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**Australian Centre for  
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## **Improving marketing efficiency, postharvest management and value addition of sweetpotato in Papua New Guinea**

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# 1 Acknowledgments

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## 2 Executive summary

The overall aim of this project was to improve the livelihoods of farmers and other participants in the sweetpotato supply chain in PNG, and the potato supply chain in Australia, by improving marketing efficiency, postharvest management, and value addition. The project aimed to address issues in heavy product losses and high costs of marketing in long distance sweetpotato marketing from the PNG highlands to coastal markets.

The project began with a detailed mapping of the social, economic, and technical components of the PNG sweetpotato supply chains. While the social and economic components focused on relational, institutional, and cost issues, the technical component focused on issues related to postharvest management and value addition. Supply chain mapping was done through a series of stakeholder consultations from farm to market, and consignment trials. The results indicated that there were serious concerns regarding packaging (bags too big), postharvest handling (high product losses), transport infrastructure (high costs, poor roads and no specialised transport system), and supply chain coordination (no collaboration or communication between potential partners). For women, there were gender-specific issues related to personal safety, poor market facilities, and inequality in the division of labour and the distribution of income within the household. Technical issues were addressed through packaging trials, a curing trial, disease identification to find locally appropriate methods to reduce produce losses, and an exploration of options for sweetpotato processing. Other issues were addressed through: financial literacy training and linking farmers to financial institutions to improve farmers' access to credit, finding ways to consolidate sweetpotato bags and link farmers to transporters and buyers, and providing training in marketing and financial literacy to improve women's participation in sweetpotato marketing.

### **Our achievements** included:

A successful application of participatory and interdisciplinary approaches that brought researchers and stakeholders together and fostered collaboration between partner organisations.

Successfully linked farmers to the National Development Bank's microcredit scheme.

Provided women's groups with training in marketing principles and financial literacy.

Built capacity of junior researchers in PNG through feedback, mentoring, training, and working closely together. They were trained on how to conduct consignment trials, disease survey and identification, data analysis, surveys, report writing, PowerPoint presentations, and facilitate workshops.

Raised awareness and improved understanding of factors impacting on costs of marketing, and profit, and quality outturn, and how performance could be improved.

Produced significant research outputs and disseminated them through various means: kaukau fair (one of its kind in PNG), stakeholder workshops (five altogether), FPDA and NARI newsletters, FPDA extension networks, extension materials (DVDs, booklets, fact sheets and posters), and publications (journal articles, conference papers, and technical reports).

### **Most significant impacts** included:

Increased income for smallholder farmers through improved access to credit and money management skills, better postharvest handling practices, and improved understand of marketing costs and returns.

Empowerment of women due to improved marketing skills and financial literacy.

Improved capacity for extension officers in linking farmers to services providers.

**Areas for further research** include: better understanding of social and cultural factors to encourage technology adoption and collective action; the identification of appropriate social groupings for training, extension, and development purposes; and more research on local marketing issues for women.

### 3 Background

Sweetpotato is by far the most important staple food crop in Papua New Guinea, providing 43% of total dietary intake (as measured by weight and food energy). Annual production is estimated to be around 3 million tonnes, with 75% of this crop produced in the Highlands. The market potential for sweetpotato in PNG as a cash crop has increased significantly in recent years due to increasing urbanisation in coastal cities, especially Lae and Port Moresby and will improve further with the development of the PNG LNG project and subsequent income growth. The decline in the value of the Kina also makes locally produced products such as sweetpotato more competitive with imported rice and wheat products. However, marketing opportunities are being constrained by poor postharvest handling and packaging, poor marketing infrastructure (market information, storage, transportation and market facilities), fragmented supply chain relationships, and a lack of understanding of market requirements and consumer preferences. As a result, postharvest losses are high. Often, 30-50% of product is unsaleable on arrival in Port Moresby due to rots and/or physical damage. Consultations between ACIAR and PNG partners have identified consumer preferences, marketing, and postharvest management of sweetpotatoes as priority research areas that need to be addressed to meet increased demand for sweetpotato in the coastal cities and to enhance smallholder incomes.

