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Final report

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2 Executive summary

Taro (*Colocasia esculenta*) has a significant identity in the Pacific islands in both traditional and economic settings and is a root crop that has withstood the tests of time through climatic hazards and outbreaks of pests and disease. Both Fiji and Samoa benefit from the domestic consumption and export of taro as people depend on this root crop to sustain their lives throughout many generations. The taro industry in both countries is a viable export commodity having gained market access recognition in countries like New Zealand, Australia, USA, Canada, American Samoa, Tokelau and other small Pacific islands. In 2014, Fiji income from taro exports was valued at over $22million, which is approximately 7,916.5 metric tonnes of fresh taro (*Fiji Ministry of Agriculture, 2016*). Samoa has recently resumed taro exports to New Zealand in 2010 through their new and improved varieties, which are resistant to taro leaf blight attack and is poised to impact the market. The taro industry of both countries face similar issues and challenges in terms of phytosanitary measures needed to minimize, if not eliminate, mites and nematodes on taro corms.

The aim of this project was to find ways to improve and sustain the taro supply chain, evaluate heat treatment as a phytosanitary option to treat mites and nematodes on taro and disseminate results of the project to taro farmers. The key research activities in this context comprised of;

- Investigating the effect of *Mucuna pruriens* on nematode populations in Fiji soil; investigating the transport options to minimize post-harvest damage by using crates instead of sacks; determining minimum packhouse standards through the PHAMA program; topping and tailing options for the Australian markets and identification of nematodes associated with taro in Samoa to determine their regulatory status;
- Establishment of hot water kill temperature and exposure times to eliminate mites and nematodes; and
- Training workshops to disseminate research results to transfer knowledge gained to farmers and (Ministry of Agriculture (MOA) Extension officers.

The principal research findings in relation to these objectives were;

- *Mucuna pruriens* used as a fallow and cover crop has the potential to reduce nematode numbers in the soil and is proven to suppress 18 types of weeds. *Mucuna pruriens* cultivation and adoption by taro farmers is foreseen as supporting the sustainability of the taro supply chain.
- Taro farmers in Fiji and Samoa would benefit from continued training and awareness on post-harvest handling techniques that would reduce damages to taro corms. Replacing the use of sacks requires the improvement of infrastructure such as farm roads to impact positively on post-harvest losses. The PHAMA Taro production and processing guidelines containing standard pathway procedures needs to be empathized throughout the taro industry.
- Although hot water treatment of taro has proven effective in eliminating mites and nematodes, the costs of installing and operating a commercial sized hot water dip may discourage its use.
- The Taro Working Group (TWG), consisting of key industry and government advisors, needs to be maintained to ensure the key findings of this project are disseminated to the production, processing and export supply chains.

The project has identified potential measures to address the phytosanitary and quality issues facing the taro export industry of Fiji and Samoa. Building strong partnerships between Government, Private sector and Regional Organizations such as SPC will continue to strengthen the taro export industry.

3 Background

The ACIAR project No: HORT/2007/118 – "Developing cleaner export pathways for Pacific agricultural commodities" was the result of two Short Research Activities (SRA), PC/2008/029: Cost effective disinfestation treatments for Pacific horticulture and PC/2010/032: Defining the quarantine environment for Pacific horticultural exports. The SRAs focussed on providing research-based recommendations for strengthening Pacific island taro exports that will complement other work on taro undertaken by the Pacific Agribusiness Research for Development Initiative (PARDI) (PC/2008/044) and the DFAT-funded Pacific Horticultural and Agricultural Market Access program (PHAMA).

In August 2010, SPC/ACIAR/ MPI – convened an SRA workshop to identify research needs for cleaner export pathways for Pacific Island commodities with particular reference to taro and cut flowers and foliage. The objectives of the workshop were:

1. Through stakeholder consultations, identify the research needs to improve quality and minimize infestation and infection of pests and pathogens on taro and cut flowers and foliage (and confirm whether these commodities are of priority interest to exporters); and
2. Seek stakeholder views and encourage private sector participation in identification and adoption of alternative methods to improve quality and minimize infections and infestations of both commodities.

The outcome of the workshop was the development of a project proposal to ACIAR titled "Developing cleaner export pathways for Pacific agriculture commodities" that was endorsed with funding of AUD$820,000 over 5 years.

The two major taro exporting PICs namely Fiji and Samoa were chosen for the project that was launched in 2011. Within the broader development goal of improving the economic and environmental sustainability of intensive smallholder crop production in the Pacific Region, the aim of this project is to restore and maintain the viability of export pathways for taro. Specific objectives are to:

1. Improve the sustainability of the taro supply chain by

- Identifying improved on-farm production techniques to reduce key quarantine pest (nematodes and mites) infestation for export grade product;
- Determining suitable transport, handling and processing techniques to reduce post-harvest damage leading to post harvest fungal infections;
- Determining minimum pack-house sanitary standards to ensure taro is processed and packaged to meet export needs; and
- Conducting trials to determine a suitable post topping-and-tailing treatment to prevent fungal infections during transport to Australia.

2. Evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

3. Ensure coordination of research and dissemination of outputs (in the context of multiple efforts to improve taro production, supply and market access).

The partners to this ACIAR project (HORT/2007/118) are: the Pacific Community (SPC), Kalang Consultancy Services Pty Ltd, Fiji Ministry of Agriculture (MoA) and Samoa Ministry of Agriculture and Fisheries (MAF).

SPC being the regional agency with technical experts in pests and diseases was the implementing agency for the project. SPC's role was to work with the national partners (Fiji and Samoa) to address the issues associated with post-harvest handling, and frequently intercepted pests on taro such as nematodes and mites.

Kalang's responsibilities were primarily a project management role by providing consultation with SPC, Fiji MoA and Samoa MAF on agreed deliverables of the project. Kalang also assisted in the development of interim and final reports.

The project provided scientific, capacity and community impacts benefiting the Pacific scientific and extension community, and improving capacity to deliver information that meets the needs of landholders and exporters. This has led to improved livelihoods of communities through more sustainable and secure food production.

The major focus of the project was on taro production sites, processing facilities and the associated communities. A capacity building and communication strategy has been developed to achieve wider impact and adoption of project findings.

The project aimed to work closely with other relevant programs and existing activities associated with taro supply chain and export. It is envisaged that the outcomes of the project will be directly transferrable to other PICs seeking to develop international taro export pathways.

Following mid-term reviews in March 2013 and August 2015, it was evident that some preliminary activities had been conducted without the rigour needed to produce quantifiable and repeatable results. It was also apparent that the originally intended outcomes of some of the activities may no longer be operationally or economically feasible. As a result of these reviews the project design was refocused with revised methodologies to produce robust experimental outcomes. Based on the mid-term review it was recommended that two activities be terminated:

1. Preliminary trials using reusable plastic crates to transport corms from the field indicated this method is less functional than using traditional sacks in the rugged terrain of some Fijian production areas and not cost effective. Further trials were terminated. A cost benefit analysis was conducted on this activity by the Fiji Taro Working Group (TWG).
2. A review of hot water dipping as a post-harvest treatment for mites and nematodes on taro corms showed that this would be impractical and expensive with the volumes of taro being packed for export and current pack house layout. Further research work by the Fiji TWG was warranted to gather data on the costs of running such hot water dipping techniques on a commercial scale. The use of hot water dipping to treat taro for planting to reduce the incidence of pests and the effect on yield was an area the reviewers recommended for further investigation by the TWG.

The Fiji Taro Working Group (comprising of the MoA, exporters and SPC) was revamped in 2015 after a lapse of 4 years. The TWG visited the taro growing areas (Viti Levu and Vanua Levu) providing:

- Training to growers and communities on soil testing and its importance;
- Explanation of the benefits of using Mucuna as a cover crop;
- Information on taro pests and diseases;
- Explanation of taro export standards; and
- Discussions on the economic importance of taro.

The Samoa project team accompanied the TWG to the Vanua Levu training sessions, where they shared Samoa's experience with taro leaf blight.

A total of 910 farmers participated during the Fiji TWG training that was held at various localities in Viti Levu and Vanua Levu.

The challenges faced during the life of the project, which saw the delay in some of the deliverables, included:

- Staff turnover by national government partners – staff movements within and out of the Ministry as a result of promotions, secondments, new appointments, study and maternity leave.
- Delayed submission of acquittals – this in turn delayed the disbursement of next tranche of funds, affecting project deliverables.

4 Objectives

Within the broader development goal of improving the economic and environmental sustainability of intensive smallholder crop production in the Pacific Region, the aim of this project was to restore the viability of export pathways for taro. Specific objectives were to:

1. Improve the sustainability of the taro supply chain by

1.1 Identifying improved on-farm production techniques to reduce key quarantine pest (nematodes and mites) infestation for export grade product

1.2 Determining suitable transport, handling and processing techniques to reduce post-harvest damage leading to post harvest fungal infections

1.3 Determining minimum packhouse sanitary standards to ensure taro is processed and packaged to meet export needs

1.4 Conducting trials to determine a suitable post topping-and-tailing treatment to prevent fungal infections during transport to Australia.

2. Evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

3. Ensure coordination of research and dissemination of outputs

Expected outputs are the research, development and extension of a series of national standards for the production (with a focus on reducing pest loads), transport, processing and packhouse facilities for taro. In addition, pilot studies to determine disinfestation schedules for mites and nematodes using hot water dipping will be developed. It is anticipated that this work will deliver clear requirements to growers, packers and exporters of taro that meet Australian and New Zealand quarantine requirements and greatly reduce the incidence of quarantine intervention that is severely handicapping this important export industry.

Community-level impacts of the project will include more sustainable incomes from one of the key commodities in Fiji (and of rapidly increasing importance in Samoa once again) with reduced environmental impacts from agriculture, more efficient use of agricultural inputs, and improved food security. Importantly, this project will also play a coordinating role to ensure that other donor projects or programs complement rather than duplicate work to be conducted on taro. The collective result of this coordinated focus will the development of robust, cost effective and sustainable taro export pathways.

5 Methodology

The methodology applied in each of the project activities is summarised below. All field based activities were conducted in the taro growing regions of Samoa and Fiji in accordance with the respective agricultural Ministries advisory agricultural practices currently practiced in both countries. Some laboratory work was also conducted at the Pacific Community's laboratory in Suva, whilst identification of nematodes and fungal cultures were done in Australia and New Zealand.

