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Final report

project

Strengthening the Fiji Papaya Industry through applied research and information dissemination

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1 Acknowledgments

PC/2008/003 embodied the ideals of a good Public -Private Partnership (PPP) which has resulted in many scientific, economic and social impacts. The authors would like to acknowledge all the dedicated personnel involved in the implementation of this project in both Fiji and Australia. Specific organisations that were directly involved in the implementation of PC/2008/003 include:

1. Queensland Department of Agriculture and Fisheries (DAF).
2. The Secretariat of the Pacific Community (SPC)
3. Nature's Way Cooperative (Fiji) Ltd
4. Koko Siga (Fiji) Ltd.
5. The Fiji Ministry of Agriculture (MOA)
6. The Fiji Biosecurity Authority (BAF)
7. Sabeto Organic Producers Association (SOPA)

The project also benefitted significantly from constant support (technically and administratively) provided by ACIAR through its Country Program Managers.

2 Executive summary

The Fiji Papaya Project, PC/2008/003 began in July 2009, with the aim of strengthening the papaya industry in Fiji and Australia, within the broader development goal of improving the livelihoods of rural people in Viti Levu. As of November 2015, the Fiji Papaya industry and related partners (Ministry of Agriculture, Biosecurity Authority of Fiji and SPC) had established a very strong research and extension foundation to continue the development of the papaya industry. Significant credit for the growth of the industry in terms of export and capacity must be attributed to this project which has maintained a high level of research and development outputs over the project period and through the series of extensions. As indicated in the 2012 external review of PC/2008/003, the Project has delivered on all of its milestones and in fact exceeded many of the projected outputs. The success of PC/2008/003 can be largely attributed to the commercial orientation of the project, strategic private and public sector partners and strong project management.

Some hallmark successes of PC/2008/003 in Fiji over the six years of the project include:

- The establishment of an industry-led working committee made up of representatives of exporters, farmers, government officials and technical advisers involved horticultural export crops. This committee grew out of the Fiji Papaya Project (FPP) Technical Advisory Board and the Pacific Breadfruit Project (PBP) Technical Advisory Board. These have now been institutionalised by Nature's Way Cooperative (NWC) in the form of the NWC Research and Extension Partnership (REP) Committee.
- The establishment of a certified seed producer's scheme for Fiji Red Papaya. This scheme was developed based on research findings from the project and is now run as a commercial scheme managed by NWC with oversight from the Ministry of Agriculture. There are now twelve commercial seed producers.
- Investment in a commercial hot water dipping treatment to be available to Fiji papaya exporters through NWC. This investment is expected to overcome a major source of post-harvest loss currently being suffered by the industry. This commercial treatment resulted from collaborative research between the FPP, Queensland Government's Department of Agriculture, Fisheries and Forestry (QDAFF) and the Secretariat of the Pacific Community (SPC) and has the potential to save the industry approximately 2 million dollars annually.
- Commercial investment at the farm and exporter level in organic papaya production. This development came as a direct result of field trials exploring the economics of organic papaya production and market research that was undertaken as a lead up to the FPP. The FPP has been assisting NWC in facilitating the necessary market access for this papaya into the United States.
- A platform has been established that has attracted investment from private and public sector partners. PC/2008/003 has encouraged new exporter and farmer entrants to the industry. The project has also attracted investment from development partners such as IFAD, NZAid, AusAID, EU and the ACIAR PARDI Project.

While the impacts of PC/2008/003 have been substantial, there is much more work to be done for the Fiji Papaya industry to continue to be competitive in export markets. As a result of PC/2008/003, industry and public stakeholders are now better positioned to continue with research and innovation, however further involvement by ACIAR will continue to produce high rates of return on these research investments.

3 Background

At the time of the initial development of the project, Fiji was facing an economic catastrophe with the demise of its sugar industry due to the phasing out of preferential access to the EU sugar market. The predicament faced by Fiji's farmers was accentuated by the political crisis that engulfed Fiji in December 2006. Diversification of export and livelihood opportunities was (and is) urgently required if a major calamity is to be avoided. The growing papaya industry provides one of the most promising diversification avenues for many small farmers who have access to suitable land.

Fiji is well placed to become a substantial papaya producer, based on a number of factors, including:

- Favourable soils and climate
- Favourable pest and disease status.
- A functioning commercial quarantine treatment
- Strong export and local market demand for (Appendix 1)

The Fiji papaya industry is comprised of:

- 9 exporters
- 11 larger papaya farmers (producing more than 1 tonne a week)
- Some 100 small farmers
- 1 industry owned and operated quarantine treatment facility (Nature's Way Cooperative)

Papaya has become Fiji's most important fruit export commodity and offers the prospect of becoming a major industry. Farmers in the Nadroga/Navosa and the Ba provinces are now recognizing the potential papaya provides in household income generation. As a result many new growers are taking up papaya farming. Although there is considerable information on papaya production from around the world, until PC/2008/003, this had not been "customised" for use by Fijian farmers, furthermore there had not been any formal research into the issues facing the commercial papaya industry in Fiji. As a result of this lack of sound information with regards to production, harvest and post harvest issues there were serious quality and consistency issues that threatened the long term viability of the Fiji papaya industry.

The ACIAR project "Strengthening the Fiji Papaya Industry through applied research and information dissemination" aimed at addressing the immediate needs of the industry as well as establishing the framework to take the industry forward. The project was developed and implemented in close collaboration with the Fiji Papaya industry through Nature's Way Cooperative (Fiji) Ltd. The project also drew on the experiences and expertise of the papaya industries in Australia and Hawaii.

The primary aim of the Project was to substantially increase the contribution of fruit and vegetable exports to livelihoods of rural people in western Viti Levu. The expected outputs of the project include: a three fold increase in exports of papaya; a doubling of persons involved in the papaya industry; a 50% reduction in culled fruit from the farm; an increase in competitiveness of Fiji Papaya on the export market through the use of sea freight.

Prior to the start of the project, the papaya industry in Australia was significantly undeveloped due to high levels of losses in the supermarket system and inconsistency of product flavour and fruit ripening behaviour. While the industry had invested in Research and Development to improve cultivar performance there was a need for a supply chain approach to reducing costs and to better meet customer requirements. It was therefore determined that as part of this project consignments for each supply chain and season of activity will be monitored for quality and handling practices and conditions. Results would be reviewed, and

analysed to determine areas for improvement. Subsequently improvement plans would be developed and assessed. It was foreseen that this approach would provide resources to solve key research problems in the supply chain and to foster wide uptake of improvements by farmers and other supply chain members. Based on the Australian experience it was determined that there was a high probability that the supply chain component would deliver short term benefits to farmers in both Fiji and Australia. Expected benefits included: stronger chain relationships, a reduction in market losses (10%), lower transaction costs and higher through-put. An assured supply of good quality papaya should contribute to an improvement in the demand for higher quality tropical fruits both domestically and for export.

4 Objectives

Within the broader development goal of improving the livelihoods of rural people in Viti Levu, based on increased production and improved marketing of fruit and vegetables, the purpose of this project was to strengthen the papaya industry in Fiji and Australia.

The project planned to achieve this goal through the following objectives and activities:

Objective 1: Strengthen the capacity of the Fiji papaya industry to plan, conduct and adopt the products of problem-solving research

Activity 1.1 Establish a standing technical advisory board (TAB) and processes for prioritising and managing research

- Identify stakeholders in papaya production and market chain; identify representatives of key stakeholders for R&D management; and establish regular meetings
- Establish process for obtaining feedback from activity 2 and other sources of problem identification and, based on this, for planning and resourcing research

Activity 1.2 Establish quality monitoring, traceability and feed-back system to farmers

Activity 1.3 Establish infrastructures for identifying producers' problems and conducting on-farm research

Activity 1.4 Establish mechanisms for effective feedback, adaptation and adoption of innovations

- Compile results from research applications and analyse. With assistance from the TAB, review the results of the research applications and extract the most relevant information for use in information sheets and other extension materials.
- Coordinate papaya extension programme that levers available resources from all partners to effectively disseminate findings.
- Hold regular field days at demonstration farms and encourage lead farmers to model best practice techniques to surrounding farmers.

Activity 1.5 Provide targeted technical support in key areas

- Technical support missions from QDPI specialists in pest and disease management, nutrition management.
- Technical support missions from Hawaii to develop organic systems and improved post harvest handling and quarantine treatment.

Objective 2: To expand and increase the resilience of the Fiji papaya industry

Activity 2.1 Identify and evaluate local and export markets and strategies to enhance or sustain the value chain for Fijian papaya to these markets

- Evaluate the market for certified organic papayas and assess the costs and benefits of available organic certification regimes
- Evaluate the possibilities for export of Fiji papaya by sea freight
- Analyse the economics of growing papaya under a variety of different management systems including organic. Prepare farm management budgets based on field trials and lead farmer data collection.
- Design and implement a risk management plan for Papaya ringspot virus (PRV) entering Fiji (including a range of precautions, such as strengthened quarantine

legislation and actions, to keep PRV out of Fiji and trialling of suitable resistant varieties - as below).

- Collate nutritional and papaya use material suitable for Fiji consumers to enhance the domestic market for Fijian papaya.

Activity 2.2 Identify and evaluate new genetic resources to underpin sustainability

- Import pure 'Solo Sunrise' variety seeds from The University of Hawaii
- In traditional growing regions, evaluate with farmers selected varieties similar to 'Solo sunrise' from Hawaii but with possible other desirable characteristics that could enhance the 'Fiji Red' brand
- In new growing regions, evaluate with farmers selected varieties (e.g. Waimanalo) that perform better in more humid and wet conditions but still have export potential. (It is anticipated that opening new growing regions will broaden the production base of the industry, make it less vulnerable to natural disasters and provide papaya-based livelihoods outside the current commercial production areas).
- Identify and evaluate, at selected sites, cultivars resistant to Papaya ringspot virus
- Collect, identify and evaluate locally available papaya varieties with the aim of determining the most suitable types for home gardens. (Of particular interest will be varieties that are nutrient rich, tolerant to strong winds and adverse soil conditions and easily propagated and cultivated).

