughts of eradication had been abandoned, and the focus turned to containment and control. Was the response any better for CRB than it was for taro leaf blight?

As we have seen, FAO reacted immediately in both instances, assisting through TCPs; SPC was involved at an early stage, too, with coordination, and assistance with *Metrahizium* control. In 2015, the Pacific Plant Protection Organisation meeting, the Secretariat of which is hosted by SPC, requested SPC to coordinate a search for funding, and to establish and manage a program to "minimise impact from the newly discovered G biotype of coconut rhinoceros beetle"[87].

Other donors contributed at this early stage. Australian Aid assisted with coordination and technical advice in Solomon Islands through PHAMA, and later backed research by UQ through ACIAR. The New Zealand Aid Programme supported research by AgResearch Ltd. that was involved in the Guam outbreaks a few years earlier, and was a source of OrNV for the already CRB-infested countries of the region.

The difference between the two outbreaks was that major funding to deal with taro leaf blight took five years, whereas for CRB it was three. AgResearch Ltd. began a regional program in February 2018 and UQ started to research beetle genetics and biocontrol options later that year. This is an improvement. But three years is still a long time before an appropriate response is mounted to a pest with a history of causing considerable economic impact in the region.

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[86] The app Pacific Pests and Pathogens is available for download from Apple and Google stores, containing a majority of the common pests of the Pacific island countries as well as those not present but with invasive potential..

[87] The matters arising from the 2015 PPPO/RETMPP meeting were discussed at a PPPO Executive Meeting, and reported in the Minutes of the 9th Pacific Plant Protection Organisation (PPPO) Board Meeting and the 17th Regional Technical Meeting Plant Protection (RTMPP), 23-24 August 2018, Nadi, Fiji Islands. 57 pp. The PPPO is one of the Regional Plant Protection Organizations recognised by the International Plant Protection Convention hosted by FAO.

Coordination and cooperation

Once TaroGen was funded, it accelerated taro breeding and assumed the role of program coordination, which was crucial. There were frequent meetings with the team leaders of associated projects on DNA fingerprinting, virus-indexing, germplasm collecting and conservation, lab assessments of leaf blight tolerance, eight Pacific island countries and NGOs, all reporting to the one program director. In this case, the program director was a member of the commercial company that had won the contract to implement TaroGen. It was a fulltime job. It was imperative to have one person in charge overall.

By contrast, it's fair to say that the new *Oryctes* invasions – have been a huge challenge to national agencies, regional organisations and donors. Commercial oil palm concentrated on destruction of breeding sites, insecticide applications, mass trapping using pheromone and surveys for new virus strains – a 'collector' was recruited by PNG OPRA to source new OrNV isolates from Southeast Asian countries. Resources were made available to do whatever was necessary. Government agencies focussed on the smallholder coconut sector and, together with overseas institutes and donor support, embarked upon a wide-ranging program of awareness, IPM practices, and research into biological control.

Coordination of the contributing parties was not centralised in contrast to TaroGen, and different groups met according to affiliations with research institutes and respective donors. Occasionally, teleconferences were held which tried to bring the parties together, but key partners were often neglected. What was needed was a coordination of inputs and strategic direction to address the needs of the region, and this should have been administered by a unit independent of the parties, but one that they all respected.

Cooperation is another issue for comparison. Although there have been several regional meetings bringing together countries concerned with taro leaf blight and CRB, it has been noticeable that there have been few exchanges of technologies or sharing of experiences between those countries where CRB invaded recently and those where it had been present for more than 100 years[88]. This was surely a major oversight. It was only in late 2019, for instance, that staff from the very active CRB program of Fiji visited Solomon Islands to demonstrate inexpensive beetle capture techniques, and where they were best placed to collect a maximum number of beetles.

An emergency or just another research project?

It felt at times to me as an onlooker that the response to CRB lost sight that the outbreak in Solomon Islands was an emergency, not 'business as usual'. This was not a time for training or even long-term research; it was a time for action. It was a time for bringing countries together to help formulate an emergency response plan, and for recruiting a program manager experienced in coordinating outbreaks of this kind.

The removal of breeding sites, particularly fallen coconuts after cyclones, a concentration on residual 'hot-spots' using simple traps laced with pheromone, and introducing OrNV into the environment, have been the mainstay of management measures keeping CRB in check since

[88] It was not until 2018 that it was suggested "to have a skills audit around the region to ascertain where the technical expertise available are (sic) that would be called during an emergency". See 9th Pacific Plant Protection Organisation (PPPO) Board Meeting and the 17th Regional Technical Meeting Plant Protection (RTMPP). 23-24 August 2018, Nadi, Fiji Islands, op. cit., p. 29.

the 1970s. These should have been followed strictly in the current outbreak. Instead much time was spent attempting to bulk the fungus, *Metarhizium anisopliae*, and establishing it in artificial breeding sites. All evidence suggests the fungus is never likely to be effective without the complementary effects of OrNV.