FIJI COMPONENT

Objective 1: Improve the sustainability of the taro supply chain

Activity 1.1: Identifying improved on-farm production techniques to reduce key quarantine pest (nematodes and mites) infestation for export grade product

This research activity was conducted in two locations namely Lomaivuna and Koronivia to assess the effects of Mucuna Bean (*Mucuna prurience*) on nematode populations in the soil. Nematode extraction from soils was undertaken before planting Mucuna, during growth and at the end of 6 months of growth. The nematodes were extracted from soil samples at the Ministry of Agriculture Koronivia pathology laboratory. High concentrations of L-DOPA in the soil has been known to be the toxic or allelophatic agent contributing to the suppression of plant parasitic nematodes (Fuji, 1999). In addition to this Mucuna seed bank sites were established in the taro growing regions of Fiji namely Taveuni, Namosi, Serua, Ra, Naitasiri, Tailevu North, Tailevu South, Bua and Rewa. These sites were established to provide easy access to Mucuna seeds for taro farmers. These activities were then disseminated to taro farmers and Fiji Ministry of Agriculture extension officers via training workshops in Taveuni, Savusavu, Bua, Serua, Namosi, Naitasiri, Ra, Tailevu North, Tailevu South and Rewa.

Potting trials to determine which combination of treatments applied controlled or minimized rot on taro. This was conducted in Taveuni with 8 treatments plus 1 control with 5 replications each. The treatments are as follows:

- **Trt 1**: Anti Rot (Phosphoruous acid) + NPK;
- **Trt 2**: Sundomil (Mancozeb & Metalaxyl) + NPK;
- **Trt 3**: HWT (10 mins) + NPK;
- **Trt 4**: HWT (15 mins) + NPK;
- **Trt 5**: Sundomil/HWT(10mins) + NPK ;
- **Trt 6**: Sundomil/HWT (15mins) + NPK ;
- **Trt 7**: Anti-rot/HWT(10mins) + NPK;
- **Trt 8**: Anti-rot/HWT(15mins) + NPK;
- **Trt 9**: Untreated PM + NPK (infested soil); and
- **Trt 10**: Uninoculated + untreated PM +NPK (inoculated soil).

The objective of the potting experiment was to find out if treatments consisting of hot water and fungicides reduced pest load on planting materials and decreased the rate of corm rots in exported grade taro. This research activity was carried out at the Mua Agricultural Station in Taveuni. Pathogen specimens collected from corm rots were isolated and multiplied at the Koronivia Research Station's Pathology Laboratory, after which pure cultures were sent to the New Zealand Plant Health and Environment Laboratory for identification.

Activity 1.2: Determining suitable transport, handling and processing techniques to reduce post-harvest damage leading to post harvest fungal infections

The research carried out on this particular activity comprised of two initiatives. The first being the use of plastic crates instead of sacks to minimize post-harvest damages to the taro corms. This activity was carried out in the interior regions of Taveuni, Namosi and Naitasiri. The cost of using the crates was also considered during this exercise.

Activity 1.3: Determining minimum packhouse sanitary standards to ensure taro is processed and packaged to meet export needs

This activity was conducted by the Pacific Horticultural and Agricultural Market Access (PHAMA) program based in Suva, Fiji, and titled “Development of and Training on Taro Production and Packhouse Standards (FIJI05)”. During the mid-term review in 2013, the PHAMA Short Term Advisor briefed participants on the objectives and scope of FIJI05. To prevent the duplication of activities, it was decided at this workshop that FIJI05, which was already in progress, would have primary carriage of developing the taro production and processing operational guidelines, while PC/2007/118 would develop extension materials to support the operational guidelines.

Activity 1.4: Conducting trials to determine a suitable post topping-and-tailing treatment to prevent fungal infections during transport to Australia

This research activity was carried out using sodium hypochlorite as a post-processing dip prior to export to prevent fungal infections. This trial was conducted during the 2014-2015 project period using 0.05% sodium hypochlorite, the incidence of rots was assessed after treatment. This activity also examined residual chlorine in taro corms after dipping, and tests for these were carried out at the University of the South Pacific, Suva.

Objective 2: Evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

This research activity consisted of three trials to determine the kill temperature for plant parasitic nematodes and mites. Heat has had a variety of uses since primitive times, such as cooking and food preservation, but its use was limited as a pest control method for stored products until the modern era (Tang et.al, 2007). Hot Water Immersion has proven to be a promising phytosanitary treatment for tropical floral commodities (Tsang.M,et.al, 1995), control of mites on taro (Brash.D,et.al, 2006) and plantain suckers for the control of nematodes (Hauser et.al, 2008) to name a few. A study by Tsang, et.al (1995) treated red ginger flowers for pests by exposing them to water at a temperature of 49^{o}C for 12mins followed by cooling in tap water at 24 ^{o}C for 12mins. According to Lurie (1998), many fruits and vegetables tolerate exposure to water temperatures of 50-60^{o}C for up to 10mins, but shorter exposure at these temperatures can control many postharvest plant pathogens.

To conduct these trials a hot water disinfestation unit was installed at the IMPEXTEK Laboratory, SPC, Nabua. The unit consisted of a hot water immersion tank using preheated water with additional heating elements to maintain the required temperatures. The water was circulated using an electric pump to enable even distribution of the water temperature.

The water temperature was monitored by probes and together with the two heating elements, connected to a digital thermostat. The water temperature was automatically controlled by the thermostat +/- 1^{0}C. The unit design was based on units used within US Department of Agriculture (Hawaii) for disinfestation of certain commodities against surface pests. A hydro cooling tank was used to cool the commodity after treatment.

The first hot water dipping trials determined the kill temperature for plant parasitic nematodes on taro corms. Soil samples were also taken from the site where the taro was planted (and collected for trials) and nematodes extracted from these samples to determine the presence/absence of plant parasitic nematodes.

Infested taro corms were dipped between 50°C - 51°C at 8, 10, 12, 14 minutes time interval as exposure times. The second hot water dipping trials were conducted using taro that have undergone the taro processing standards for both New Zealand and Australia. Batches of taro for each standard was dipped in 50°C for 12mins and tested for the presence of live parasitic nematodes. Nematode extraction was conducted at the Koronivia Research Station pathology laboratory. The third hot water treatment experiment was to determine the internal taro corm temperature when the water temperature reaches 50°C and exposed for 12mins. The experiment also determined the corm temperatures at longer exposure times the maximum being 35mins at 50°C. Nematodes were extracted from the taro corms using the Whitehead and Hemming tray extraction method.

Objective 3: Ensure coordination of research and dissemination of outputs

This activity was carried out during the 2015-2016 period after research activities were completed. More than 400 farmers in Taveuni, Savusavu, Bua, Ra, Naitasiri, Serua and Namosi, where a majority of taro production exists, were updated on the research results from the Mucuna trials activity.

Field days were held and farmers briefed on the use of Mucuna to improve soil health and decrease the presence of nematodes in soil, and at the same time reducing the over-use of pesticides and labour by suppressing weeds in and around their plantation. In addition to this, farmers were made aware of the importance of soil testing, Biosecurity requirements, taro pest and disease, and planting taro as an export business.

The project team also produced awareness materials such as Mucuna posters, taro production DVDs, Biosecurity and quality requirement posters and brochures. Another important feature of this activity was the re-establishment of the Taro Working Group consisting of representatives from the Ministry of Agriculture (Extension, Research and Economic planning division), Kalang Consultancy Services Pty Limited, SPC, Ben'sTrading Ltd., Garden City Exports Ltd. and Agro Marketing Authority. The main role of the TWG was to identify technical limitations in the pathway and provide solutions through research recommendations.

SAMOA COMPONENT

Objective 1: Improve the sustainability of the taro supply chain

Activity 1.1: To collect and fix nematodes from soil and root samples

Containers of taro are regularly fumigated with methyl bromide on arrival in New Zealand, if regulated pests are found. Biosecurity New Zealand is concerned with the increasing cost of methyl bromide and its disadvantage in reducing quality and shelf-life of taro. Biosecurity NZ in collaboration with Plant Food Research NZ were also investigating the use of hot water dips (*Biosecurity New Zealand Issue 70, 15 September 2006*), however, formal results of the trials were not available at the time of report finalisation.

The assessment of fresh taro corms for the presence of pests such as nematodes and mites and their formal identification is an important step to ensure that regulatory procedures undertaken by importing countries, such as NZ, are justified.

Twenty six samples of extracted live nematodes from soil and roots of taro were fixed in 4% formalin solution and sent to CABI for identification in July 2014. The samples were collected from commercial taro growers on the islands of Savaii (10 samples) and Upolu (10 samples). The sites were randomly selected based on the location of taro plantations.

Activity 1.2: To identify and describe nematodes associated with taro before export

To confirm the presence of plant parasitic nematodes at the conclusion of pre-export processing, approximately 50kg of taro was sampled from a container ready for export. The nematode specimens collected were viewed under a light microscope for verification, and later sent to CABI for further identification.

Objective 2: Evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

The objective of these experiments was to provide data-based evidence that a hot water treatment will eliminate or reduce the potential for the interception of mites and nematodes at the New Zealand border while retaining product quality.

The initial activities of this objective focused on inputs and advice from MAF Samoa researches and taro corm exporters to design and implement hot water trials and determine taro and nematode sampling areas. Mites were also collected from taro corms and associated soils in preparation for hot water dipping trials. The mites were identified as *Rhizoglyphus minutus*.

Nematodes and mites identified from the previous activities enabled the researches to specify which nematodes were of concern when it came to export taro. Further work with Plant and Food New Zealand focused on the rearing of these nematodes to use in the treatment of taro corms using hot water treatment and high water pressure.

Objective 3: Ensure coordination of research and dissemination of outputs

Brochures and banners depicting the post-harvest processes of export taro were published and this were disseminated and displayed for awareness. An operation manual was also produced as part of the Cleaner Pathway Project in collaboration with Samoa Quarantine. The main objective was to inform farmers and exporters of the biosecurity and operations requirements for exporting taro.