The PNG component of this project complements a series of other ACIAR projects that deal with farm-level production issues by focusing on marketing (consumer preference and quality, price and health/dietary issues) and postharvest and processing performance of sweetpotato varieties. It is consistent with the five development goals of *the Medium Term Development Strategies 2005-2010 (MTDS)*, including (1) export-driven economic growth, (2) rural development, (3) poverty reduction, (4) good governance, and (5) promotion of agriculture, forestry, fisheries, and tourism on a sustainable basis. It is also consistent with *the PNG National Food Security Policy 2000-2015*, in which a key strategy is to improve food security in PNG by “improving production, downstream processing, marketing and utilisation of food”. In addition, it supports Subprogram 1 (the Enhancement of smallholder incomes from agriculture) and Subprogram 4 (Institutional and individual capacity building) of *the Indicative Priorities for ACIAR projects for Papua New Guinea*.

The Australian component of this project focuses on similar technical themes – enhanced supply chain management and reduced postharvest losses for potatoes (fresh, seed, and processing potatoes) given its greater relative importance to the Australian industry. The Australian potato industry produces 1.3 million tonnes per annum, and is valued at \$480 million. In NSW, the major production regions are the Riverina, Tablelands, and Coastal areas. In contrast to other vegetable crops, the Australian potato industry has seen increased exports in recent years to its key markets in Asia. However, in some years they experience excessive losses due to postharvest rots and sprouting. The Australian component of this project analyses the supply chain to identify practices that may be contributing to these losses. It then looks to improve control of postharvest diseases through the application of both conventional and new control measures. New control measures, using biocontrol methods and essential oils, may be more acceptable to consumers who are increasingly concerned with food safety and are averse to postharvest chemical usage. These alternative control options and technologies may have broader applications for both the potato and sweetpotato industries in PNG as they use plant extracts that are familiar traditional approaches of disease control.

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## 4 Objectives

The overall aim of this project is to improve the livelihoods of farmers and other participants in the sweetpotato supply chain in PNG, and the potato supply chain in Australia, by improving marketing efficiency, postharvest management, and value addition.

**Specific objectives** of this project are:

Objective 1: To map social, economic and physical components of sweetpotato supply chains.

Objective 2: To develop locally appropriate postharvest handling and processing options.

Objective 3: To facilitate the development of stakeholder-driven strategies for improving the marketing efficiency, postharvest management and value addition of sweetpotato.

Objective 4: To assist stakeholders in implementing the strategies identified in objective 3.

Objective 5: To assist the Australian potato industry in developing effective supply chain solutions to reduce postharvest losses en route to export and distant domestic markets.

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## 5 Methodology

In this project, a *participatory action research approach* (comprising the Research-Planning-Action-Reflection cycle) was taken to encourage stakeholder participation and adoption of research outputs. One key element of a participatory action research is that researchers are mainly facilitators in the change process; therefore, any changes to emerge from the process are owned and directed by the stakeholders. Another key element of action research is “learning by doing”, which results in empowerment and capacity building of participants. Most importantly, participatory action research, and the process of change, enables us to move beyond simply identifying the constraints in the marketing system, and to focus on those particular areas that real changes are deemed desired/necessary by the stakeholders.

In this approach, the cycle began when the research team generated an understanding of the sweetpotato marketing system through supply chain mapping and technical trials (the research phase). Findings from the research were then presented at the stakeholder workshop and used as baseline information for discussion. Through a consensus decision making process, workshop participants then identified priority issues and suggested intervention strategies to address those issues. Those intervention strategies were developed further by the research team into action plans, which were then carried out by work groups (comprising of researchers, farmers and supply chain operators in relevant locations). Outcomes from the action plans were again presented at a stakeholder workshop for another round of feedback and further action. This cyclic process continued until problems were solved to the stakeholders’ satisfaction.

Other methods used in this project include: supply chain mapping, consumer and farm surveys, focus groups, case studies, stakeholder workshops, costs and returns analysis, impact assessment, training the trainer, technical trials (consignment, packaging, curing, and varietal trials), *in vivo* and *in vitro* laboratory experiments. The details are summarised below.