Activity 2.3 Strengthen the seed system to disseminate high quality planting materials

- Design and implement a programme for maintenance of homogenous papaya seeds through regular and effective monitoring and implementation of technical processes involving collaboration between NWC, seedling suppliers and the Ministry of Agriculture.
- Training, awareness, and competency building to encourage establishment of small enterprises and individual growers producing high quality papaya seeds and a revolving industry fund established for the purchase of high quality papaya seedlings and seeds.

Activity 2.4 Improve production systems through participatory, on-farm research

- Conduct field trials at selected sites to determine the most effective and economic set of production practices for the currently preferred and most promising proposed varieties planted at the two different sites. (Trials will analyse both conventional and organic cropping systems. The production practices likely to be investigated include: land preparation, fertilizer rates, weed control techniques, fruit thinning etc.)
- Conduct research to solve production-linked problems identified by the processes set out in Objective 1. Problems already identified for immediate attention include:
  - Minimising the impact of phytophthora fruit/root rot and other fungal diseases on commercial papaya plantings (using pest/disease sampling etc)
  - Controlling problem of hard lumps in the fruit (using soil and foliage analysis to investigate possible nutrient deficiencies etc)
  - Address problem of irregular fruit set in commercial papaya plantings

- Controlling problem of speckled marks on fruit
- Activity 2.5 Improve post-harvest handling
- Conduct research to solve post-harvest problems identified by the processes set out in Objective 1. Problems already identified for immediate attention include:
- Extend shelf life of fruit (e.g. through fruit wax, hormone control, cool chain etc.)

- Conduct research to optimise conditions for export of papaya by sea freight

Objective 3: To enhance the profitability and competitiveness of the Australian papaya industry by improving the supply chain

Activity 3.1: Identify and mobilise commercial partners who can champion improvements in papaya chains and where benefits and cost savings are shared by all members of the chain.

Activity 3.2: Identify strategies to improve product flows/handling, information systems, supply chain relationships and value adding to all participants in the supply chain.

Activity 3.3: Identify post harvest disease issues and implement possible remedial strategies.

Activity 3.4: Trial supply chain interventions with commercial partners to improve product flows/handling, information systems, supply chain relationships and value adding to all participants in the supply chain.

Objective 4: To promote the adoption of project outputs in the Fiji papaya industry and elsewhere

Activity 4.1 Identify potential beneficiaries within papaya industry and beyond (e.g. nascent papaya industries in others PICs, other existing or potential fruit industries in Fiji) and define strategy for reaching them

Activity 4.2 Compile, review and analyse results from field trials and all other research activities.

Activity 4.3 Prepare information dissemination materials and processes to bring research outputs to priority beneficiaries (as identified above) including:

- a 'Fiji Papaya' website that will promote Fiji papaya and make available information on the ACIAR project and other parallel activities.
- information sheets, training manuals and posters.

Activity 4.4 Conduct Papaya Industry Stakeholder Workshops (to share outputs from the Project and develop consensus on 'next steps' for further development of the industry)

Activity 4.5 Conduct Australia-Fiji Papaya Industry Learning Workshops (for exchange of experiences in developing papaya value chains)

Activity 4.6 Conduct briefings and informal workshops to transfer conclusions of project to other potential beneficiaries (Fiji Ministry of Agriculture, Koronivia Research Station, Fiji College of Agriculture etc.)

5 Methodology

Objective 1: Strengthen the capacity of the Fiji papaya industry to plan, conduct and adopt the products of problem-solving research

Activity 1.1 Establish a standing technical advisory board (TAB) and processes for prioritising and managing research

Identify stakeholders in papaya production and market chain; identify representatives of key stakeholders for R&D management; and establish regular meetings. Coordination of all TAB activities will be led by Kyle Stice and Andrew McGregor. Several TAB members have already been identified and appear in this project document, further appointments to the TAB will be made in due course. It is envisaged that at least one representative from the QDPI partners will be part of this TAB.

Establish process for obtaining feedback from activity 2 and other sources of problem identification and, based on this, for planning and resourcing research. TAB will be responsible for setting up this process under the guidance of the Project Leader and Kyle Stice. With a careful analysis of the issues at hand the TAB will decide what activities are best addressed by what partner. In many instances R&D work outside of the scope of the ACIAR project will be delegated to partners such as SPC, the Taiwanese Technical Mission or the Ministry of Agriculture.

Activity 1.2 Establish quality monitoring, traceability and feed-back system to farmers. This system will be set up in conjunction with the NWC Field Service that closely monitors product that enters the treatment facility. The bilateral quarantine agreement currently in place for papaya exports requires coding of all field crates that enter the treatment facility, this coding should trace back directly to a specific farm, on a specific harvest date. This system needs to be enhanced in conjunction with the introduction of industry export standards that are applied to improve the quality and consistency of papaya exports.

Activity 1.3 Establish infrastructures for identifying producers' problems and conducting on-farm research. Extension partners will have regular task of visiting farming areas to document problems faced by stakeholders and receive requests for assistance. TAB will be tasked to evaluate issues and requests and respond by delegating responsibility to the most appropriate partner to address the issue.

Activity 1.4 Establish mechanisms for effective feedback, adaptation and adoption of innovations

Compile results from research applications and analyse. With assistance from the TAB, review the results of the research applications and extract the most relevant information for use in information sheets and other extension materials.

Coordinate papaya extension programme that levers available resources from all partners to effectively disseminate findings.

Hold regular field days at demonstration farms and encourage lead farmers to model best practice techniques to surrounding farmers.

Activity 1.5 Provide targeted technical support in key areas

Technical support missions from QDPI specialists in pest and disease management, nutrition management and post harvest handling. It is also envisioned that QDPI will provide technical assistance to the TAB in the design of experiments and establishment of field trials.

Technical support missions from Hawaii to develop organic systems and improved post harvest handling and quarantine treatment. Farmer/exporter Grant Schule has already been identified to carry out this activity.

Objective 2: To expand and increase the resilience of the Fiji papaya industry

Activity 2.1 Identify and evaluate local and export markets and strategies to enhance or sustain the value chain for Fijian papaya to these markets

Evaluate the market for certified organic papayas and assess the costs and benefits of available organic certification regimes. This analysis will be undertaken by Andrew McGregor and Kyle Stice and will form the basis for the organic production field trials.

Evaluate the possibilities for export of Fiji papaya by sea freight.

Analyse the economics of growing papaya under a variety of different management systems including organic. Prepare farm management budgets based on field trials and lead farmer data collection. Coordination of economic analysis and preparation of financial models will be undertaken by Andrew McGregor and Kyle Stice.

Design and implement a risk management plan for Papaya ringspot virus (PRV) entering Fiji (including a range of precautions, such as strengthened quarantine legislation and actions, to keep PRV out of Fiji and trialling of suitable resistant varieties - as below). Kyle Stice will undertake the coordination of this activity and likely draw on expertise from QDPI to carry out this activity.

Collate nutritional and papaya use material suitable for Fiji consumers to enhance the domestic market for Fijian papaya. These materials will be prepared in collaboration with supermarket chains and domestic wholesalers. It is envisioned that this activity will work in conjunction with the Ministry of Health initiative to promote a healthy diet by consuming more fruits and vegetables.

Activity 2.2 Identify and evaluate new genetic resources to underpin sustainability

Import pure Hawaiian solo "sunrise" variety seeds from The University of Hawaii. The project will import its own seed for use in field trials and for establishment of nursery development activities.

In traditional growing regions, evaluate with farmers selected varieties similar to Hawaiian solo "sunrise" from Hawaii but with possible other desirable characteristics that could enhance the 'Fiji Red' brand. Several varieties have already been identified and it will be left up to the TAB to determine the most suitable varieties to be trialled in the two locations.

In new growing regions, evaluate with farmers selected varieties (e.g. Waimanalo) that perform better in more humid and wet conditions but still have export potential. (It is anticipated that opening new growing regions will broaden the production base of the industry, make it less vulnerable to natural disasters and provide papaya-based livelihoods outside the current commercial production areas). TAB will make all final selections on varieties to be trialled.

Identify and evaluate, at selected sites, cultivars resistant to Papaya ringspot virus. Varieties will be selected based upon their marketability and suitability to Fijian conditions.

Collect, identify and evaluate locally available papaya varieties with the aim of determining the most suitable types for home gardens. (Of particular interest will be varieties that are nutrient rich, tolerant to strong winds and adverse soil conditions and easily propagated and cultivated). This activity will be coordinated by Kyle Stice with technical assistance from Roger Goebel.

Activity 2.3 Strengthen the seed system to disseminate high quality planting materials

Design and implement a programme for maintenance of homogenous papaya seeds through regular and effective monitoring and implementation of technical processes involving collaboration between NWC, seedling suppliers and the Ministry of Agriculture.

Training, awareness, and competency building to encourage establishment of small enterprises and individual growers producing high quality papaya seeds and a revolving industry fund established for the purchase of high quality papaya seedlings and seeds.

Activity 2.4 Improve production systems through participatory, on-farm research

Conduct field trials at selected sites to determine the most effective and economic set of production practices for the currently preferred and most promising proposed varieties planted at the two different sites. (Trials will analyse both conventional and organic cropping systems. The production practices likely to be investigated include: land preparation, fertilizer rates, weed control techniques, fruit thinning etc.)

Conduct research to solve production-linked problems identified by the processes set out in Objective 1. Problems already identified for immediate attention include:

Minimising the impact of phytophthora fruit/root rot and other fungal diseases on commercial papaya plantings (using pest/disease sampling etc)

Controlling problem of hard lumps in the fruit (using soil and foliage analysis to investigate possible nutrient deficiencies etc)

Address problem of irregular fruit set in commercial papaya plantings

Controlling problem of speckled marks on fruit

Activity 2.5 Improve post-harvest handling

Conduct research to solve post-harvest problems identified by the processes set out in Objective 1. Problems already identified for immediate attention include:

Extend shelf life of fruit (e.g. through fruit wax, hormone control, cool chain etc.)