There were also two Farmer Field days which were organised by the project and this was conducted in Sava'i and Upolu. Farmers were informed of the findings on the nematode identification in the taro fields and pack-house. They were given an overview of the current export pathway and the responsibilities of everyone in the taro pathway. An exporter invited to the workshop also shared the many issues and costs incurred during the export of taro. Farmers were also encouraged to grow Mucuna and were informed of the soil health findings which showed a much healthier composition of soil when using Mucuna.

An officer from the project team also used the opportunity of being invited to a radio talkback show to discuss the importance of maintaining a clean taro pathway and the implications of having pests intercepted on fresh taro at the New Zealand ports.

In addition, the Open days during the Samoa Agriculture week provides an avenue for the project to showcase their activities and findings. This was an opportunity to inform the public on taro pests of concern to their export industry and ways they can minimise the presence of this pests. With more varieties being made available because of the taro breeding programme, the farmers are being reminded of the opportunities available for taro export and pests that they need to be concerned about in order to maximise their chances of export.

6 Achievements against activities and outputs/milestones

FIJI

Table 1

Objective 1: To improve the sustainability of the taro supply chain

No.	Activity	Outputs/ Milestones	Completion date	Comments
1.1	Identify improved on-farm production techniques to reduce key quarantine pest (nematodes and mites) infestation from export grade product	1. Effect of Mucuna on nematodes in soil – Trials in Lomaivuna and Koronivia 2. Establish Mucuna seed bank sites in taro production areas of the Northern and Central division 3. Hot water and fungicide dipping of taro suckers 4. Potting trials - Dipping of taro suckers with Anti-rot and hot water for 10mins at 50ºC minimizes rot infection from early planting	2012 2016 2015 2015	Internal project report circulated in 2012. Activity results used at training workshops in 2015-2016 to promote inclusion of Mucuna in taro production systems. Mucuna seed bank sites were established in Namosi, Serua, Naitasiri, Ra, Tailevu North, Tailevu South, Rewa, Bua and Taveuni. Increasing accessibility for farmers is key for this activity. Taro suckers were dipped in hot water and fungicide to reduce fungal infection during production In order to minimize rot infection through production it is vital that farmers begin with clean planting material. Together with good agricultural management practices, this will lead to healthy crops. Cultures sent to NZPHEL for identification confirmed that pathogen causing rot to be the fungus *Fusarium solani*
1.2	Determining suitable transport, handling and processing techniques to reduce post-harvest damage leading to post harvest fungal infections	1. Completion of Crate vs Sack trial to determine the suitability of using crates to reduce post-harvest damage 2. Report of crate vs sack trial compiled with limited raw data – generally crate use would be a loss for farmers given the harsh geographical locations farmers face.	2012 2015-2016	Taro packed in sacks have an average rejection rate of 30% at the packhouse. Crates have reduced this average to 10%. However the crate use maybe uneconomical for farmers due to crate unit cost and labour needed to carry and transport crates to collection points and packhouse. Perhaps crate subsidy by Government could assist its eventual use.

1.3	Determining minimum packhouse sanitary standards to ensure taro is processed and packaged to meet export needs	Completed project under PHAMA FIJI05 – contains taro processing and production guidelines and packhouse poster	2013	Carriage for the development of awareness and extension material (along with conducting workshop activities) to supplement the operational guidelines document has been passed to the Australian Centre for International Agricultural Research (ACIAR) Developing Cleaner Export Pathways for Pacific Agricultural Commodities project (PC/2007/118). This division of effort was previously agreed to during planning for this activity and the ACIAR project in order to enable both activities to conduct complementary work rather than duplicate efforts.
1.4	Conducting trials to determine suitable post topping-and – tailing treatment to prevent fungal infections during transport to Australia	1. Sodium hypochlorite dipping of taro processed using New Zealand and Australia standards 2. Confirmation under PHAMA FIJI06 – Substantiation of Australia's requirements for devitalisation of taro imports.	2015 2013	There was no significant difference between non-dipped taro and dipped taro during the trials in terms of preventing fungal growth on taro. Residual analysis of sodium hypochlorite was well below allowed NZ and Australia standards. Residual = <0.05mg/kg; Standard = 1mg/kg

PC = partner country, A = Australia

Table 2

Objective 2: To evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

No.	Activity	Outputs/ Milestones	Completion date	Comments
2.1	Trial 1: Establish kill temperature and exposure times for nematode and mites	The project team managed to establish the kill temperature; Parasitic Nematodes 50°C for 12min and Mites: 48°C for 12-14 mins.	2012	The project team established the hot water temperature and exposure time to eliminate mites and nematodes from taro corms. This was first established through literature reviews and trial runs.
2.2	Trial 2: Hot water treatment of taro processed under New Zealand and Australia standard requirements	Taro processed under NZ and Australian standard were dipped in hot water. Parasitic nematodes and mites were successfully eliminated.	2015	50°C for 12min was used during these trials which showed a high number of dead saprophytic and parasitic nematodes. However a small number of saprophytic nematodes were also found alive suggested a higher heat tolerance capability by saprophytic nematodes

2.3	Trial 3: Hot water vs taro corm temperature (Preliminary tests)	Taro corm temperatures were assessed against hot water temperatures to find out heat tolerance of saprophytic nematodes	2016	Preliminary trials carried out showed that at 35min of exposure at 50ºC hot water the surface corm temperature averaged at 40.6ºC. In addition, all saprophytic nematodes were found dead.

PC = partner country, A = Australia

Table 3

Objective 3: Ensure coordination of research and dissemination outputs

No.	Activity	Outputs/ Milestones	Completion date	Comments
2.1	Taro farmer training workshops	Trained 910 taro farmers throughout the Northern and Central Division	2016	Outputs of project were disseminated including importance of soil sampling, pests and diseases, taro export standards, taro economic performance
2.2	Mucuna Training for Taro farmers	Trained 100 farmers Mucuna seeds distributed to farmers	2016	Farmers were trained on Mucuna growing practices and its benefits. Reduce nematodes counts in the soil was priority among other benefits of Mucuna.
2.3	Publications	Banner and stand-up posters Taro Export Standards	2016	These publications were utilized during training workshops and awareness programs for farmers. The project donated these publications to Fiji MOA
		Taro pathway DVD	2016	The taro pathway DVD was distributed to participants of final project workshop

PC = partner country, A = Australia

SAMOA

Table 4

Objective 1: To improve the sustainability of the taro supply chain

To collect and fix nematodes from soil, root samples and containers.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	To identify nematode species associated with taro from root samples	*Preliminary trial:* Identification of nematode species infecting taro species Establishment of the most applicable procedures for carrying out these identification Analysis of the results to verify Samoa taro's marketing and exporting quality	2011	Sampling of 20 samples randomly collected from a site in Upolu. The unavailability of special equipments prevented identification down to the species level, but confirmed the presence of plant parasitic nematodes on taro. Sampling from Moamoa ;7 soil samples and 4 root samples
		Identification and establishment of nematodes down to the species level associated with taro from the farms	2014	20 samples were collected: 10 samples from 10 sites in Upolu 10 samples from 10 sites in Savaii All samples were sent to CABI for Identification
1.2	Sampling of taro samples from containers	Identification of nematode species found on taro in storage containers Identification of the effectiveness of the taro cleaning process	2014	Two preliminary samplings were conducted at Atele pack-house. 11 bags of 20kg taro were observed at Nu'u Research 2 final samplings of 10kg taro bags, with 10 taro randomly selected from each bag for observation
1.3	Procuring of lab materials and equipments (microscopes and sieves)	2 microscopes were purchased And sieve sets for extraction	May 2014	1 NIKON SMZ 1000, 1 NIKON E200-LED Received equipments in Sept 2014

Table 5

Objective 3: To ensure coordination of research and dissemination of outputs

No.	Activity	Outputs/milestones	Completion date	Comments
3.1	Publication of posters	Awereness posters on biosecurity stansards and operations were published and disseminated	2012	
3.2	Taro Operations manual	The Manual provides information on the requirements that need to be met when processing and exporting taro	2016	
3.3	Farmer Field Days	The field days were conducted in Upolu and Savai and farmers were informed of the importance of maintaining a clean taro export pathway. The famers were also advised on how to better manage their taro farms and the different varieties available to plant in our changing conditions.	2015	Farmers were informed of the outputs of the projects and reminded of the importance of maintaining a clean taro pathway.
3.4	Radio Talkback Shows	People were informed of the objectives and activities of the Taro Cleaner Pathway and the implications of having taro fumigated at export destinations. The public was also able to ask and raise any queries they have regarding the taro export market in Samoa.	2015	A brief explanation of the project objectives was discussed on the show and an overview of activities that were being carried out to meet this objectives.

7 Key results and discussion

FIJI

The aim of the project was to improve the sustainability of the taro supply chain, evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites and ensure coordination of research and dissemination of outputs to taro farmers, government officials and the private sector.

Taro remains the backbone of agricultural exports for Fiji and earns more than $20million of revenue annually. Samoa on the other hand, having dominated the taro export industry in the Pacific up to the late 1980's has now introduced their taro leaf blight resistant varieties into the export market after a 20 year lapse. Taro production has been an important part of farmer's lives where income has catered for costs of living, education, investments and development at the rural level.

Both export destination countries in New Zealand and Australia have specific entry requirements and each container load is assessed independently to ensure requirements are met and quality conditions for the market are achieved. Most of the results presented are based on these requirements as the benchmark for all producers and exporters to work towards. Over the course of this project other factors such as fluctuating farm gate price per kilo has often been raised as an impediment to production and quality, however this issue has been left to national governments to address.

The on-going issues of taro fumigation in New Zealand and Australia due to the interception of mites and nematodes has been a hindrance to the quality and shelf life of taro from both Fiji and Samoa. Hence the results of this project are aimed at addressing this issue and looking at the impact of research results now and in the next 5 years. The current export situation is that both the farmers and exporters have yet to find solutions to the ongoing interceptions of mites and nematodes. Therefore the key results and discussions are summarised below.