### 5.1.1 Improving marketing efficiency: economic/social component

#### A1. Supply chain mapping

Key sweetpotato supply chains were researched in detail through a series of stakeholder consultations from farm to market (women’s groups, farmers, farmer-marketers, semi-commercial and commercial marketers, road and sea transporters, institutional buyers, and consumers). It aimed to understand the social, economic, and physical components of the sweetpotato supply chains, and to identify major issues, opportunities and possible solutions from the perspective of supply chain operators. The methods used included:

**Focus groups of farmers.** Two focus groups of farmer suppliers were conducted in May/June 2008 in Mt Hagen and Goroka, with each focus group consisting of 6 to 10 farmer suppliers. The questions for discussion focused on their operations, the relationships with their buyers, issues and problems they faced, and opportunities and possible solutions they envisaged.

**Personal interviews with wholesalers.** Eight wholesalers (semi-commercial and commercial) were interviewed, based on a semi-structured questionnaire.

**Personal interviews with road transporters and shipping companies.** In July/August 2008, 8 truck drivers were interviewed at the Lae market while sweetpotato bags were being off-loaded, and managers of two shipping companies (Consort and Bismark) were interviewed at their offices. Two different sets of semi-structured questionnaires were developed.

**Personal interviews with institutional buyers.** In August/September 2008, National Catering Services (Unitech), Lae Technical College Massing Facility, and 6 kai bars operators in Lae were interviewed based on a semi-structured questionnaire.

**Focus groups of women leaders.** Two focus groups of women were conducted in September 2008, one in Goroka (8 participants), and one in Mt Hagen (13 participants). These women represented their districts in both provinces. The participants were both sweetpotato producers and marketers, and had been involved in both local and long distance marketing. In the Western Highlands Province, the venue of the workshop was at Maria Kwin Resource Centre, and in the Eastern Highlands Province, the Vena Ritini Numuni Conference Centre in North Goroka was used. The focus groups were conducted in Pidgin. Three sets of lead questions were discussed, focusing on marketing issues; the division of labour; and the distribution of income.

## **A2. Improving access to information: Market analysis**

This subproject involves analysing (1) prices and marketing margins in 4 major urban centres (Mt Hagen, Goroka, Lae and Port Moresby), (2) marketing costs associated with selling sweetpotato from the Kasena valley into 4 alternative markets, and (3) volumes of sweetpotato sold through the Lae market, as well as (4) a consumer survey to better understand consumer's preferences for sweetpotato.

**Price analysis.** Statistical analysis was conducted using time series data from 1992-2009 to better understand factors contributing to significant variability in prices, both from year to year and within the year, as well as comparing marketing margins and price linkages between the four markets.

**Marketing cost analysis.** Costs of marketing from Kasena village to Goroka, Lae, and Port Moresby were itemised and compared to identify strategies by which marketing costs could be reduced and returns to farmers increased. Costs of marketing include: costs associated with packaging, packing, loading/unloading, market entry fees, transport for both the sweetpotato and the farmer-marketers, communications, living expenses when away from the home, product losses, and opportunity costs of being away from the farm for 3-5 days.

**Volume assessment.** Three volume assessments were conducted at the Lae main market in 2008. The objectives were to find out how much sweetpotato was sold at Lae (and Port Moresby), and to explain, if data permitted, the price differentials between the two markets. The first assessment was done during the week from 31 March to 5 April; the second from 11-16 August; and the third from 17-22 November. Each assessment involved (1) counting the number of sweetpotato bags that came through the Lae market gate between 7:00 am and 10:00 am over the weekly trading period (Monday to Saturday), (2) taking the beginning inventories on early Monday morning before the market was open, and (3) taking the ending inventories on late Saturday afternoon after the market was closed. Weekly disappearance was then arrived at by adding the beginning inventory to new arrivals and taking away the ending inventory.

**Consumer preference.** Ninety two women volunteers from 7 church and social groups in Lae were interviewed in February 2009. Non-probability sampling was used because of a lack of a well-defined sampling frame. The questionnaire for this study was largely structured, but with several open-ended questions. It consisted of 38 questions on staple food consumption, preference for sweetpotato against other staples, varieties, product characteristics, and eating quality of sweetpotato that were important to consumers.

**Marketing workshops for farmers and buyers.** Two workshops were held, one in Goroka and one in Hagen. At each workshop, farmers (mostly women) and 3-4 wholesalers were brought together to voice their requirements and concerns regarding the buying and the selling of sweetpotato, as well as other fresh produce. Farmers were taken to a wholesaler's depot and were shown buyers' quality requirements and how grading was done. In addition, workshop participants were given a gender training to raise

awareness of gender inequality in the division of labour and the distribution of income within the household. Basic marketing principles, including the marketing concept and 4Ps (product, price, place and promotion), were also discussed briefly to emphasise the importance of meeting consumer demand and buyers' requirements.