Conduct research to optimise conditions for export of papaya by sea freight

Objective 3: To enhance the profitability and competitiveness of the Australian papaya industry by improving the supply chain

Activity 3.1: Identify and mobilise commercial partners who can champion improvements in papaya chains and where benefits and cost savings are shared by all members of the chain.

Activity 3.2: Identify strategies to improve product flows/handling, information systems, supply chain relationships and value adding to all participants in the supply chain.

Activity 3.3: Identify post harvest disease issues and implement possible remedial strategies.

Activity 3.4: Trial supply chain interventions with commercial partners to improve product flows/handling, information systems, supply chain relationships and value adding to all participants in the supply chain.

Objective 4: To promote the adoption of project outputs in the Fiji papaya industry and elsewhere

Activity 4.1 Identify potential beneficiaries within papaya industry and beyond (e.g. nascent papaya industries in others PICs, other existing or potential fruit industries in Fiji) and define strategy for reaching them

Activity 4.2 Compile, review and analyse results from field trials and all other research activities. This activity will be coordinated by Kyle Stice and Andrew McGregor with constant consultation with the TAB.

Activity 4.3 Prepare information dissemination materials and processes to bring research outputs to priority beneficiaries (as identified above) including:

a 'Fiji Papaya' website that will promote Fiji papaya and make available information on the ACIAR project and other parallel activities.

information sheets, training manuals and posters.

Activity 4.4 Conduct Papaya Industry Stakeholder Workshops (to share outputs from the Project and develop consensus on 'next steps' for further development of the industry)

Activity 4.5 Conduct Australia-Fiji Papaya Industry Learning Workshops (for exchange of experiences in developing papaya value chains). Direct project personnel from Fiji and Australia will be involved in these visits.

Activity 4.6 Conduct briefings and informal workshops to transfer conclusions of project to other potential beneficiaries (Fiji Ministry of Agriculture, Koronivia Research Station, Fiji College of Agriculture etc.) These meetings will be an ongoing component of the extension programme. It is also envisioned that through representation of the various agencies in the TAB there will be a constant flow of information from the project to the target beneficiaries.

6 Achievements against project activities and outputs/milestones

Objective 1: Strengthen the capacity of the Fiji papaya industry to plan, conduct and adopt the products of problem-solving research

No.	Activity	Outputs/Milestones	Completion date	Comments
1.1	Establish a standing technical advisory board (TAB) and processes for prioritising and managing research	TAB has been established with twenty meetings completed. TAB has grown into an industry body for papaya and all meetings are well attended.	Yr 1, M6	A major achievement of the TAB has been the leveraging of technical inputs from other stakeholders. The papaya TAB meeting has evolved into the newly established Nature's Way Cooperative Research and Extension Committee.
1.2	Establish quality monitoring, traceability and feed-back system to farmers	Monitoring and feedback system is in place and operational. The Project collates all export data on a quarterly basis for reporting back to the industry in the form of TAB reps, newsletter and the website.	Yr 1, M10	Through regular monitoring of export consignments, the Project has an up to date reading on all quality and supply issues.
1.3	Establish infrastructure for identifying producers' problems and conducting on-farm research	Monitoring system is in place to identify producers' problems.	Yr 1, M10	The TAB is actively reviewing issues and making appropriate recommendations for action.
1.4	Establish mechanisms for effective feedback, adaptation and adoption of innovations	The FPP website and quarterly newsletter are fully operational and widely distributed locally, regionally and internationally. Research activities have all been participatory in nature. Twelve workshops and farmer field days have been organised by the FPP, in collaboration with Fiji's Ministry of Agriculture (MOA) and the Taiwan Technical Mission (TTM), to present findings.	Yr 1, M10	Information and content from the Fiji Papaya Project website is currently being transferred to the soon to be launched Nature's Way Cooperative Research and Extension Network website where it will be managed and updated for the foreseeable future.
1.5	Provide targeted technical support in key areas	The SPC Plant Pathology team have provided regular disease monitoring and sampling to the Fiji Papaya industry and has assisted in the identification of disorders. QDAFF and the FPP team have completed nine collaborative research activities over the five year life of the project. QDAFF and the FPP have co-published four scientific papers on this collaborative research. The Project has worked with Hawaii's Kumu Farms to establish organic papaya production in Fiji.	Yr 3, M10	The targeted technical inputs from QDAFF, SPC and Kumu Farms have led to significant scientific impacts.

PC = Partner Country, A = Australia

Objective 2: To expand and increase the resilience of the Fiji papaya industry

No.	Activity	Outputs/Milestones	Completion date	Comments
2.1	Identify and evaluate local and export markets and strategies to enhance or sustain the value chain for Fijian papaya to these markets	An extensive analysis of the Fiji papaya supply chain was undertaken. Detailed market surveys to NZ, Australia, USA and Japan have been completed. A paper based on these studies was presented at a CTA International Value Chain conference in Nov 2012 and has been accepted for publication by CTA. Fruit quality assessments for two Fiji exporters were carried out on the Melbourne market in 2012 and one in 2014 to identify key quality issues and propose strategies to address these issues.	Yr 1, M6	The FPP project has used the results of this market research to design the targeted research interventions. The FPP is also working with other support agencies to meet identified market requirements; including the HACCP certification of NWC which is a joint initiative with the EU funded SPC (Facilitating Agricultural Commodity Trade (FACT) project. The FFP is currently collaborating with the Pacific Organic and Ethical Trade Community (POETCom) on organic certification of Fiji Papaya.
2.2	Identify and evaluate new genetic resources to underpin sustainability	Seed block trials to introduce the package of best practices to collect seed from inbred papaya lines and initiate a programme for selection of a locally adapted solo sunrise variety has been completed. A package of best practices for seed selection has been developed using information from this trial.	Yr 3, M10	The Fiji Papaya Project in collaboration with the Ministry of Agriculture's Research Division and industry partners have agreed on a national seed production standard that has been adopted by both government and private sector seed producers.
2.3	Strengthen the seed system to disseminate high quality planting materials	As a result of the seed production research findings, the FPP have initiated a certified seed producer's scheme using best practice techniques. The scheme draws on systems developed for the Hawaii and Australia industries. The seed production scheme involves private sector seed producing enterprises certified by the MOA Research Division.	Yr 1, M8	The FPP is working closely with eight private sector seed producers throughout the country to ensure production guidelines and quality standards set out in the Seed Producer's Scheme are closely adhered to. Nature's Way Cooperative launched this certified 'Fiji Red' seed to the industry in February 2014 and seed sales are progressing well. The industry is no longer a risk from imported seed.

No.	Activity	Outputs/Milestones	Completion date	Comments
2.4	Improve production systems through participatory, on-farm research	A number of field trials have been completed while some trials had to be abandoned due to extreme flooding and a cyclone. Successful trials have included: - Seed block trials to introduce the package of best practices to collect seed from inbred papaya lines. - Production trials using conventional and organic treatments to determine the economics of organic papaya production and certification under Fiji's conditions. A paper has been published by the ISHS using results from this trial. A number of commercial farmers have invested in organic production including the Sabeto Organic Producers Association (SOPA).	Yr 2 - Yr 4	
2.5	Improve post-harvest handling	In Fiji, a number of activities have been completed to improve post-harvest handling including: - Harvest and post-harvest assessments to identify the critical areas where physical damage is occurring on the product. - Trial sea freight shipment of Fiji papaya into New Zealand. - Relationship between tree age and post-harvest disease severity. - Assessments of Fiji papaya fruit out-turns at the Melbourne market. - Investigation of post-harvest treatments in conjunction with high temperature forced air (HTFA) for the control of fungal diseases.	Yr2 – Yr 4	Positive outcomes resulting from trials include: - An awareness among growers and exporters as to best practice harvest and post-harvest practices in order to minimize physical damage. - An adoption of low cost newspaper as a liner for harvesting bins and as an alternative packing material for export cartons. - It has been demonstrated that it is economically viable to sea freight papaya to New Zealand. Sea freight will be critical for the future of the industry with decreasing air freight capacity, increasing air freight charges and increasing production. - The identification of hot water as a possible post-harvest treatment for the control of fungal diseases. These findings have now been adopted by the industry via a NWC capital investment.

PC = Partner Country, A = Australia

Objective 3: To enhance the profitability and competitiveness of the Australian papaya industry by improving the supply chain

No.	Activity	Outputs/Milestones	Completion date	Comments
3.1	Identify and mobilise commercial partners who can champion improvements in papaya chains and where benefits and cost savings are shared by all members of the chain	Four major commercial partners have been involved in repeat supply chain studies on wet season and dry season fruit. These include - Tropical Coast Papaya - Mackay Estates - Lecker Farm - Skybury Farm	Y2 (3-4)	All producers have been kept updated via papaya association meetings. Two major producers are incorporating changes into their post-harvest packing lines and ripening facilities to take into account outcomes form project work.
3.2	Identify strategies to improve product flows/handling, information systems, supply chain relationships and value adding to all participants in the supply chain.	Supply chains have been mapped and a number of external issues impacting on quality have been identified.	Y2 (4-6)	External factors influencing out-turn of fruit include; - Wet vs. dry season fruit - Post-harvest disease control and commercial application systems - Ripening temperatures - Growing location. - Tree age (variety 1B) Research emphasis is currently on the use of fruit coatings with added fungicidal adjuvant; hot water for post-harvest disease control and the use of individual fruit modified atmosphere packaging (MAP) solutions.
3.3	Trial supply chain interventions with commercial partners to improve product flows/handling, information systems, supply chain relationships and value adding to all participants in the supply chain	Individual grower suppliers have made subtle changes to the pre-dispatch papaya supply chain. Most notable changes are due to ripening temperature. The work has highlighted the importance of pre-harvest disease control as the major factor effecting fruit presentation at market. Several commercial producers have acknowledged the merits of using postharvest hot water dips for disease control and are now considering the costs / logistics for implemention within their packing lines.	Y2(5)–Y2(8) Y3(2-12) Y3-Y4 (5)	Project work has concentrated on; - The use of prochloraz (Sportak®) as a post-harvest fungicide. This includes commercial application methods, effect of solution pH and potential alternative fungicides. - The effect of tree age on post-harvest disease. - Preliminary examination of alternative post-harvest disease control treatments such as hot water dips/sprays, coating technology. Additional work conducted on: - The use of a range of pre-harvest fungicides on post-harvest quality. - Preliminary evaluation of harvest maturity effects on post-harvest quality in a new hybrid.