Table 6: Summary of key results for the project objectives and activities

Objective	Sub-objective	Associated activities	Key results	Main outputs (Annex 1)
1. To improve the sustainability of the supply chain	1.1 Identify improved on-farm production techniques to reduce key quarantine pest (nematodes and mites) infestation for export grade product	1.1.1 Mucuna Trials in Lomaivuna and Koronivia	*Mucuna pruriens* reduces incidence of nematodes *Mucuna pruriens* successful as a weed suppressant	JP1, PI17, PC1, PC6
		1.1.2 Establishment of Mucuna seed banks in taro production regions	Mucuna seed bank sites established in Serua, Namosi, Naitasiri, Ra, Bua, Tailevu North, Tailevu South, and Rewa. Increase accessibility of Mucuna seeds to farmers	PI 7, PI 8, PI 9, PI 10, PI 11, PI 12
		1.1.3 Potting trials - Dipping of taro suckers with combinations of chemical and hot water dipping,	Dipping of taro suckers with Anti-rot and hot water for 10mins at 50ºC minimizes rot infection from early planting	PI1, PI16, PC1, PC10
	1.2 Determining suitable transport, handling and processing techniques to	1.2.1 Crate vs sack trial in Taveuni, Naitasiri and Namosi	Crates unfeasible to use for farmers given difficult terrain and high costs associated	PC8

	reduce post-harvest damage leading to post harvest fungal infections	1.2.2 Sodium hypochlorite dipping – Trial 1	with crates in terms of labour and transport Taro dipped in sodium hypochlorite – no negative feedback from export destination country	PC8
		1.2.3 Sodium hypochlorite dipping – Trial 2 (Rot assessment)	Taro dipping in sodium hypochlorite dipping slightly slowed rot progression	PI14, PC12
		1.2.4 Sodium hypochlorite dipping – Trial 2 (chemical residue analysis)	Taro dipped in 0.5% sodium hypochlorite residue analysis was <0.05% mg/kg which lower that NZ/AUS Standard of 1.0mg/kg	PI14, PC12
	1.3 Determining minimum pack-house sanitary standards to ensure taro is processed and packaged to meet export needs	1.3.1 Completed through PHAMA project FIJI05	Taro Production and Processing Guidelines document Taro Production and Processing Guidelines Workshop Pack House Poster for ACIAR Project	PR4
	1.4 Conducting trials to determine a suitable post topping-and-tailing treatment to prevent fungal infections during transport to Australia	1.4.1 Completed through PHAMA project FIJI06	Technical Report 51: Substantiation of Australia's Requirements for Devitalisation of Taro Imports	PR5
2. Evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites	2.1 Establishing hot water kill temperature and exposure duration to eliminate parasitic nematodes and mites	2.1.1 Hot water dipping trials of taro at 50ºC for 12 min and 51ºC for 10 min.	Established treatment most feasible treatment regime at 50ºC for 12 min to kill parasitic nematodes and mites	PI13, PC1, PC9
		2.1.2 Hot water dipping of taro processed under NZ and AUS requirements at 50ºC for 12 min	Parasitic nematodes and mites killed at 50ºC for 12 min. Some saprophytic nematodes found alive.	PI13, PC1, PC9
		2.1.3 Hot water dipping trials – Corm temperature vs hot water temperature of 50ºC at exposure times of 6, 8, 10, 12, 14, 20, 25, 30, 35 minutes	Corm temperature after 12min averaged 35.8ºC – where parasitic nematodes killed Corm temperature after 35min averaged at 40.6ºC where all nematodes (saprophytic and parasitic) were killed.	PI13, PC1, PC9

		2.1.4 Cost benefit analysis of hot water treatment – installation of 3 HWT machines and operational cost for 10 years	Over a period of 10yrs the total cost is more than the intended benefit by $235,540 FJD	PI15, PC9
3. Ensure coordination of research and dissemination of outputs	3.1 Farmers training/workshop – dissemination of outputs	3.1.1 Carried out training/workshops to 490 farmers across the Northern Division and Central Division – 2015	Farmers willing to adopt Mucuna as fallow crop, weed suppressant and nematode reduction mechanism	PI2, PI3
		3.1.2 Carried out training/workshops to 420 farmers across the Northern Division and Central Division – 2016	Farmers willing to adopt Mucuna as fallow crop, weed suppressant and nematode reduction mechanism	PI4, PI5
	3.2 Mucuna Training for farmers	3.2.1 Total of 100 farmers trained across Serua, Namosi, Naitasiri, Tailevu (North and South), Rewa, Ra and Bua	Adoption process by farmers through willingness to use Mucuna as cover and fallow crop	PI6, PC7
		3.2.2 Distribution of 20 – 30 Mucuna bean seeds to each farmer	Farmers will test Mucuna as fallow crop and may produce own seeds	PI6, PC7
	3.3 Publications – Posters and banners, DVD	3.3.1 Stand-up posters and banner depicting the taro pathway and focus areas in each component of the pathway	Basic visual aid during training workshops for farmers, MOA Extension Officers and exporters to understand.	PM1, PC7
		3.3.2 Taro standards posters – showing Biosecurity and Quality requirements for taro export	Farmers informed role in export pathway and also roles of other players in the pathway	PM2, PC7
		3.3.3 DVD production of taro pathways-from production to export. Also includes Mucuna segment as fallow crop	DVD on taro production in Fiji distributed to selected farmers and MOA officers during project closing workshop	PM3, PC7
	3.4 Establishment of Taro Working Group (TWG)	3.4.1 TWG consisted members from MOA (Extension, Research, EP&S, and Information), SPC, Kalang Consultancy Services, Private sector (exporters).	Formation of TWG crucial in addressing crucial issues through dialogue on proposed way forward.	PM4, PC7
		3.4.2 Held 7 meetings from Dec 2015 – October 2016. Project updates, technical advisory and future projects	Established forum to look into technical issues affecting taro exports (pests and diseases and quality issues) Proposal to	PM4, PC7

			continue with TWG after life of project.	

Overview and discussion of key results by objectives

Improving the sustainability of the taro supply chain

The project developed methods to decrease the incidence of nematodes within the soils where taro is grown by using of *Mucuna pruriens* as a fallow crop and weed suppressant. The trials conducted in Koronivia showed better results over the trial in Lomaivuna due to the fact that Koronivia Mucuna growth covered the area densely therefore providing a more favourable situation for the Mucuna to impact the populations of nematodes in the soil and adequately suppress 18 types of weeds after the 6 month fallow.

Mucuna therefore has demonstrated through these results that it can increase the quality of taro exports over time and shorten the traditional fallow period which is between 1-2 years. A DVD video developed by the Fiji Ministry of Agriculture (MOA) demonstrated the benefits of Mucuna to farmers by (i) increasing essential minerals and earthworm population in the soil; (ii) improving soil structure by decomposing into high organic mulch, improves organic matter, biological activity and suppresses weeds; (iii) reduced the costs of production by reducing fertilizer application and chemical weedicides; and (iv) increased average yields from 1.5kg to 2.5kg per taro corm.

Given the demonstrated potential of Mucuna trials to improve the quality and yield of taro, an extensive program of field days and farmers meetings were conducted by the TWG. In addition, the project team established Mucuna Seed Bank sites in the Central Division (Serua, Namosi, Naitasiri, Tailevu North and Tailevu South, Rewa) and the Northern Division (Bua and Taveuni). Approximately more than 300 seeds were planted for each site and is estimated to produce more than 1000 seeds for farmers from these sites through the assistance of MOA Extension officers.

The hot water dipping potting trials of taro planting material resulted in reduced rots at harvest. This suggested that to produce healthy taro crops cleanliness starts with clean planting material together with good agricultural practices. These results were also disseminated to producers and exporters.

The crate vs sack trial was designed to reduce post-harvest damage losses from rough handling during packing using sacks. Taro exporters have experienced losses when receiving taro at their pack houses from the field and these losses often amount to 30% of the taro received. Reasons for these losses are due post-harvest bruising and cuts into the flesh of the taro and also through rots from the field. In an attempt to minimise these losses the crate trials were carried out in Taveuni, Naitasiri and Namosi all with differing topography in terms of the most difficult location to reach.

The study was abandoned given the extremely difficult conditions to carry crates from the bottom of slopes and at the same time having travelled more than 1km to reach the farm location added to the strain to make crates as a feasible option to sacks. In Namosi, the project team had to cross the same river 4 times to reach the farm. In addition, there was a huge difference in loading numbers as compared to the sacks and it was evident that more taro was packed in sacks than crates and more sacks were packed in trucks than crates. Therefore the crates were deemed unfeasible, however, could be more adequate for flatland farms.

The Pacific Horticultural and Agricultural Market Access (PHAMA) developed minimum packhouse sanitary standards and sought substantiation of Australia’s requirements for devitalization of taro imports from Australian quarantine authorities. These works were done under PHAMA projects FIJI05 and FIJI06 respectively. FIJI05 developed a guideline document the *Taro Production and Processing Guidelines* which outlined the roles of each player in the taro production and export supply chains. The guidelines were also used by the MOA to provide extension services to the farmer, and the Biosecurity Authority of Fiji (BAF) to ensure phytosanitary measure have been followed. The document is now in the custody of BAF.

In FIJI06 it was determined that Australia's devitalization requirement will not change given the evidence presented in this report has confirmed the absence of Taro vein chlorosis rhabdovirus (TaVCV) in Australia. The TaVCV is present in Fiji therefore the quarantine treatment includes "removing all petiole material and apical growing points from corms of large corm taro (*Colocasia esculenta* var. *esculenta*)". In addition taro corms are "topped" to remove leaf petioles and growing points and scraped to remove dormant buds. Since Australia does not have TaVCV the devitalization treatment remains in play as a specific requirement for exporting taro from Fiji.

<u>Evaluating hot water dipping trials as a phytosanitary treatment</u>

The project team established the kill temperature and exposure time to kill parasitic nematodes and mites in two trials to be 50°C for 12 min. The results showed that there were no live parasitic nematodes found in the samples extracted for nematodes, however, there were a number of saprophytic nematodes found to be alive. In addition, taro treated at 50°C for 12 min showed minimal corm rots after for 21 days in dry storage. This indicated that hot water treatment may add value to the shelf-life of the taro as reported by Brash *et al* (2006) who also conducted hot water trials on taro in New Zealand.