It was right to check all the OrNV strains held in collections in New Zealand against the strain G beetles of Guadalcanal. Ten strains were sent to Solomon Islands for testing by Biosecurity Solomon Islands scientists in 2015, and two were selected as potentially useful, and others were under test when the work was stopped because lab-bred beetles of CRB became contaminated by fungus. However, as we have seen, in 2019, UQ reported that OrNV was present already in the CRB populations of Guadalcanal[89]. More than 60% of the beetles were infected. But not all agreed that this was anything except contamination from beetles collected in pheromone traps. But whether it was due to contamination or not isn't really the point. What matters more is whether the virus is spread between beetles in the wild and, if it is, what effect it is having on the CRB population. This still remains to be determined even though it is 18 months since OrNV was detected widespread in Guadalcanal beetle populations and reported.

A wake-up call?

Part of the problem is that in recent decades, plant protection capabilities have plummeted in Pacific island countries: research stations have been abandoned or no longer function effectively; there are few staff with the expertise needed to identify pests and diseases of concern; and there are difficulties in developing coherent strategies and plans to deal with pest problems as they arise, and especially to argue the case for funding. Worse, even when emergency funds have been agreed by governments and donors, they have either been slow to materialise, too little, or need to be spent in too short a timeframe. Add to this, the lack of unified plant health systems, with research, extension and biosecurity services often acting independently rather than collegially, it is unsurprising that when new pests and diseases arrive, or are threatening from the borders of the region, that there is an inability to deal with them.

The downturn in national capabilities has shifted the burden of responsibility for invasive pests onto regional development assistance agencies. However, they too are feeling the challenge. For instance, SPC fields requests from 26 member countries and territories, which means that with a small plant health capability it can easily become overwhelmed. It is very difficult for the organisation to devote adequate resources to the implementation of a single project or program when there are so many other issues that call upon its resources. It is not just for want of funds; it is the necessity to have well-trained and resourced staff and effective national partners.

What we are seeing is not new. Almost 30 years ago, a keynote address at an SPC seminar on plant pathology by Bob Fullerton noted the downturn in plant protection capabilities in the region that began with the move to self-government in the 1960s and 70s, a trend which has continued to the present day. SPC has provided a regional service but has traditionally had a

[89] Kayvan Etebari, School of Biological Sciences, The University of Queensland, St Lucia, Queensland, Australia, travelled to Solomon Islands to present the results of his research at a seminar held in Honiara on 9 September 2019, entitled: *Responding to emerging pest and disease threats to horticulture in the Pacific islands* (HORT/2016/185).

strong focus on quarantine matters because of its links to trade[90]. At the time of the address in September 1991, there were few national staff working as plant pathologists or entomologists, and almost no one had undergone specialist training. At that meeting only two of 18 papers were presented by Pacific nationals.

The situation today is the same or, in some countries, worse. Thirty years on, the region is almost totally dependent on outside resources for specialist skills. This being the case, it is no surprise that invasive alien pests cannot be dealt with adequately and will continue to play havoc with Pacific island country economies.

Positive signs of change

However, the need to improve national and regional plant protection is well agreed and there are attempts to make fundamental changes. Solomon Islands, for instance, has amalgamated its three divisions of plant health - biosecurity, research and extension - under one high-level portfolio; let's hope it will go on to create a plant health system, which is very much needed.

Regionally, there has been an acknowledgement that emergency response plans are needed. The 2018 PPPO meeting looked at past attempts to develop plans and tasked SPC as its Secretariat to review what was available and relevant both nationally and regionally for pests of concern. The new invasions of CRB are a reminder to develop the plans[91].

SPC has also alerted donors to the urgent need to deal with the transboundary spread of pests and diseases based on the examples given above, and framed the need in terms of climate change which is likely to exacerbate an already difficult situation Whatever the outcome of these discussions, it is to be hoped that donors are in for the long haul, as it will take many years to set up the systems required both nationally and regionally, and to make sure that they can be sustained when external funding is withdrawn. Pre-feasibility studies are needed which describe present realities, and formulate pragmatic solutions.

The region needs to develop sound plant health systems with scientists trained and resourced for the tasks. For instance, and coming back to our main theme, there is need to breed taro and other root crops for tolerance to pests and diseases, especially. But for that to happen, appropriate methods are needed, expert plant scientists, and donors that support long-term food security projects. Plant breeding has to be foremost, because for adaptation to climate change and mitigation of its effects, there is no other way. New priorities need to be set, acknowledging that tropical root crop staples in many countries contribute greatly to GDP.