PC = Partner Country, A = Australia

Objective 4: To promote the adoption of project outputs in the Fiji papaya industry and elsewhere

No.	Activity	Outputs/Milestones	Completion date	Comments
4.1	Identify potential beneficiaries within the papaya industry and beyond (e.g. nascent papaya industries in other Pacific Island Countries (PICs), other existing or potential fruit industries in Fiji) and define a strategy for reaching them	The Project has been able to create a cohesive industry from previously fragmented papaya growers well positioned to respond to the needs of its members. At the core of the system is the TAB. With its strategic membership, the TAB has been able to respond to many issues that are outside of the direct realm of ACIAR activities. The FPP website and quarterly newsletters are fully operational and have been highlighted by a number of regional information hubs.	Yr 1, M10	Activities of the FPP have been highlighted in a documentary which aired on a regional TV programme entitled 'Pacific Way'. A Cook Islands industry representative has participated in several papaya related meetings in Fiji including the industry presentation of the market study findings. FFP staff assisted the Samoa Farmers Association in addressing papaya production problems for their members. Requests for certified Fiji papaya seeds are being received from regional countries (Vanuatu, Samoa and Palau). FPP have assisted the Tutu Rural Training Centre (TRTC) on Taveuni, to establish a commercial papaya planting programme which now supplies local markets including hotels. TRTC is also being developed as one of the diversified seed sources, as an industry cyclone mitigation measure.
4.2	Compile, review and analyse results from field trials and all other research activities.	The FPP collates data on a quarterly basis for presentation to the TAB. Several research activities have been completed and the results analysed by the project staff and collaborating scientists from QDAFF. Research reports and information sheets are distributed by print and email as well as being available on the FPP website.	Yr 3, M4	
4.3	Prepare information dissemination materials and processes to bring research outputs to priority beneficiaries (as identified above).	The FPP staffs have completed a number of publications based on research findings which are available on the Project website. Between the Australia and Fiji partners, five scientific papers[1] have been published as direct outcomes of research carried out under PC/2008/003.	Yr 3, M6	

[1] *Campbell, Diczbalis, Stice and Tora: Optimising Harvest and Handling systems for Sea Freight Fiji Papaya: Paper presented to the 3rd International Papaya Symposium, Chiang Mai, Thailand. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)*
Stice, Tora and McGregor: The Economics of Organic Papaya Production in Fiji: Paper presented to the 3rd International Papaya Symposium, Chiang Mai, Thailand. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

No.	Activity	Outputs/Milestones	Completion date	Comments
4.4	Conduct Papaya Industry Stakeholder Workshops (to share outputs from the Project and develop consensus on 'next steps' for further development of the industry)	Eight workshops and farmer field days have been organised by the FPP, in collaboration with MOA and TTM, to present findings. A major Papaya Industry Stakeholder Workshop was held in the Sigatoka Valley on May 24th 2011.	Yr 3, M10	
4.5	Conduct briefings and informal workshops to transfer conclusions of project to other potential beneficiaries (Fiji Ministry of Agriculture, Koronivia Research Station, Fiji College of Agriculture etc.)	Beneficiaries as described above are all represented on the TAB and therefore they receive reports from the project on a quarterly basis. In addition, the FPP has presented its findings to the Fiji Produce Exporters Association and several key cluster farmer groups. MOA Extension Division has brought several groups of staff to observe trial sites. The entire staff of the Fiji College of Agriculture has visited the FPP trial site and discussed avenues for collaboration.	Yr 2, M8	

Stice and McGregor: Natural Disaster Mitigation Strategies for the Fiji Papaya Industry: Paper presented at International Horticulture Congress – Lisbon, Portugal. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

Diczbalis and Henriod: Evaluation of the use of Sportak® (prochloraz) for control of post-harvest diseases of papaya in Australia. Paper presented to the 3rd International Papaya Symposium, Chiang Mai, Thailand. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

McGregor Andrew, Stice Kyle, Livai Tora and Kaitu Erasito. An Appraisal of Value Chain Development in the Pacific. CTA Value Chain Series (in-press)

7 Key results and discussion

7.1 Fiji

7.1.1 On-farm activities

1. Field trials to determine the economics of organic papaya production in Fiji

Summary

Phase 1 field trials were established in Sigatoka and Nadi with the aim of comparing a'best bet' package of organic practices with the conventional package of practices.

Phase 2 trials were established in Sigatoka and Nadi with the aim of replication and up scaling taking into account lessons learnt from phase 1. FPP supported a Kumu Farms commercial organic production planting in Nadi.

Results

Phase 1 trial results compiled and published by ISHS as proceedings for the 3rd Intl Papaya Symposium.

Phase 2 trial and Kumu Farms planting destroyed by March 2012 flood.

Farmer group involved in on farm trials has taken up the package of practices and are producing organic papaya under the Participatory Gurantee System.

2. Seed block trial to introduce the package of best practices to collect seed from inbred papaya lines and initiate a programme for selection of a locally adapted solo sunrise variety.

Summary

Seed blocks established in Sigatoka and Nadi with foundation seed from the University of Hawaii. The FPP re-introduced and trialled field selection criteria to identify good performing, locally adapted trees. Trialling of various flower bagging practices. Collection of inbred selections from seed blocks and replanting for evaluation and seed bulking.

Results

A package of best practices for seed selection has been developed using information from this trial.

The package of practices developed form the basis for the Fiji Papaya Seed Producers Scheme.

3. Evaluation of papaya seedling production practices.

Summary

The FPP in collaboration with the AusAID funded Small and Micro Nursery Enterprise Development Project for Sustainable Seedling Supply developed and evaluated a model for the cost-effective production of high quality papaya seedlings. Seedling production trials and demo nursery were carried out at the FPP Nadi trial site.

Results

A package of best practices for low cost papaya seed production was developed and promoted amongst mini and micro nursery enterprises across the country. This technology has been widely adopted by an number of other extension related agriculture projects.

4. Variety evaluation trial – UH Waimanalo

Summary

Yellow fleshed variety, Waimanalo, was imported from the University of Hawaii and planted out with Solo Sunrise as a variety evaluation trial in Nadi.

Results

Bearing trees were destroyed by flooding before full data collection could be completed.

TAB decided to not repeat trial and focus on other research activities as current surveys clearly indicated Fiji's compartitve advantage was on the production of the 'Fiji Red' variety.

5. Field trials to determine the effect of thinning on yield

Summary

Trial blocks in Sigatoka and Nadi were established to carry out an analysis of the effect of fruit thinning on yield.

Results

Bearing trees were destroyed by floods before full data collection could be completed.

TAB determined that the benefits of fruit thinning are already well documented and many farmers are already following this practice and therefore there was no need to repeat the trial but instead focus on other research activities.

6. Field trial to investigate the benefits of drip irrigation

Summary

Field trial established in Nadi to investigate the benefits of drip irrigation vs. the conventional non-irrigated system.

Results

Trial was established and costs of production for both systems clearly documented, however bearing trees were destroyed by flooding before full data collection could be completed. TAB decided to prioritise other research activities and this trial was not repeated.

7. Trials on pre and post cyclone mitigation strategies for papaya farmers

Summary
The FPP took advantage of tragedy by carrying out a series of observational trials pre and post TC Evan that could lead to new strategies for preparing and responding to cyclones. The trial work looked specifically at three actions:

1. Ratooning pre-cyclone
2. Defoliation pre-cyclone
3. Control of sunburn post-cyclone

Results

Ratooning pre-cyclone - An observational trial was established on the morning of TC Evan which involved the chopping of selective papaya trees 1 meter from the soil level. The theory was that if the cyclone reached the intensity to knock down the papaya trees than all would be lost, however with the trees that had been chopped a ratoon papaya crop could still be salvaged. The nature of Evan was such that only a few trees in the trial were completely knocked over. However the trial is providing invaluable data on the response of a papaya ratoon crop following a cyclone.

Defoliation pre-cyclone - It is widely accepted that reducing the surface area and weight of a tree canopy can help reduce the damage caused by strong winds. With the imminent approach of TC Evan, a quick trial was put in place to investigate the benefits of removing the tree leaf canopy prior to a cyclone. Outside of this observational trial, several growers also chose to remove all of the leaves of their papaya trees with the hope of saving them from completely falling down. Preliminary findings indicate that with TC Evan there was no major benefit to defoliation pre-cyclone. This was mainly due to the fact that Evan was an unusual cyclone with relatively little associated rainfall which prevented the softening of soil and the resulting blowing over of the trees. Thus on this occasion, the response of the papaya trees that were manually defoliated was the same as the papaya trees that were defoliated by the cyclone.

Control of sunburn post-cyclone - With widespread defoliation of the papaya canopy following a cyclone, the surviving fruit are very susceptible to sunburn which causes pre-mature ripening and unsalable fruit. This observational trial looked at various materials that can be used to cover fruit following a cyclone to reduce sunburn damage and allow the fruit still to be marketed fruit. Preliminary findings suggest that the cotton material used to cover exposed fruit within 3 days following the cyclone significantly reduced the amount of sunburn damage. At a cost of only $1/meter, the expense to the farmer could be recovered with only 1-2 saved fruit. Other materials trialled such as sarlon cloth and onion bags caused a rubbing damage to the fruit or did not provide adequate shading.