Since saprophytic nematodes were found alive during the 50°C for 12 min hot water treatment the project team conducted preliminary studies on the effect of hot water on the surface temperature of the taro corm. The results firstly showed that at 50°C for 12 min the taro corm temperature averaged at 35.8°C where parasitic nematodes were eliminated and where saprophytic nematodes were also found to be alive.

The taro corms were further exposed until 35mins and results revealed that all nematodes, including the saprophytic, were dead. The results also suggest that saprophytic nematodes have a higher heat tolerance than parasitic nematodes. After conducting these research experiments and establishing that hot water is able to kill parasitic nematodes a "cost-benefit analysis" was conducted.

The CBA analysis was done to determine the viability of setting up Hot Water Treatment Plants at the major taro exporters premises in Fiji. Currently there is no hot water treatment of taro to eradicate or kill nematodes to avoid fumigation by the importing country. Fumigation deteriorates the quality of taro and decreases the shelf life hence leading to fewer profits by the importer.

The CBA considered whether it is economically sound to set up the hot water plants at 3 major exporter's premises. The CBA measured the costs and benefits against Fiji's major importer of taro which is New Zealand. The CBA assumed that all nematodes were killed by the hot water treatment and there would be no fumigation at all if the taro is hot water treated by Fiji. An additional consideration is that fumigation costs are currently paid by the importer so if hot water dips proved to be cost effective beneficiaries will be the importers of New Zealand. The CBA analysis showed that it is not viable to setup the hot water treatment machines since the costs outweigh the benefits by approximately $250k over a ten year period.

<u>Ensure coordination of research and dissemination of outputs</u>

The project made important contributions to the knowledge and skills of taro farmers and MOA Extension and Research officers in Fiji. The project disseminated research outputs and taro export pathway information to 910 farmers across the Northern and Central Division where taro production for export is located. The delivery of the training workshops were carried out by capable personnel in MOA, Kalang Consultancy Services and the Pacific Community (SPC) Biosecurity and Trade team. Farmers and extension officers were provided with information concerning their role in the taro pathway in terms of good agricultural practices that will produce quality taro for the export market.

Other information communicated to the farmers and MOA extension officers centred on Mucuna as a fallow crop and nematode suppressant, other taro pests and diseases, biosecurity and quality requirements and taro economic performance from 2009 – 2014. The participants were delighted to be presented with such information and this has equipped them to be better decision makers in terms of reducing post-harvest losses and having the willingness to adopt the Mucuna technology.

Other issues were raised based on farm gate price per kilogram of grade 1 and grade 2 taro however this was an issue better addressed by the national government.

Following the successful training workshop for taro farmers and MOA extension officers the project took additional steps to encourage farmers to adopt the use of Mucuna by organizing and conducting a training program on how to grow Mucuna. The training was delivered through literature and DVD's produced by the MOA of Fiji.

A select group of taro farmers identified by the MOA participated in the training in Navua (Serua and Namosi farmers), Lakena (Naitasiri, Tailevu and Rewa farmers), Nalidi Village (Ra farmers) and Nabouwalu (Bua farmers). These farmers were also presented with 20 – 30 Mucuna seeds each to test at their taro production sites. The project produced publications in the form of posters, banners and stand-up posters which were used during the training workshops.

The posters explained biosecurity and quality requirements for taro exports to New Zealand and Australia and consisted of more photos and less text primarily for farmers to understand and better relate to in terms of their experiences in the field. The stand-up posters and banners showed the taro pathway components and the focus activities relevant to each component in land preparation, production practices, product processing and certification and the requirements of the market.

The project also produced a DVD showing the taro pathway from on-farm production to export. Also included in the DVD the benefits of Mucuna for taro production were explained. The formation of the Taro Working Group (TWG) was a very important component of this project in that it provided a consolidated voice and direction needed to address technical problems in the taro production and export pathway. The TWG comprised of representatives from the MOA Research, Extension and Economic Planning, private sector (exporters), Kalang Consultancy Services and Pacific Community (SPC). The TWG was involved in the research areas of the project and undertook training of MOA extension officers and taro farmers. The future funding of the TWG remains unclear at project completion.

SAMOA

Samoa taro production has progressed significantly since the incursion of the Taro Leaf Blight in 1993. After more than two decades of selective breeding the Samoan Government with the assistance of the Pacific Community (SPC) have now re-engaged exports to New Zealand through the successful breeding of TLB resistant varieties. Not only are they resistant to TLB the new varieties has a similar taste to the Tausala ni Samoa currently exported by Fiji. The new varieties are set to spearhead a strong resurgence in the NZ market and with the assistance of ACIAR and SPC through this project Samoa continues to move towards the establishment of a successful taro export pathway to NZ.

The activities covered in this project are aimed at establishing the identities of nematodes associated with taro in Samoa. The activities are tabled below.

Table 7: Summary of key results for the project objectives and activities

Objective	Sub-objective	Associated activities	Key results	Main outputs (Annex 1)
1. To improve the sustainability of the supply chain	1.1 To collect and fix nematodes from soil and root samples	26 samples of extracted nematodes from soil and roots	Positive identification of common nematodes species associated with taro Majority of plant parasitic nematodes not new *Rotylenchus reniformis, Aphelenchoides bicaudatus, Helicotylenchus mucronatus* are regulated in NZ. This was found on taro roots and soil where taro is grown.	PC13 PI19 PI20
	1.2 To identify and describe nematodes associated with taro before export	10 samples of extracted nematodes from taro scrapings	Positive identification of common nematodes species associated with taro Majority of plant parasitic nematodes not new	PC13 PI20
3. Ensure coordination of research and dissemination of outputs	3.1 Publication of awareness brochures	Brochures for Taro Preparation for the export markets published in both English and the Samoan language		PM5 PM6
	3.2 Completion and published Taro Operations Manual	Operations Manuals were done in collaboration with Samoa Quarantine and was published and distributed to the relevant stakeholders	The Manual provides both pre and post-harvest requirements that will ensure that export taro meets the quality and biosecurity standards set out by NZMPI and the New Zealand market This is referred to by farmers and exporters.	PM7
	3.3 Farmer Awareness Workshop	Carried out workshop in Sava'i and Upolu	Workshop participants were informed on the nematode work and identifications resulting from the project experiments	PI18 PC15 PC16
	3.4 Two Radio Talkback Shows	The project coordinator was invited twice to a radio talkback show where he discussed the objectives of the project and all the activities being implemented in the project. The findings of the experiments	Public awareness was created on developing a cleaner export pathway for taro and the work that was being carried out to meet the project's objectives.	

		and questions raised by the public were discussed.		

Overview and discussion of key results by objectives

Improving the sustainability of the taro supply chain

Majority of the plant nematodes found were associated with taro; however they were not new species except for the two highlighted in yellow which have no occurrence records in Samoa. They are mostly available in very low population densities and cause minimal to no damage..

The frequency of nematode population is mild and does not appear to be at a damaging level. Having samples extracted and nematode species identified is vital in reviewing the nematode status on taro export. Despite the work done on nematode identification, the containers are fumigated at arrival despite it being free-living or very small population.

Additionally, the possibility of finding nematodes on export taro will also depend on how clean the corm is and how much fiber is present on it.

Upon observation of soil samples from areas surveyed, the list of nematodes from CABI occurred in low numbers. Nematodes that are regulated in New Zealand include:

- *Rotylenchus reniformis,*
- *Aphelenchoides bicaudatus,*
- *Aphelenchoides bicaudatus*
- *Helicotylenchus mucronatus.*

Helicotylenchus dihystera was the only species found to be non-regulated in New Zealand. However, some important nematodes such as Meloidogyne sp., are considered a risk if found on taro despite some of their species being non-regulated. Examples include *M. incognita* and *M.javanica.*

Ensure coordination of research and dissemination of outputs

The project has been very instrumental in creating public awareness on the Cleaner Pathway project activities and the work it involves. Brochures have been published showing the requirements for exporting fresh taro and the biosecurity and quality standards required of farmers and exporters.

The publication of a Taro Export Processing Manual has been a great assistance to both exporters, farmers and the relevant stakeholders. Taro growers, exporters and MAF staff are kept aware of the practices and procedures required for the successful export of approved varieties of fresh taro from Samoa to New Zealand. The manual covers grower registration, harvesting and post harvesting practices. With the introduction of the booklet, different stakeholders are now fully informed of the required obligations of exporting fresh taro to New Zealand.

In addition, the project's involvement in radio talkback shows has created much awareness for the project and the public is better informed of the requirements involved in the export of fresh taro and the implications of finding pests and diseases on taro.

The Taro Export Pathway Awareness Workshop provided a lot of information on the different aspects of the taro pathway. This included an overview of the project and the results of the nematode identification work being done. There was also a climate change component in the workshop which addressed the impacts of farming on climate change and how to create a sustainable farming system of taro with the option of using Mucuna. The workshop also provided information on the work being done on mass production techniques of taro.

Exporters contributed with their feedback of the export pathway highlighting the need the need to improve fresh taro and other value adding opportunities along the value chain. The option for an alternative treatment of taro such as hot water treatment was also discussed.

Findings and results were presented in simple layman terms which were understandable to the farmers. This was also the case for awareness materials disseminated which included posters, pamphlets, and brochures in both English and the Samoan language. Self- explanatory photos were used with minimal words for easy understanding.

8 Impacts

FIJI

8.1 Scientific impacts – now and in 5 years

The scientific impacts realised by the project are summarised by objective below, and discussed subsequently.

Objective 1 – Improve the sustainability of the taro supply chain

- Enhanced knowledge of researches at MOA and Pacific Community (SPC) on Mucuna research.
- *Mucuna pruriens* was proven to drastically reduce populations of nematodes in the soil and suppress major weeds over a six month period. In addition Mucuna was able to increase soil fertility through encouraging biological process in the soil and enhances yield of taro, an observation from the ACIAR Soil Health Project.
- The dipping of taro planting material in anti-rot fungicide together with hot water dipping at 50ºC for 10min has been proven to minimize rot infection from early planting through to final harvest.
- Using crates in place of sacks may not be feasible for farmers in very difficult terrain. Even though the crates may reduce post-harvest losses the costs outweigh its benefits.
- Taro dipped in 0.45% – 0.5% sodium hypochlorite slightly slowed rot progression however may not be practical to use. Residue analysis result which <0.05mg/kg was lower than the accepted levels of 1.0mg/kg under NZAUS Food Standards.
- The Taro production and processing guideline provides valuable insight into the responsibilities of each player in the taro pathway. The guidelines were produced under PHAMA FIJI05. Under PHAMA FIJI06 the report was able to justify the Australian phytosanitary treatment of complete removal of petioles on top and around the taro corm because of the absence of Taro vein chlorosis rhabdovirus (TaVCV) in Australia which is present in Fiji.