A good place to start would be in national universities where biosecurity, research and extension staff are educated. Present curricula, facilities and staff training for crop protection need upgrading, otherwise it is unlikely that we will see a marked improvement in present standards. And efforts should be made to train scientists for higher degrees within the region, rather than overseas, where the likelihood of them not returning is all too common.

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[90] Seminar on Pacific Plant Pathology in the 1990s (Suva, 5-7 September 1991). South Pacific Commission, Noumea, New Caledonia, 1996. 37 pp.

[91] 9th Pacific Plant Protection Organisation (PPPO) Board Meeting and the 17th Regional Technical Meeting Plant Protection (RTMPP). 23-24 August 2018, Nadi, Fiji Islands, op. cit., p. 30

Not all countries have the economies to support viable plant health capabilities, and the research which underpins them, but they can all benefit from coming together on common problems and sharing the results. PRAP and later DSAP did this, two large EU-funded agricultural R&D programmes, and so did TaroGen, SPYN (yams), INEA (global taro improvement), and the current ACIAR IPM project. Just because there is no regional research facility does stop countries from creating regional research networks, and pooling the resources that each has to offer.

But these regional networks need to exchange knowledge, information and data from research done presently, but also previously in Pacific island countries. We don't want to repeat what has been carried out because we have forgotten or did not know. This is crucial, but often it's difficult to obtain the results of work done because it is not written up and published in scientific journals. It lies in reports and documents of various kinds that are not easily accessed.

In the past, SPC took a lead role in collecting the information that existed, and donors were keen to help. There also have been significant national efforts. NAIS, the National Agricultural Information System, was developed in Papua New Guinea, a consortium of seven crop research institutes, SoNAIS, in Solomon Islands, and an amalgamation of these, first as MAIS, the Melanesian Agricultural Information System, and then PAIS, the Pacific Agricultural Information System. The end result is not only a database of reports, journals, and other kinds of documents with a focus on delivery in electronic format, but also information on the various projects that have been carried out or are currently being carried out. Information including what the project is about, and why; who is participating, and where; and in the case of completed projects, what lessons were learned. Perhaps most intriguingly, the current capacity of PAIS includes the ability to host exactly the kind of knowledge sharing dialogue among researchers in the region that is so necessary.

For a while, all seemed to be well, with online hosting supported by the Pacific Islands Rural Advisory Services, based within SPC, with people across the region routinely adding data, but momentum has again stalled through scarcity of funds. It is astonishing that this initiative does not receive adequate resourcing.

In addition to the need to access information, there is also a need to assist countries learn from what has been done. All too often projects are not evaluated, the results of the evaluations are not presented and discussed or, worse, evaluators are asked to remove critical comment in case it impedes the chance of future funding.

Development projects are all too often funded without seeking reference to past experiences and, in the process, there is a possibility that the same mistakes will occur once more. There is also a much larger issue of projects being researcher-driven, rather than farmer-driven.

Let us hope that SPC LRD will recall the days when the provision of information was a core function of its agriculture programs, encouraging and guiding research. Perhaps it's time to make it the central pillar that it once was.

Let us hope, too, that these remarks will make people more aware of these important aspects of agricultural development in Pacific island countries.

Last words

Finally, what do I feel looking back? That's easy. Excitement that a foe has been vanquished; farmers in Samoa are back in the taro business, fulfilling domestic needs, and even sending consignments overseas, albeit the trade is yet a fraction of pre-blight days[92]; and in that country and Papua New Guinea, blight-tolerant selections have made their way to SPC CePaCT and are available to any country that needs them. In fact, many have already been distributed worldwide through INEA.

However, I still feel the loss of Dala which was totally unnecessary, and remains unexplained. And I feel concern, too, about the lack of developing plant health systems in the region, the lack of collaboration among countries, especially the sharing of research, information and knowledge. Above all, I am concerned about the potential for further taro leaf blight outbreaks. Perhaps most painful to accept is the fact that leaf blight-tolerant taro have not reached farmers, so that when the blight jumps once again another Samoa 1993 is a distinct possibility.

Also, I am concerned that if there was a sudden outbreak of blight, and countries decided to distribute blight-tolerant taro to farmers, we do not know the best ways to do it. We have not thought how it might vary between different countries, and collected the data necessary to do the modelling required.

The taro leaf blight story has many things to tell us, and I believe we are not paying attention to the lessons that can be learned. The same mistakes are being made as I have tried to tell.

The immediate question is whether taro leaf blight will return to concentrate our minds.

Perhaps I am just kidding myself that my obsession led to its 'downfall' after all. A battle has been won but the war is not over. I just hope I don't have to last another 50 years to do it all again!

THE END

[92] Samoa launches new taro export varieties. SPC LRD Genetic Resources (November 2015): https://lrd.spc.int/our-work/genetic-resources/centre-for-pacific-crops-and-trees/samoa-launches-new-taro-export-varieties.