Papaya fruit covered by cotton material immediately after the cyclone were protected from sunburn and remained

8. Field days at FPP trial sites

Summary
The FPP trial sites in Sigatoka and Nadi were used to host over eight major training events including; farmer field days, MPI extension training visit, NWC AGM farm visit, Fiji College of Agriculture staff training visit, regional farmer organisation training day etc.

Results/impacts

FPP trial sites produced valuable data but also served as a useful training ground for stakeholders to observe trial results and production practices that are being promoted for adoption. The FPP gained credibility as an 'action' project that understands the challenges of farming papaya.

7.1.2 Off-farm activities

1. Farmer surveys on the incidence and severity of key pest and diseases over 12 months

Summary

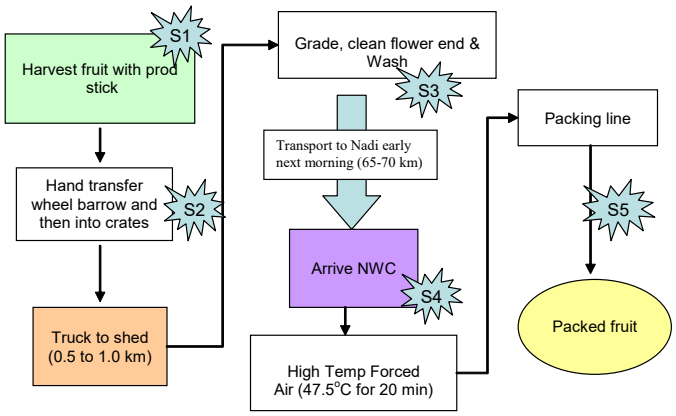
Farmers in the main papaya production areas of Fiji were surveyed over a period of 12 months to determine the incidence and severity of pests and diseases on the farm as well as other major issues facing the farmers.

Results
The key findings from the surveys were presented to the TAB and priority activities were established accordingly. Key information on the incidence of severity issues such as freckles on the fruit (kanikani) and lumpy fruit (linked to boron deficiency) was documented with links to certain areas and certain times of the year. Fungal disease issues were closely monitored with strong links found to time of the year and site selection. These findings strongly influenced the design and prioritisation of the projects off-farm research activities.

2. Harvest and post-harvest assessments to identify the critical areas where physical damage is occurring on the product.

Summary
A series of harvest and post-harvest assessments were carried out on October 18-25, 2010 in collaboration with DEEDI. These assessments tracked the supply chains of two local papaya exporters to try and investigate where the greatest level of physical damage was occurring and make recommendations as to how this could be better managed.

Results
Physical damage was observed through the various steps of the supply chain however the assessment revealed the transportation sector from Sigatoka to Nadi as having the most significant impact on physical damage to fruit. As a result of this trial, there is now awareness among growers and exporters as to best practice harvest and post-harvest practices in order to minimize physical damage.



3. Trial sea freight shipment of Fiji papaya into New Zealand.

Summary

In March 2011, a trial freight container was monitored from treatment and packing in Nadi, to arrival and ripening in Auckland, New Zealand. Fruit condition particularly, ripening behaviour and disease development was measured over the 12 days following treatment, packaging, transport, customs clearance and ripening before dispatch. A number of specific innovations were trialled and evaluated.

Results

This trial shipment demonstrated that high quality Fijian papaya can be delivered to market by sea freight without loss of quality. The strategy to send fruit in a backward condition and to ripen at the market worked well and was assisted by the ripening facilities and knowledge of the importers. The cost of freight was nearly 50% less than the cost of air freight. These research findings led to a number of follow up commercial consignments which included the refinement of the system. These findings also attracted investment from NWC for improving sea freight facilities at the HTFA complex.

4. Fiji Papaya Seed Producers Scheme

Summary

A core activity of the FPP was the development of the Fiji papaya certified seed producers' scheme. After field trials and industry consultation, a seed production standard has been developed and agreed by MPI, NWC and FPP. The scheme developed involves a PPP where the private sector takes on the role of seed production and the public sector (MoA) assumes the role of audit and certification for the system.

Results

NWC has fully assumed responsibility for coordination of the scheme which has been profitable for all actors in the chain. This scheme has strongly influenced the outcomes of Fiji's seed policy formulation process.

5. Relationship between tree age and post-harvest disease severity.

Summary

A trial to investigate the linkages between papaya tree age and fruit disease susceptibility was carried out in the Sigatoka Valley in August 2011. The trial was replicated again in March 2012. The research hypothesis was that disease inoculums build up with time. A total of 360 sample fruit were selected from 6 farms representing 3 age groups on each farm. As the fruit ripened, they were monitored for incidence of post-harvest rots.

Results

Statistical analysis of the data from both trials indicated there was no significant link between tree age and disease susceptibility. This result has important positive implications for the economics of papaya production.

6. Assessments of Fiji papaya fruit out-turns at the Melbourne market.

Summary

The FPP in partnership with DEEDI Australia carried out two independent product assessments of Fiji papaya in the Melbourne market. Two exporters with regular shipments to Australia were selected as trial partners. In July 2011, commercial consignments from the two exporters were monitored from arrival at NWC through to the retail outlets in Melbourne. Samples were monitored for transportation temperatures, fruit maturity, physical damage, rots, and packing uniformity.

Results

The findings of the two reports along with recommendations were provided to the participating exporters. A summary of the relevant conclusions is available to the entire industry in an effort to boost Fiji Papaya exports to Australia.

7. Investigation of post-harvest treatments in conjunction with HTFA for the control of fungal diseases.

Summary

In March 2012, the FPP undertook a major research trial to evaluate several post-harvest treatments to help control fungal diseases on papaya. Treatments included; pre HTFA chlorine wash, post HTFA hot water dip and a post HTFA application of the fungicide prochloraz (Sportak®). The trial was a collaborative effort between the FPP and Queensland DAFF. Fiji MPI pathologist, Mereia Lomavatu, also assisted to positively identify pathogens and the USP lab assisted to analyse residue levels from the fungicide treatments.

Results

The results of the trial indicated that the hot water and fungicide treatments provide very good control of disease with no adverse effects on fruit quality. The industry asked the

FPP to continue to investigate commercial hot water dips with the possible aim of providing this treatment at NWC.

8. Approvals and trial shipments with newspaper as a packing material

Summary

After a submission by the FPP, full approval has been granted by both New Zealand and Australia for the use of newspaper as a packing material for papaya. Approval was granted on the basis that NWC would source and store newspaper under strict HACCP conditions. Following these approvals, the Fiji Papaya Project conducted training with NWC packing staff and sent a trial shipment to NZ.

Results/impacts

The trial demonstrated that a 1 tonne consignment will use less than 15 kg of newspaper ($4.68/tonne). This can be compared to using foam as a packing material which is estimated to cost around $200/tonne. Several exporters are now reaping the benefits of this work with regular shipments using this low cost packing material.

9. Fruit quality evaluations to determine extent of possible 'out crossing' from unbagged seed

Summary

The FPP carried out fruit quality assessments from 6 export orientated farms to determine the extent of possible 'out crossing' that may have occurred from using unbagged seed. All samples were ripened and evaluated for flesh colour and sugar levels (brix).

Results

Fruit with low colour ratings and low brix were observed from several farms. On closer investigation it was revealed that these farms were planted with seedlings derived from unbagged seed. The FPP in conjunction with MPI extension and TTM followed up with these farmers on the issue and advised the use of only 'bagged and certified' seed.

10. Trial on long term storage of papaya with and without modified atmosphere packaging (MAP)

Summary

The FPP in collaboration with the Queensland DAFF, is implementing a trial to simulate long term sea freight with and without modified atmosphere packaging (MAP), with the hope of developing technology that will allow for sea freight of Fiji papaya to Australia. The average transit time for sea freight from Lautoka – Melbourne is 15 days and therefore the trial will be investigating three storage times: 21, 14 and 7 days. The MAP component of the trial is evaluating several bag types that will allow for the appropriate gas exchange of CO_2 and O_2, slowing down respiration and arresting the ripening of the papaya. The trial is also evaluating the effectiveness of potassium permanganate ($KMNO_4$) as an ethylene absorber in the carton.

Results

Research findings indicated that a number of MAP treatments are effective at delaying ripening with no adverse impacts on fruit quality. However, similar results were achieved with effective cooling and therefore the TAB concluded that further MAP trial work was not necessary at this stage.

11. Papaya rehabilitation and replanting programme

Summary

Following the January and March 2012 floods, NWC and the FPP have begun implementation of papaya rehabilitation and replanting programme, with assistance from AusAID. The programme involves support to some 30 NWC members actively involved in exporting. This replanting programme is being implemented in close conjunction with the MPI and TTM rehab assistance programmes. The NWC programme also includes the establishment of seed production blocks around Nadi, Sigatoka and Taveuni to help ensure a consistent supply of high quality papaya seed.

Results

According to the MPI Flood Damage Assessment report, a total of 81 acres of papaya was completely destroyed by the floods in the Nadroga/Navosa and Ba provinces. Figures compiled by the FPP indicate that an estimated 80,930 papaya seedlings have been supplied to affected farmers as of August 2012. With a planting density of 500 trees per acre, these seedlings represent around 161 acres of papaya that has been established following the floods.

12. Exotic disease surveillance on Viti Levu.

Summary

The plant pathology component of SPC, with plant pathologists from the ministry of Agriculture and the Biosecurity Authority of Fiji (BAF) conducted numerous survey missions around Fiji for exotic diseases including Bacterial Crown Rot (BCR). Samples were collected and analysed locally as well as sent overseas. .