Objective 2 – evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

- Established the kill temperature and exposure time to eliminate parasitic nematodes and mites on taro corms and determined at 50ºC for 12min. Other organisms such as diptera larvae, beetles, worms and mealybugs were also eliminated at 50ºC for 12min.
- Shelf-life of taro increased to 21 days with minimal rot progression during storage which is more than enough time to be bought during exposure at ambient temperatures. Hot water treatment could increase shelf-life for taro if progressed in the next 5 years.
- Even though parasitic nematodes were eliminated at 50ºC for 12min there were still a few live saprophytic nematodes. These nematodes may have nil quarantine significance in terms of its regulatory status, however, interception at the border could still mean fumigation. In addition the results suggests saprophytic nematodes have a higher tolerance to heat than parasitic nematodes.
- The corm temperature vs hot temperature preliminary experiment yielded tangible results which suggested heat dynamics on the taro corm may recommend other means of heat treatment such as high temperature forced air or vapour heat treatment as a

cost effective measure. The project found that the average corm temperature was 35.8ºC when the corm was treated at 50ºC for 12 min. Therefore at 35.8ºC corm temperature parasitic nematodes were eliminated however there were parasitic nematodes found to be alive. The trials were continued to expose the corms for a further 25min, 30min, 35min and 40 min period. The results after 40 min showed all saprophytic nematodes to be dead at average corm temperature of 40.6ºC. Further work is needed to further realise this potential.

- The cost benefit analysis of using hot water treatment against fumigation showed that the cost outweighs the benefits. Therefore the hot water treatment is not feasible to be used by Fiji's exporters given the costs in 10 years is $235,540.00 more than the benefits.

8.2 Capacity impacts – now and in 5 years

The capacity impacts realised by the project are summarised by objective below, and discussed subsequently.

Objective 1 – Improve the sustainability of the taro supply chain

- The benefits of Mucuna are now being realised through the results of the research conducted during this project in Lomaivuna and Koronivia. This information has been passed on to farmers and MOA Extension officers in the major taro production areas in the Northern Division and Central Division.
- Farmers now realise that using Mucuna as a weed and nematode suppressant has given them an excellent reason to minimize the use of weedicides and excessive use of fertilizers. This knowledge and increased capacity has enabled farmers to make wise decisions for themselves, their land and future generation.
- MOA extension officers are now capable of promoting sustainable use of Mucuna to farmers as a solution to dwindling soil health.
- The purchase of good quality microscopes to identify nematodes during this experiment has greatly assisted the staff in identifying taro pests and will further boost any future work on nematodes and enhance the abilities of MOA staff in nematode ID work.
- Farmers also now understand the post-harvest handling issues that affect taro exports and are able to take steps to improve handling of taro to ensure damages to taro corms are minimized. Hence given the use of crates to be demonstrated to be unfeasible the use of sacks should be used in more cautious and less damaging manner.
- Farmers and MOA extension officers now understand that clean planting material is critical in reducing rot infestation at the early stages of production. Now they have the option of treating the taro planting material with anti-rot fungicides together with hot water to ensure healthy taro crops in the future.
- The PHAMA FIJI05 Taro production and processing guideline is an excellent document presenting the different roles farmers, middle-buyers, MOA, BAF and agents have to play in the taro pathway. This document is useful in developing a knowledge base which will assist everyone understand each other's roles for producing taro for the export market.

Objective 2 – evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

- The MOA Research and SPC Biosecurity now have the capacity to conduct hot water treatment assays given the successful conduct of the research during this project.

- The results of the hot water treatment trials have shown positive results and can be used for other commodities through more research. Here the capacity developed will enable Fiji MOA and SPC to progress research through HTFA and/or vapour treatment.

Objective 3 – ensure coordination of research and dissemination of outputs

- More than 900 farmers, including MOA Extension officers were trained during the 2015-2016 course of the project in the Northern and Central Division where the production of taro in Fiji is located. The project conducted an extensive outreach campaign in these areas where most farmers are isolated from the developments in the taro industry. Including these farmers and and enabling them to participate during the training workshops strengthened their identity in the taro pathway.
- Farmers and extension officers built their capacity to grow Mucuna as a cover crop. With the increasing interest that Mucuna has drawn a selected farmer group from each production area were provided with first-hand knowledge of the husbandry practices of Mucuna and its benefits. This capacity building exercise has now the potential to improve the sustainability of the taro industry in the next 5 years.
- With the assistance of visual aids (stand-up posters and banners of the taro pathway), showing the relevant steps in taro production and export, the MOA divisions were given these aids to assist with future training workshops and display during conferences and agriculture shows. These visual aids, which also include the biosecurity and quality standards of the taro export market, provided a professional outlook during the training workshops and clearly demonstrated how important the taro pathway is to farmers, exporters and the Fiji government as a whole.

8.3 Community impacts – now and in 5 years

The community impacts realised by the project are summarised by objective below, and discussed subsequently.

8.3.1 Economic impacts

Objective 1 – Improve the sustainability of the taro supply chain

- The use of Mucuna as a fallow crop has been identified by the project as a potential impactor in terms of encouraging the sustainability of the taro supply chain through its proven benefits. *Mucuna pruriens* is able to drastically reduce populations of nematodes in the soil and suppress major weeds over a six month period of healthy growth. In addition Mucuna is able to increase soil fertility through encouraging biological process in the soil and enhances yield of taro. More importantly reduction in populations in nematodes could potentially mean reduction in fumigations hence saving fumigations costs and maintaining taro quality and shelf-life at export destinations.
- The increases in yield has been revealed by a taro farmer in Taveuni whereby his taro yields per corm increased from 1.5kg to 2.5kg after using Mucuna as a fallow crop. He also revealed that labour costs have been reduced due to the suppressant effect of Mucuna on weeds and also reduced regular purchases of weedicides. The returns for this farmer using Mucuna has been significant given the fact that he now sells A grade taro (>800grams) which is bought at a higher price. This revelation has been video documented and is available online and used by the project through the MOA as a conceptual testimony to farmers and exporters.

- The use of clean planting material at the early stages of production is crucial to producing healthy crops. Therefore the use of anti-rot fungicide dipping together with hot water dipping at 50ºC for 10min provides a solution to “bad beginnings” during planting of taro. Infected planting material means infection throughout the production cycle or could mean more chemical fungicides application during production.

Objective 2 – evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

- The economic impact in using a hot water machine set (6m x 5m x 1m) would be determined by the cost of its installation and its operational maintenance and cost through a 10 year period described in this project as being higher than the intended benefit by $235,540.
- Although the results show that parasitic nematodes and mites can be eliminated at 50ºC for 12min and subsequently all nematodes eliminated by the 35th minute the costs to install and maintain the hot water machines is making this venture unfeasible.
- However, there are opportunities to proceed further with this research through the use of vapour or hot air. The reason for this is that these techniques use less water as compared to hot water baths or tubs to treat the same volume of corms. This may prove to be a more cost effective heat treatment, however, further trials to prove the concept are required.

Objective 3 – ensure coordination of research and dissemination of outputs

- The delivery of training workshops has provided significant benefit to farmers and MOA extension officers as new technology in Mucuna has been communicated.Together with the promotion of good agricultural practice and minimal standards for exports of taro farmers are adopting sustainable measures to improve the quality of taro. This will ultimately turn into better production practices and higher rewards from high quality taro.

8.3.2 Social impacts

Objective 1 – Improve the sustainability of the taro supply chain

- Mucuna now has the potential to increase yields for farmers and increase the likelihood of producing A Grade taro (<800grams) for the export market. This new technology incorporated into their taro farming system and the income generated from A Grade sales will encourage other farmers, especially women and youths to produce more taro. The project is confident that it will produce these results in the next 5 years.

Objective 2 – evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

- Hot water dipping of taro as a treatment for mites and nematodes is not considered a cost effective treatment option for exporters.
- However, if the use of HTFA or vapour heat becomes is proven to be a feasible option, with the end result being a reduction in fumigation cases the demand for Fiji taro will be expected to increase over the next 5 years. Therefore increasing the potential for farmers to produce more taro and encourages new farmers, including women, to adopt the new profitable venture in the future.

Objective 3 – ensure coordination of research and dissemination of outputs

- More than 900 farmers, including MOA Extension officers were trained during the 2015-2016 course of the project in the Northern and Central Division where the production of taro in Fiji is located. The project made an extensive outreach campaign in these areas where most are isolated from the developments in the taro industry.
- The project views the number of farmers and MOA extension officers that were trained as an enormous step in the right direction for farmers to be encouraged to practice sustainable farming and to maintain the taro export industry. Ultimately the information disseminated to the farmers will result in better living conditions in the rural areas given the increased income they will receive from taro sales.

8.3.3 Environmental impacts

Objective 1 – Improve the sustainability of the taro supply chain

- The demonstrated weed suppressing properties of Mucuna have been demonstrated to reduce weedicide application by farmers. Therefore reducing chemical run-offs from farms into nearby rivers and streams and increasing the survival of marine life which is also part of the livelihoods of farmers as well.

Objective 2 – evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

- The results of the hot water treatment has aroused the potential to further the research into HTFA or vapour heat treatment as a feasible means to treat taro using heat. If this is successful its intended impact will be a reduction in fumigation therefore reducing the use of methyl bromide and its release into the atmosphere.

SAMOA

8.4 Scientific impacts – now and in 5 years

The scientific impacts realised by the project are summarised by objective below, and discussed subsequently.