Results

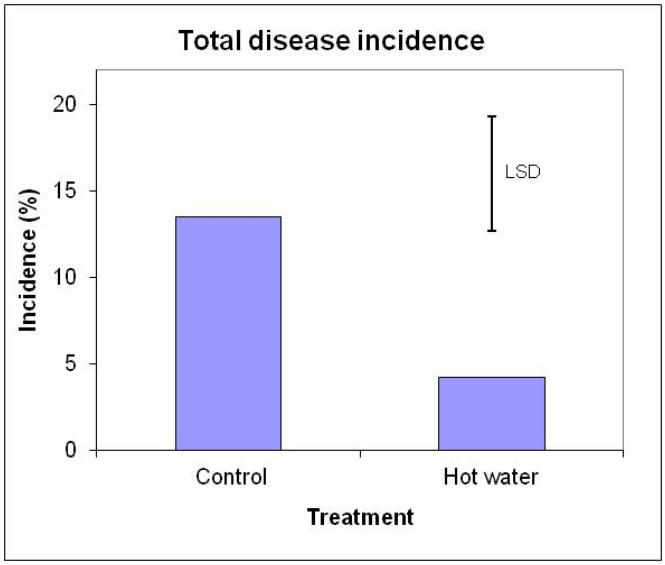
The results of all survey work and sample analysis over multiple years have shown no important diseases present on Viti Levu. A lot of young papaya trees were submerged under water during the heavy rain in January 2014 and eventually died after infection by **Phytopthora parasitica**. The farmer was advised to raise ridges higher and have bigger main drains to allow rain water to drain off easily during such rainy periods

MoA, BAF and NWC officers were all trained to detect primary symptoms of the major exotic diseases. This survey work continues on monthly basis.

13. Development of commercial hot water treatment for controlling post-harvest papaya diseases

Summary

After three years of research into post-harvest disease control measures for Fiji papaya, a hot water treatment regime (54 deg C for 2.5 mins) was trialled in August 2013 comprising of over 180 kgs of test fruit under commercial conditions.



Results

The hot water dip treatment was able to reduce both disease incidence and severity to around 10%. Exporters currently loose about 10% of potential income due to rot, this can be even greater in the wet season or in times natural disasters, with the hot water treatment that is being proposed, this could be reduced to 1%. If the industry exports around 800 tonnes of papaya at an fob value of $2.66/kg, the hot water treatment could reduce the unsalable fruit from10% down to 1%, this could save the industry roughly $1,915,200 annually.

7.2 Australia

7.1.3 Supply Chain Monitoring

Summary

Supply chain monitoring of commercial papaya farms in far north Queensland was carried out on farms located on the wet coast from Innisfail to Tully and on the Atherton Tablelands a dryer environment to the west of the coastal farms. Temperatures were monitored from farm to market as was fruit quality and disease incidence prior to dispatch and after arrival in the markets.

Laboratory trials were carried out to assess the effects of pre-ripening temperature on fruit disease incidence and severity.

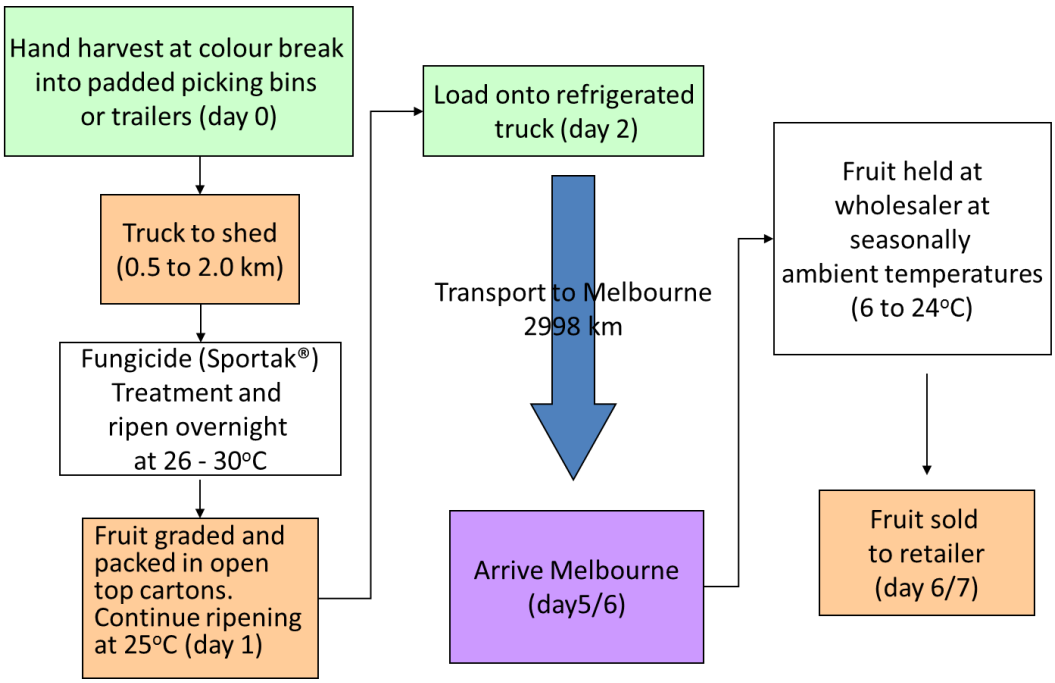
Results

Fruit load monitoring and out-turn reports were carried out in conjunction with papaya producers to document pre-load temperature storage conditions, transport temperatures and fruit quality issues on ripening.

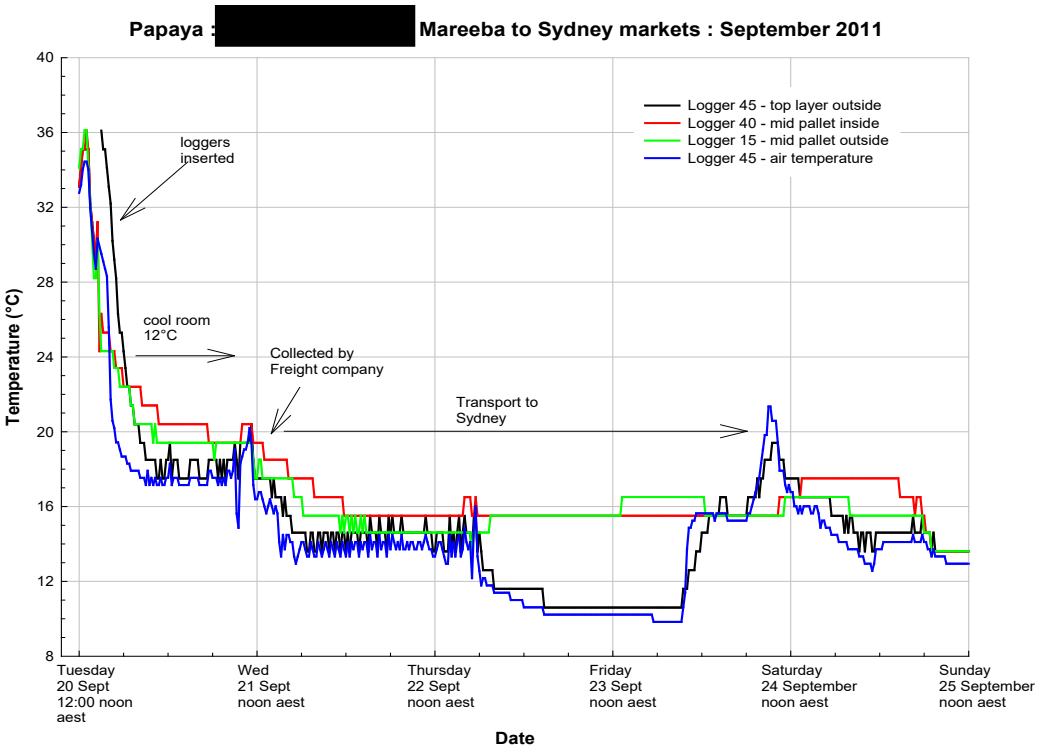
A summary of observations;

- Pre-ripening fruit prior to dispatch improves uniformity of colour development which is desired by the market.
- There are large differences in pre-ripening temperatures used by producers. At times this is seasonally dependent, with limited or no pre-ripening occurring for summer fruit relative to winter fruit. Pre-ripening temperatures used were in the range of 28 to 30^{o}C.
- The downside of high temperature pre-ripening conditions was that fruit were often too soft at arrival at market leading to excessive rot development by ripening (6 to 8 days after harvest).

- Temperatures in the pallet pre transport and during transport were variable depending on carton position with fruit on the outer or top layers cooler than fruit in internal cartons (See Figure below).
- Incorrect handing by staff harvest and packing may be exacerbating problems with fruit bruising and stem end rots.
- Fruit rots were higher in fruit harvest during the summer months (wet season) compared to fruit harvest during the winter spring months (dry season).
- Fruit from wet coast producers had a higher rot incidence than that from Tableland producers.
- Papaw/papaya variety also appeared influential on the amount of rots with the yellow fleshed 1B being particularly susceptible to Anthracnose.



Typical Australian pre farm-gate handling chain. Note; Transport times to closer markets such as Sydney and Brisbane are two and one day respectively.



Temperature monitoring of a papaya loads from Mareeba to Sydney. Note variation in temperature depending on the position of the carton in the pallet.

Fungal species most commonly identified are; Anthracnose (Colletotrichum gloeosporiodes), Stem-end rots caused by *Mycosphaerella* and/or *Phomopsis*, Black rot - *Phoma sp*., Rhizopus rot – *Rhizopus sp.,* Phytophthora fruit rot - *Phytophthora palmivora*

During the wet season fruit spoilage at the market could be as high as 30% on average.

Examples of papaya fruit rots;

7.1.4 Effect of ripening temperature on postharvest disease

Summary

High ripening temperatures were suspected to exacerbate postharvest disease expression. Trials were carried out during the wet and dry season to test this hypothesis. Experimental work was conducted on two papaya varieties, 1B and RB1, sourced from two regions in Far North Queensland during the dry season (September 2009) and wet season (March 2010). Fruit were harvested at a commercially mature green stage (at Stage 1 or up to 10% colour break) from two farms (Wet Coast and Atherton Tablelands),

each representative of a different production region within Far North Queensland. After packing in cartons, fruit were transported to the postharvest laboratory in Cairns. Fruit were then treated to a postharvest dip for 1 minute in a solution of Sportak (55ml/100L) and Ethrel 480 (250ml/100L). A subset of fruit serving as a control, were treated only to Sportak and not Ethrel. Fruit were randomly assigned to one of three blocks per treatment, consisting of four ripening temperatures (18, 22, 26 and 30°C) with each room set to 85-90% relative humidity (RH). Replicate fruit (5 fruit per block / variety) were distributed evenly amongst the four treatments, with the additional untreated ethrel control group also treated to 18°C. After 2.5 days (60 hours), fruit were transferred into cold storage for 48 hours at 14°C (ca. 70% RH) to simulate refrigerated transport before transfer (on day 6) into a 23°C room for observation.

Results

The work confirmed that both ripening temperature and the location from which papaya fruit were sourced determined their likelihood of developing rots. In this case, ripening fruit at a higher ripening temperature (≥ 26°C) generally resulted in fruit with an increased incidence and severity of rots. Moreover, in regards to harvest location, both varieties harvested from the coastal site overall had a higher proportion of fruit with rots. This was not unexpected given the regions propensity for higher rainfall and potential greater pathogen loads in farm blocks within this region.

High ripening temperatures and use of ethryl in postharvest dips were both shown to increase the incidence and severity of disease. Fruit ripened at higher temperatures had a shorter shelf life and poorer eating qualities compared to fruit ripened at 18-22^{o}C.As a result of this work the bulk of papaya producers have reduced their pre-ripening room temperatures to 20-24^{o}C.

7.1.5 Sportak use and efficacy in commercial papaya packing sheds.

Summary and Results

Prochloraz as Sportak® at 450g a.i./L is registered for the control of post-harvest diseases in papaya in Australia. A project in far north Queensland in 2011, examined the use patterns of postharvest treatments, evaluated treatment dips and sprays for prochloraz concentrations and evaluated the efficacy of prochloraz at 0, 20, 40, 55 and 70 mL/100 L, fludioxonil as Scholar® at 260 mL/100 L and azoxystrobin as Amistar® at 50 mL/100 L.

Results showed that packing shed use of Sportak® varied with recycled and stored solutions showing a depletion of the active ingredient. Measured prochloraz in solution was highly pH dependent with nominal solution values only being measured when the pH was less than 3.0. In the fungicide efficacy trial Sportak® at the label rate of 55 ml/100L provided more effective disease control than fludioxonil and azoxystrobin. The trial also suggested that fruit from older trees showed a high degree of disease incidence relative to fruit from young trees.

7.1.6 Development of alternative postharvest treatments for papaya fruit disease control.

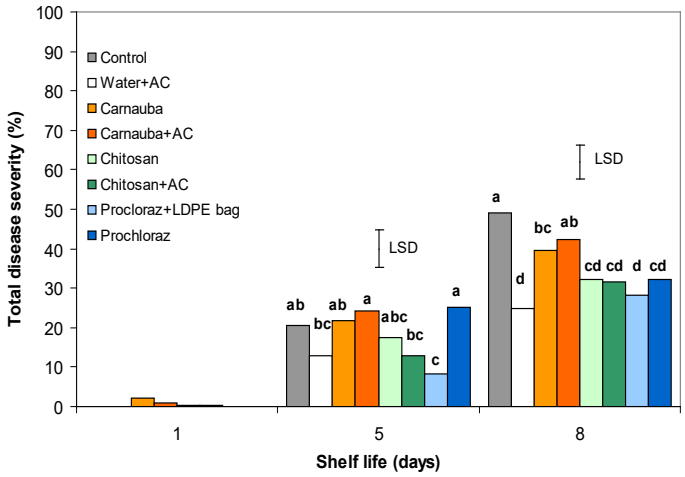
Summary

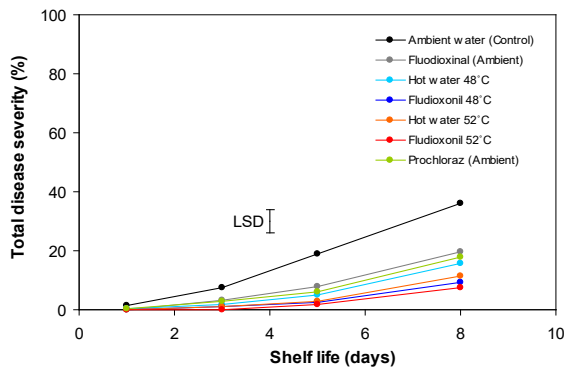
A range of trials aimed at examining the efficacy of Sportak and grower experience emphasised that Sportak was not providing an adequate level of disease control during the wet season. A range of alternative chemicals, conventional and others "generally considered as safe – GRAS", coatings and hot water treatments were examined for their efficacy against postharvest disease. Hot water treatment was seen as the most consistently effective treatment and experiments were targeted at refining the temperature by exposure times to ensure disease control without causing scald damage and delays to ripening due to high temperature breakdown of ripening enzymes.

Results

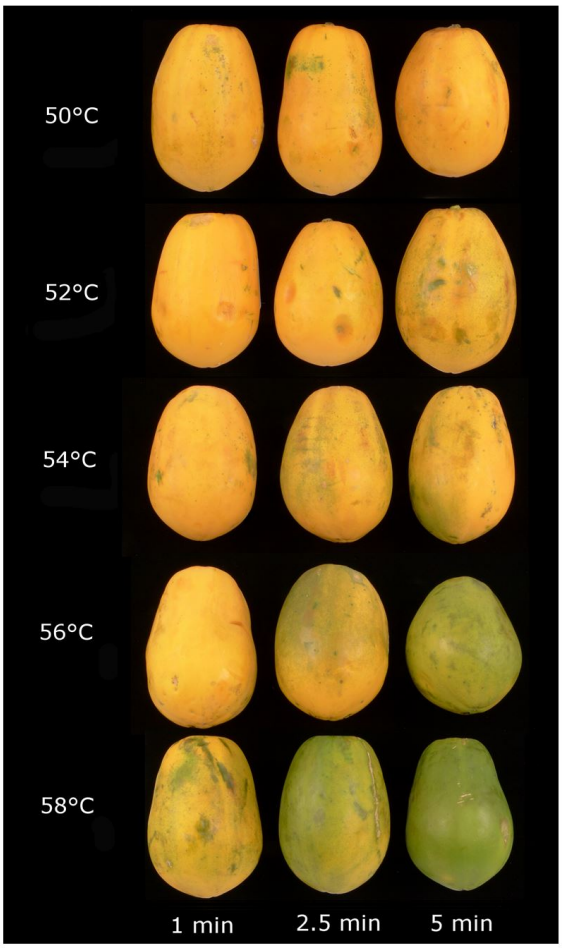
A range of treatments provided control of postharvest disease at 5 days after treatment. These included Chitosan (1.5%) + ammonium carbonate (3%) coating; water + ammonium carbonate (3%) and prochloraz + fruit wrapping in low density poly ethylene. By day 8 after treatment all treatments provided similar disease control to prochloraz alone.

In a second experiment, treatments which included hot water were shown to be efficacious and provided additional disease control relative to prochloraz treated fruit. Hot Fludoxinal® and Hot water both applied at 52°C for 5 minutes were equally effective at controlling postharvest rots.





Five commercially grown varieties (RB1, RB4, Solo, Skybury and 1B) were evaluated for tolerance to hot water temperature (50, 52, 54 56 and 58°C) x exposure time (1, 2.5 and 5 minutes). Varieties varied in their tolerance to hot water and exposure time with Skybury being the most tolerant, whereas RB1 was the most sensitive to heat and extended exposure. An interim recommendation of 52°C for 5 minutes is suggested as a standard protocol.



Effect of hot water temperature x exposure time on scalding and de-greening of papaya, variety RB1.

Australian papaya producers remain interested in the use of hot water as a postharvest treatment but to date have not invested in the technology. Funds are being sought to conduct the work in conjunction with a commercial shed and incorporate fruit in the commercial supply chain to southern markets.

8 Impacts

As a result of PC/2008/003 an estimated 300 farming households (approximately 900 people) and 11 exporter enterprises (approximately 100 people) in Fiji gained access to and used improved agricultural technologies. In Australia an estimated 32 farm enterprises gained access to and used improved agricultural technologies

Twelve workshops and farmer field days have been organised in Fiji through PC/2008/003 in collaboration with MOA and TTM, to present findings. A major Papaya Industry Stakeholder Workshop was held in the Sigatoka Valley on May 24th 2011. Total estimated number of farmers trained – 300.

4 FPP staff and 1 MOA staff were trained by QDAFF scientists on a variety of post-harvest assessment tools including:

- Value chain analysis
- Fruit quality evaluation
- Temperature monitoring and analysis
- MAP gas measurement and analysis.

FPP staff attended 3 international conferences and presented scientific papers including:

- 2nd International Papaya Symposium - India
- 3rd International Papaya Symposium - Thailand
- International Horticulture Congress – Lisbon

Over the course of the project period, both the Fiji and Australian industries have been significantly impacted by the applied research and industry development activities of the project. Strong institutional and professional relationships have also been established over this period which provides a good basis for further collaborative research work funded by ACIAR. The Fiji fresh fruit export industry is currently in discussions with QDAFF, University of the Sunshine Coast and the Pacific Islands Farmer Organisation Network on the development of a regional Tropical Fruit Tree Development Project for consideration by ACIAR. This new project builds on the successful partnership orientated approach adopted by the Fiji Papaya Project and the Pacific Breadfruit Project and extends it to other tropical fruits and to some other Pacific island countries.

8.1 Scientific impacts – now and in 5 years

Overall the project has contributed significant scientific impacts to the Australian papaya industry as well as the Fijian industry and there are still some important research interventions recommended for the future and for follow-up.

Fiji

Eight papers and a MSc. thesis are the products to date of the research inputs, with more to come as the work finalises and the papers written and are published.

A Special Final Research Report – Key Findings, Future Issues, and Interventions for the Fiji Papaya Industry is now being compiled and should be published in hard copy and in downloadable format from the Project website.