Objective 1 – Improve the sustainability of the taro supply chain

- The Samoa project team were able to identify the regulated nematodes associated with taro namely *Meloidogyne sp., Rotylenchus reniformis, Aphelenchoides bicaudatus* and *Helicotylenchus mucronatus*. However there is still a grey area in terms of *Meloidogyne ingonita* and *M. javanica* being listed as non-regulated.
- The identification of specific nematodes and mites of concern to taro has also been included in Samoa's pest list database which will assist in the future market access negotiations of taro export to Australia and other countries they wish to export to in the future.
- Staff have been engaged in practicing and learning lab and research protocols as part of the Cleaner Pathway project activities and have a good understanding of the procedures of nematode extraction to be able to use in further work of this type..
- Knowledge and skill shared during field sampling have been an additional learning curve for some of the staff who have been involved in this work.

- Samoa will be able to focus research and development plans on regulated quarantine nematodes of economic significance to taro export.

Objective 2 – evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

- Samoa has established the kill temperature and duration of exposure for mites and nematodes. This was done in collaboration with Plant and Food Research, New Zealand. Further research is still underway with Plant and Food on high pressure washing and hot water treatment of taro.

8.5 Capacity impacts – now and in 5 years

The capacity impacts realised by the project are summarised by objective below, and discussed subsequently.

Objective 1 – Improve the sustainability of the taro supply chain

- Samoa MAF have attained additional experience from this activity in terms of nematodes collection, fixing and preliminary identification. Additional capacity in terms of rigorous methodology is crucial for research purposes which has been attained during this activity.
- The renovation of the Packing Facility at Atele now also provides a better facility for experimental and research purposes and paves the way for HACCP accreditation.
- The purchase of microscopes has also improved the capacity of staff to better identify the pests and diseases found on fresh taro corms. These microscopes should better equip staff in doing any nematode ID work in the future.

Objective 2 – evaluate hot water dipping trials as a phytosanitary treatment against nematodes and mites

- The capacity to undertake hot water treatment research has been thoroughly achieved in these experiments. With the assistance of the NZ Institute of Plant and Food Research Limited, the Samoa research team have gained immense experience in conducting sound scientific research. This is essential for future research of hot water treatment of taro.

8.6 Communication and dissemination activities

FIJI

Project communication and dissemination activities are summarised below:

Primary audience	**Communication & dissemination activities** (Outputs as listed in Appendix 1)
Taro farmers training workshops	▪ Project outputs ▪ Soil Analysis ▪ Pests and diseases of taro ▪ Biosecurity and quality requirements

	▪ Taro economic performance
Taro Industry Meeting – exporters and MOA Economic Planning Division, Research Division	▪ Project outputs ▪ Importance of good agricultural practices
SPC Regional partners	▪ SPC website (2012)-Improving the taro export pathway for Fiji and Samoa ▪ SPC website (April 2016)-Farmers workshop to improve sustainability in the taro pathway ▪ SPC website (July 2016)-Taro cleaner pathway project reminds farmers of their role ▪ SPC website (August 2016)-Awareness materials to promote a sustainable taro pathway
Fiji national media	▪ Fiji Times (2015)-Drop in dalo quality

SAMOA

Project communication and dissemination activities are summarised below:

Primary audience	**Communication & dissemination activities** (Outputs as listed in Appendix 1)
Taro Export Pathway Awareness Workshop	▪ Project overview ▪ Sustainable Farming System of Taro using Mucuna ▪ Nematode Identification ▪ Current Export Pathway and responsibilities of different stakeholders; Issues & Resolutions ▪ Biosecurity and quality requirements ▪ Update Report for Taro Exports ▪ Mass Production Techniques
Radio Talkback Shows	▪ Project overview ▪ Project activities ▪ Importance of compliance to taro export requirements
Samoa local Television Station	▪ A story covering the Taro Pathway Workshop was aired on the television news and an interview was

	conducted where a brief on the aims and objectives of the project was discussed

9 Conclusions and recommendations

The project was conceived through the SPC/ACIAR/MPI SRA workshop which was convened to identify research needs for cleaner export pathways for Pacific Island commodities. A particular concern at the time of the workshop was the continuous fumigation of taro exports to Australia and NZ due to detections of nematodes and mites. As a result of this workshop the project objectives were designed to address the issues from taro production to export in Fiji and Samoa. The general contexts and premises for the project remained relevant over the life of the project, and are expected to continue post project.

9.1 Conclusions

FIJI

The principal conclusions from the project are summarised below.

The demand for taro in the export market still remains strong, reflecting the growth of the industry with exports of more than 12,000 tonnes in 2011 which was valued at more than $FJD22million (EP&S, MOA 2015). However, the export tonnage dropped to under 6,100tons in 2012 due to tropical cyclones and reduced numbers of farmers.. Since then Fiji exports have been steadily increasing and 7,900 tonnes was exported in 2015 valued at $FJD22.5million (EP&S, MOA 2015). Hence the export market for taro from Fiji is still as lucrative as it was 10 years ago. Therefore this project assisted in identifying solutions to ensure the export industry is sustained, maintained and drastically improved.

The Mucuna plant has demonstrated positive benefits in terms of encouraging the sustainability of the taro supply chain. *Mucuna pruriens* is able to drastically reduce populations of nematodes in the soil and suppress major weeds over a six month period of healthy growth. In addition Mucuna is able to increase soil fertility through encouraging biological process in the soil and enhances yield of taro. The Mucuna plant could potentially be one of the keys to addressing biosecurity and quality issues of exported taro.

The crate trials offered some positives in terms of reducing post-harvest losses and the use of crates may be recommended for flatland geographical locations that are easily accessible by vehicles. However for undulating terrain crate use was of minimal success as it was a labour intensive exercise and could not transport as much taro as efficiently as compared to the widely used sack. In addition the price of a crate is too expensive with a price of $FJD54.00 per crate whereas a sack is just $FJD0.50 and more taro is packed in a sack than in crates; 50 – 60 corms to 12-14 corms respectively.

Taro exporters have often remarked that during the sorting and grading process at the exporter’s packhouse losses due to rots, bruising and under-size corms are approximately 30% of the taro quantity received from the farmers. The project concluded that better handling by farmers, agents and middlemen through improved extension and communication these losses could be drastically reduced.

Dipping taro planting material in anti-rot fungicide (7ml/L water) and hot water (50ºC for 10min) provided a solution to minimizing rot infection from early planting. The project has always stressed to farmers that starting with clean material coupled with good agricultural practices will more than likely result in healthy crops.

The PHAMA program has been of immense assistance as evident in their work on PHAMA FIJI05 and FIJI06 for the project. Development of the taro production and processing guideline documented the taro production and export pathway and the responsibility of each player. This document is now in the custody and leadership of BAF. PHAMA FIJI06 substantiated Australia’s specific requirement for Fiji to remove any petiole on and around the taro corm basically leaving the taro corm with much less skin than desired. The absence of Taro vein chlorosis rhabdovirus (TaVCV) in Australia has justified the removal of petioles as a quarantine treatment and as such will remain.

The dipping of taro in 0.5% sodium hypochlorite proved to be insignificant in terms of addressing rot progression, however, hot water treatment had a better effect on taro in terms of longevity on shelf-life. Residue analysis on taro dipped in sodium hypochlorite was negligible at <0.05mg/kg as compared to the allowable levels under NZAUS Food Standards (2014) of 1.0mg/kg.

The hot water temperature and duration of exposure as a treatment for parasitic nematodes and mites on taro was confirmed at 50°C for 12min. The only disadvantage at this temperature was that saprophytic nematodes were found to be alive. Therefore with the current NZ Ministry of Primary Industries stance on fumigating consignments of taro irrespective of whether parasitic or saprophytic nematodes are intercepted the project decided to conduct preliminary trials to test the thermal heat tolerance of saprophytic nematodes together with investigating the corm temperatures against the hot water temperature.

Saprophytic nematodes were found to be dead at 35min of exposure at 50°C with an average corm temperature of 40.6°C. The cost benefit analysis was another issue the project had to consider. The results basically labelled the use of hot water at a commercial level unfeasible where the cost outweighed the benefits by $FJD235, 540 over a period of 10 years after installing 3 commercial size machines.

The dissemination of project outputs significantly covered taro farmers and MOA staff throughout the Northern and Central division of Fiji during training workshops where 910 farmers and MOA staff actively participated for their benefit. The farmers were trained on how Mucuna reduced the incidence of nematodes in the soil and how this would benefit the taro industry in the future given the fact that nematodes are a major influence on fumigation of taro.

Other areas covered with farmers were pest and disease management, soil fertility testing and its importance, biosecurity and quality requirements of the export market and taro economic performance from 2000 – 2014. Publication materials such as stand-up posters and banners on the taro pathway and the taro export standards were also disseminated to the farmers to increase their capacity of the export pathway and enabled them to identify themselves as an important component of the Fiji taro export industry.

SAMOA

Samoa has had some major achievements since the successful breeding of taro leaf blight resistant varieties and selecting the new improved varieties of taro for export. Since 2010 the new pink and white varieties namely Samoa 01, 02, 03, 04 and 05 were selected as export varieties for Samoa. Further research in 2015 established three new pink taro varieties namely Talo Lani, Fusi and Tanu, which are very similar in size, texture and taste to the Tausala ni Samoa frequently exported by Fiji. These varieties have featured prominently in the NZ market and are cheaper than the Tausala ni Samoa. These achievements have contributed to the rapid increase in the number of export containers, the high demand for fresh taro in NZ, American Samoa, the USA and Tokelau.

Developments at the national level include the increase in the number of taro farmers producing export grade taro, the increase in the number of taro exporters, increase in infrastructure development such as access roads, packing facilities, water accessibility and a significant contribution to food security since the inception of these new and improved taro varieties.

Given the current difficulties faced by Samoa in terms of quarantine regulations, the project has taken giant leaps to further address the limitations in export. The identification and confirmation of nematode species associated with taro in Samoa has redirected the focus for research towards reducing the number of nematode incidence on taro. This achievement will lay the foundation on nematode research in Samoa and further increase capacity and the capabilities of research staff.

The activity of nematode sampling and fixing has also contributed greatly to improving the capacity of staff involved in the work. The country's aim of improving their taro export market to New Zealand will be further enhanced with the increased capacity he project has had on the staff, particularly in sampling taros and identifying nematodes and other associated pests.