The research conducted has made important new contributions to the science of papaya production and post-harvest management as well as an important contribution to resolving supply chain issues to facilitate papaya exports, either in Fiji or elsewhere in the Pacific islands.

The plant pathology component of SPC, with plant pathologists from the Ministry of Agriculture and the Biosecurity Authority of Fiji (BAF) have been carrying out surveillance

for exotic diseases including Bacterial Crown Rot (BCR) disease in the papaya growing areas on Viti Levu all of last year. We are continuing this activity on a quarterly basis this year. This activity will continue even after the project ends in December 2014.

Australia

To date, 14 high quality reports and papers have so far been produced by the Australian Team plus 2 International conference papers, with the Fiji team. More papers are now being prepared for publication along with presentation of two papers at an upcoming International conference (IHC 2014). The focus of new publications is:

- Efficacy and commercial use of the current registered post-harvest fungicide
- Efficacy of alternative fungicides
- Evaluation of alternative post-harvest disease control strategies using hot water, fruit coatings with fungicidal adjuvants and individual fruit modified atmosphere packaging.

Many of the findings have produced new technology changes to papaya production, particularly in the post-harvest management protocols for supply chains.

8.2 Capacity impacts – now and in 5 years

In summary, the project has successfully leveraged the research inputs to train and build capacity of technical staff, farmers, exporters, MOA and TTM staff in the Fiji Papaya industry, met project milestones and delivered good impact to the industry.

Fiji

Twelve workshops and farmer field days have been organised by the FPP in collaboration with MOA and TTM, to present findings.

A major Papaya Industry Stakeholder Workshop was held in the Sigatoka Valley on May 24th 2011. Total estimated number of farmers trained – 300.

One MSc Student was supported by the project.

Three FPP staff and one MOA staff were trained by DAFF scientists from Queensland.

FPP staff attended 3 international conferences and presented scientific papers including: 2nd International Papaya Symposium - India; 3rd International Papaya Symposium – Thailand and the International Horticulture Congress – Lisbon.

Study tours were undertaken by 2 FPP staff to Hawaii and the TAB Chairman to North Queensland, Australia.

450 farmers and students visited field trial sites during the project to date.

Mentoring of Fiji project team, collaborators and stakeholders has been an important feature of the projects success.

Australia

The identification and collaboration of the industries' largest industry producers and their involvement in supply chain mapping and improvement trials has resulted in a high level of awareness of the project activities and outputs. Adoption of critical supply chain improvements such as lower ripening temperatures in summer has been undertaken, while the use of hot water treatments for disease control requires further demonstration.

Improvements to the inconsistent product flavour and fruit ripening behaviour and reduce post-harvest losses has been catalysed by the project among the wider Australian papaya industry.

Revised extension posters and notes on post-harvest handling methods, including disease treatments and revised ripening temperatures have already brought about beneficial change to farmers' management practices.

Extension of the project is justified to bring about further refinement of both pre-harvest and post-harvest management practices.

A Supply Chain Research Workshop for 32 growers and a Papaya Variety Field Day for 35 growers was supported by the project.

Attendance at monthly meetings of Innisfail Papaya Grower Association meetings by various DAFF staff aided technology transfer of project findings to the industry.

8.3 Community impacts – now and in 5 years

In summary, the overall economic benefits to date have been significant and have a very large upside potential catalysed by project support. The project has already demonstrated how losses can be reduced, costs reduced (sea freight, paper packaging, etc.,) and with better quality fruit at out-turn and better prices.

Fiji

Exports from 2008 when the project began until 2011 before the flooding disaster, doubled from around 400 MT to 804 MT. 2011 was a record year for papaya exports from Fiji.

The target is some 4,000 MT per year of exports, based on market demand so the upside yet to be realised is very significant - a 10 fold increase. This is now a realistic goal thanks to the achievements of the FPP in areas such as sea freight, certified seed and post-harvest disease control,

At the target suggested, 4000 MT per year of annual exports arising from the project and ancillary support should generate F$7 million per year with $F3.5 million in direct farm income.

Overall economic impacts are very significant when the increased employment opportunities are considered and the services, contractors, retailers, wholesalers, freight and transport etc industries are added in.

Benefits to women are very significant with at least 40% of them being beneficiaries.

Australia

Reduced costs of production by reduction of post-harvest losses from new treatment and ripening protocols developed, has led to better consistent presentation of fruit to the buyers and consumers at desired ripeness/maturity levels with increased profitability.

Higher throughputs using improved project technologies, has improved profitability of the entire papaya supply chain.

Improved technologies open up the potential to expand and target new markets as well as increase market share for papaya in existing markets.

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8.3.2 Social impacts

11 new exporter enterprises have joined NWC since the start of the project. In addition, it is estimated that an additional 110 new farm enterprises have entered the fresh produce export chain partially as a result of the Fiji Papaya Project. This has led to a very significant increase in job creation on farms, and in export companies, input suppliers, freight and transport companies etc.

Training of farmers and support by the project has opened up new productive rewarding farm returns from a new Fiji Red Papaya export crop.

Research completed to date and extended to the Australian papaya industry has already demonstrated social benefits arising from cost reductions in the entire post-harvest management supply chain of papaya.

Increased employment opportunities via expanded papaya production, and a new confidence in an industry which can recover quickly from cyclonic devastation, has already emerged.

8.3.3 Environmental impacts

In summary, papaya can be grown and developed and exported in an environmentally friendly way but more research is needed to address the above and other problems, as identified in the draft Phase II project proposal.

Fiji

Papaya has the potential to be produced in a sustainable way in Fiji without significant pesticide use and even organically with a near benign footprint. However, the sustainable practices have to be tested, including crop rotation, green manuring, more exacting soil and plant nutrition management, best organic materials to use, control of Phytophthora root rot outbreaks using alternate soil health approaches, soil organic matter preservation and pH management. Project extension would help ensure sustainability of the Fiji papaya industry.

The papaya industry needs, in part, to move out of flood prone lowlands to ensure export supplies, to avoid other suppliers filling the gap left from flood losses. Once moves are

made away from the wet zone of Sigatoka to areas around Nadi and further north, irrigation will be needed to optimise productivity. Drip irrigation technologies are most appropriate and some trialling is essential, along with how to calculate water requirements for papaya under given management systems to minimise nutrient leaking into aquifers and rivers etc.

With post-harvest management and marketing, responsible use of biodegradable materials for packaging and pre-export chemical treatments (if needed) should be clearly promoted by the industry, to reduce environmental contamination.

Australia

The project has highlighted the need for strategic use of pre-harvest fungicides and chemical fertilisers in combination with targeted post-harvest treatment methods to produce and deliver a more consistent high quality papaya to consumers with minimal environmental contamination. Project research has demonstrated these methodologies.

New clean technologies including monitored chemical fertiliser use, minimal field use of pesticides and chemical free hot water treatment for post-harvest disease control have clear environmental benefits.

8.4 Communication and dissemination activities

The FPP staffs have completed a number of publications based on research findings which are available on the Project website. Between the Australia and Fiji partners, five scientific papers have been published as direct outcomes of research carried out under PC/2008/003. These include:

Campbell, Diczbalis, Stice and Tora: Optimising Harvest and Handling systems for Sea Freight Fiji Papaya: Paper presented to the 3rd International Papaya Symposium, Chiang Mai, Thailand. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

Stice Kyle , Tora Livai and McGregor Andrew: The Economics of Organic Papaya Production in Fiji: Paper presented to the 3rd International Papaya Symposium, Chiang Mai, Thailand. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

Stice Kyle and McGregor Andrew : Natural Disaster Mitigation Strategies for the Fiji Papaya Industry: Paper presented at International Horticulture Congress – Lisbon, Portugal. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

Diczbalis and Henriod: Evaluation of the use of Sportak® (prochloraz) for control of post-harvest diseases of papaya in Australia. Paper presented to the 3rd International Papaya Symposium, Chiang Mai, Thailand. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

McGregor Andrew, Stice Kyle, Livai Tora and Kaitu Erasito. An Appraisal of Value Chain Development in the Pacific. CTA Value Chain Series (in-press)

23 papers and reports – Total plus extension posters.

9 Conclusions and recommendations

9.1 Conclusions

PC/2008/003 is considered a highly successful project by all project partners and external reviewers, the success of this project is due to a number of factors including:

- The project priorities were determined by the Fiji Papaya Industry and key industry partners were involved in the design of the project.
- The project was implemented by the private sector – Nature's Way Cooperative and Koko Siga Pacific.
- The project involved close collaboration with all stakeholders (farmers, exporters, government, research partners) through quarterly meetings that were held faithfully for over 6 years.
- The research approach was participatory and involved industry (farmers and exporters) as key implementers.
- Field trials were carried out on existing farmers' fields and not on government research stations.
- Nature's Way Cooperative as a lead implementing agency has continued with research activities and information dissemination despite the completion of the project because this is in their business interest and in the interest of their members (farmers and exporters).

9.2 Recommendations

Over the course of the project period, both the Fiji and Australian industries have been significantly impacted by the applied research and industry development activities of the project. Strong institutional and professional relationships have been established over this period which provides a good basis for further collaborative research work funded by ACIAR. It is recommended that this foundation be built upon with expanded work in the area of tropical fruit research and development. It is not recommended that ACIAR return to the public-led research approach that is has previously been characterised by lack of direction, low outputs and low industry uptake.

10 References

10.1 List of publications produced by project

A total of 23 papers and reports were produced by the project in addition to 12 extension posters. Published research reports include:

Campbell, Diczbalis, Stice and Tora: Optimising Harvest and Handling systems for Sea Freight Fiji Papaya: Paper presented to the 3rd International Papaya Symposium, Chiang Mai, Thailand. (Paper published by ISHS Acta Horticulturae http://www.actahort.org/)

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McGregor Andrew, Stice Kyle, Livai Tora and Kaitu Erasito. An Appraisal of Value Chain Development in the Pacific. CTA Value Chain Series (in-press)

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