The achievements recorded with Plant & Food, New Zealand, during the hot water treatments has also established a baseline for further research into hot water treatment. Having achieved 100 percent mortality in mites the nematode heat treatment results suggests that further work is needed to establish tangible results workable for commercial volume treatment.

Although, done with a different collaborating project partner, the high pressure washing and hot water treatment complements the work that has been done by Samoa for the Cleaner Export Pathway Project in identifying the nematodes associated with taro. During the final project workshop it was recommended that hot water treatment and high pressure washing be implemented to improve the export pathway system and to avoid fumigation.

9.2 Recommendations

FIJI

To capitalise on the work of the project, ACIAR could;

- Support a further project to integration the widespread adoption of Mucuna technology by farmers into their taro farming systems.
- Support a further project to investigate the heat treatment of taro using High Temperature Forced Air (HTFA) as an effective post-harvest treatment given the hot water trials has shown to be effective against nematodes and mites;
- Continue to support the capacity building for taro farmers and MOA extension and research staff to better manage the Fiji taro export pathway in the future.
- Continue to support the Fiji Taro Working Group (TWG). The above recommendations could easily form the mandate of the TWG post-project. With strong leadership through the TWG consisting of members from Government (MOA Extension, Research and Economic Planning), private sector and SPC the TWG is capable of producing workable results. The project firmly believes that the benefits of continuing the TWG in providing the leadership to ensure the sustainability of the taro export pathway would outweigh the costs of inaction.

SAMOA

To capitalise on the work of the project, ACIAR could;

- Continue support, directly or by catalysing other funding arrangements, for field management of nematodes and mites.
- Continue support for heat treatment of taro. Samoa's work with Plant and Food, New Zealand on hot water treatment and high pressure washing looks to be a workable and economical option for ridding these hitchhikers and further work to explore this is continuing
- The use of high water pressure to wash taro free of soil and dirt is recommended as nematodes and other microscopic pests cannot be seen by the naked eye when washing.
- The Taro Operation Manual may need updating and review to suit the current and future changes in the taro pathway.

- Continue to support the capacity building for taro farmers and MOA extension and research staff.

10 References

10.1 References cited in report

Brash & Epenhuijsen, 2006, Hot water treatment of taro for control of mites and nematodes, Crop & Food Research Confidential Report No.1696

Fuji, Y. (1999) *Allelopathy of hairy vetch and Mucuna; their application for sustainable agriculture* pp. 289-300. In C. H. Chou, G. R. Waller and C. Reinhandt (eds). Biodiversity and Allelopathy: From Organism to Ecosystem in the Pacific. Academia Sinica, Taipei.

Hauser, A., Amougou, D., Kanga Ngo, F., Pekeleke, M. (2008), *On farm demonstration, testing and dissemination of boiling water treatment for plantain (*Musa spp.*) sucker sanitation in Southern Cameroon*, Mbalmayo, Cameroon: International Institute of Tropical Agriculture.

Lurie, S. (1998). Postharvest heat treatment. Postharvest. Biol.Technol. 14, 257-269.

Lurie, S., Mitcham, E., Tang, J., Wang, S. and (2007), *Heat treatments for postharvest pest control*, Washington DC: CABI International.

Tsang, M. M. C., Hara, A. H., Hata, T. Y., Hu, B. K. S., Kaneko, R. T., and Tenbrink, V. (1994), *Hot water immersion unit for disinfestation of tropical floral commodities*, Hawaii: University of Hawaii.

10.2 List of publications produced by project

Journal publications

JP1 Buli, A., Ciri, M., Lomavatu M. (2015) *Developing cleaner export pathways for taro in Fiji and Samoa.* XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): International Symposium on Innovative Plant Protection in Horticulture, Biosecurity, Quarantine Pest, and Market Access.

Project reports

PR1 Kalang Consultancy Services, SPC, MOA (2013) *Developing cleaner export pathways for Pacific agricultural commodities 2012-2013 Annual Report.*

PR2 Kalang Consultancy Services, SPC, MOA (2014) *Developing cleaner export pathways for Pacific agricultural commodities 2013-2014 Annual Report.*

PR3 Kalang Consultancy Services, SPC, MOA (2015) *Developing cleaner export pathways for Pacific agricultural commodities 2014-2015 Annual Report.*

PR4 PHAMA FIJI05 (2013) Technical Report 27: Development of and training on Taro Production and Pack House Standards; *produced* Taro production and processing guideline.

PR5 PHAMA FIJI06 (2013) Technical Report 51: Substantiation of Australia's Requirements for Devitalisation of Taro Imports

11 Appendixes

11.1 Appendix 1:

Project internal reports

PI1 Buli, T. A. and Cawaki, U. T (2015) *SPC Duty Travel Report*: Taro potting trials to determine optimum treatment for taro planting material to reduce corm rot.

PI2 Buli, T. A. (2015) *SPC Duty Travel Report*: Training workshop for Northern Division taro farmers.

PI3 Buli, T. A. (2015) *SPC Duty Travel Report*: Training workshop for Central Division taro farmers

PI4 Buli, T. A. (2016) *SPC Duty Travel Report*: Training workshop for Northern Division taro farmers

PI5 Buli, T. A.(2016) *SPC Duty Travel Report*: Training workshop for Central Division taro farmers

PI6 Buli, T. A. (2016) *SPC Duty Travel Report*: Mucuna Training workshop for Central and Northern Division taro farmers

PI7 Biaukula, S., Dakaica, I., Khan, F. (Feb, 2016) *SPC Duty Travel Report*: Mucuna seed bank site identification, soil sampling and Mucuna planting

PI8 Biaukula, S., Dakaica, I., Khan, F. (April, 2016) *SPC Duty Travel Report*: Mucuna seed bank site fencing and trellising.

PI9 Biaukula, S., Dakaica, I., Khan, F. (Feb, 2016) *SPC Duty Travel Report*: Mucuna seed bank site inspection and billboard installation.

PI10 Biaukula, S., Dakaica, I., Khan, F. (Feb, 2016) *SPC Duty Travel Report*: Mucuna seed bank site identification, soil sampling and Mucuna planting

PI11 Biaukula, S., Dakaica, I., Khan, F. (Feb, 2016) *SPC Duty Travel Report*: Mucuna seed bank site harvesting – Mucuna seeds.

PI12 Biaukula, S., Dakaica, I., Khan, F. (Feb, 2016) *SPC Duty Travel Report*: Mucuna seed bank site replanting for farmers

PI13 Buli, T. A., Cawaki, T. U., Dakaica, I., Powell, L., Prasad, N. (2016) *Hot water immersion treatment of nematodes and mites on taro.*

PI14 Cawaki, T. U., Dakaica, I., Powell, L. (2016) *Taro dipping in sodium hypochlorite and residue analysis*.

PI15 Navneel, P. (2016) *Cost benefit analysis on the use of hot water treatment for taro*

PI16 Buli, T. A and Cawaki, T. A. (2016) *Taro potting trials to determine optimum treatment for taro planting material to reduce corm rot.*

PI17 Buli, T. A., Cawaki, T. U., Ciri, R. M. (2011) *Evaluate Mucuna as weed suppressant and nematode reducer in soil.*

PI18 Tanielu,P(2015) Taro Workshop Report, Savaii and Upolu

PI19 Tugaga,A (2011) Preliminary Trial of Nematode Identification on Taro *(Colocasia esculenta)*

P20 Tugaga,A,(2015) Identification of Plant Parasitic Nematodes Associated with Taro *(Colocasia esculenta)*

Presentations and conference papers

PC1 Buli, T. A. (2015) Training workshop presentation – Project overview, outputs and update.

PC2 Biaukula, S. (2015) Training workshop presentation – Importance and benefits of soil fertility tests.

PC3 Cawaki, T. U. (2015) Training workshop presentation – Pests and diseases of taro and its management.

PC4 Dakaica, I. (2015) Biosecurity and quality requirements for exporting taro

PC5 Veretawatini, V. (2015) Fiji taro economic performance from 2009 – 2014

PC6 Ciri, R. M. (2016) Evaluate Mucuna as weed suppressant and nematode reducer in soil – *Final workshop*

PC7 Dakaica, I. (2016) Objective 3: Ensure coordination of research and dissemination of outputs – *Final workshop*

PC8 Biaukula, S. (2016) Objective 1: Sustainability of the taro supply chain – Crates vs sack trial and sodium hypochlorite dipping of taro – *Final workshop*

PC9 Buli, A. T. and Dakaica, I. (2016) Hot water immersion treatment of nematodes and mites on taro – *Final workshop*

PC10 Cawaki, T. U. (2016) Taro potting trials to determine optimum treatment for taro planting material to reduce corm rot – *Final workshop*

PC11 Dakaica, I. (2016) Mucuna seed bank sites – *Final workshop*

PC12 Dakaica, I., Powell, L. (2016) Taro dipping in sodium hypochlorite and residue analysis – *Final workshop*

PC13 Tanielu, P. and Tugaga, A. (2016) Nematode identification on taro – *Final workshop*

PC14 Tugaga, A. and Tunupopo, F. (2016) Hot water treatment of taro; Development of Risk Management Treatments for Root Crop from Pacific Islands. *Final workshop*

PC15 SamoaTraining Workshop Presentation- Cleaner Pathway Project Overview(2015)

PC16 SamoaTraining Workshop Presentation- Cleaner Pathway Nematode Identification Work(2015)

Publications Materials

PM1 Buli, A. T and Dakaica, I. (2016) Taro pathway posters and banners; Pacific Community Communications.

PM2 Buli, A. T and Dakaica, I. (2016) Taro export standards; Biosecurity and Quality requirements; Pacific Community Communications.

PM3 Taro Working Group (2016) Taro export pathway DVD; Pacific Community Regional Media Centre.

PM4 Taro Working Group (2016) Meeting minutes and resolutions; Pacific Community, Suva, Fiji

PM5 Tanielu, P, (2011) Preparation of Taro for Export Market (English Version), Crops Division, Nu'u and Salelologa, MAFF Samoa

PM6 Tanielu, P, (2011) Preparation of Taro for Export Market (Samoan Version), Crops Division, Nu'u and Salelologa, MAFF Samoa

PM7 Ministry of Agriculture and Fisheries, Samoa,2015, Operations Manual- Export of Fresh Taro from Samoa to New Zealand