### **A3. Improving transport**

Transport was identified as one of the priority issues at the first stakeholder workshop. An action plan was developed to address the issue, which included consulting with trucking companies to find out what they had to say about the causes of the problems and possible solutions. The results clearly suggested that the only way that the trucking companies would consider sweetpotato farmers as worthy clients was for farmers to organise themselves and consolidate small holdings into container loads. In the process of finding possible consolidation depots, we came across Joe Kold has been doing exactly what the trucking companies suggested for many years. A case study was developed for what we considered to be "best practice" as far as sweetpotato marketing was concerned.

**Literature review of collection action.** Previous studies on collection action and what worked and what did not were reviewed to find out the extent to which the theory and examples are applicable to the PNG context in terms of encouraging smallholder farmers to cooperate for achieving common goals.

**Personal interviews of trucking companies.** In July/August 2009, managers of eight trucking companies (Mapai, Traisa, East West, Wahgi Valley, Wizzy, Coastal Freighters, JT Investment, ABCO) were interviewed to seek their view on transport problems and possible solutions using a semi-structured questionnaire.

#### **Joe Kold's sweetpotato supply chain: a case study**

The sweetpotato supply chain of Joe Kold, a sweetpotato farmer-marketer in the Western Highlands Province, was studied in detail, from the consolidation in the villages to the sale in Port Moresby. It can be seen as a best practice and used as a guide to improve sweetpotato marketing in other locations.

### **A4. Improving access to credit**

Credit is another priority issue identified by the stakeholders. In the action plan that followed, several activities were included: literature review, industry consultation, selecting groups for financial literacy training and linking them to microfinance providers, and assessing the impact of the latter activities on farmers.

**Literature review of microfinance.** Theory and applications of microfinance models were reviewed to determine the extent to which they are applicable to sweetpotato farmers.

**Personal interviews of financial institutions.** In July/August 2009, managers of National Development Bank, Nationwide Microbank, Alekano Savings and Loan, and Bank of South Pacific were interviewed to find out what they had to say about the causes of the problem and possible solutions using a semi-structured questionnaire instrument.

**Group profiling.** A total of 20 farmers' groups in WHP and EHP, most of them registered under the Companies Act or as co-operatives, were surveyed to understand how collective action has worked for them. Information on their organisational structure, operations and activities, access to market and services, issues and problems they faced, and opportunities to improve their performance, were collected and analysed. Of the 20 groups, six were considered "working well" and hence good candidates for receiving financial literacy training, and, if deemed appropriate, group loans to help them achieve their goal of improving the standard of living through vegetable production and marketing.

**Linking farmers to microcredit.** Six farmers' groups (Agnes's group, Lilly's group, Mitnande Mama (Ellen's Group) in Kindeng, Wayne's group in Kasena Village, Joseph's

group and Brenda's group in Banz) were linked to the National Development Bank's (NDB's) microcredit scheme between November 2010 and March 2011. This involved FPDA team members in WHP and EHP organising farmers groups and inviting loan officers from NDB to go to their villages and talk to them about how to access their group loans. All six groups, except one, have borrowed from NDB, with a first loan being K1000 per group member.

**Financial literacy training.** In 2010, a financial literacy trainer based in Madang was contracted by this project to provide training to Lilly Be'Soer's women's group in Minj, WHP. From 2011- on, Basic Financial Literacy Training was taken over by FPDA, led by the training officer (Zenaida Mira), and mainly to women's groups and FPDA's village extension workers and their contact farmers. The training focused on improving basic knowledge, skills and attitudes on money management, credit and debt management. It is mainly an awareness-raising exercise for farmers as they come to reflect on their readiness to handle their own household finances and their credit worthiness before contemplating getting loans from financial institutions. The skills acquisition session consists of individual workshops that include how to do a simple household budget and a cash flow analysis. By September 2011, five training sessions were conducted by FPDA. They included: Wayne Gorowe's group (Ambo Fresh Produce) at Kasena, Yahu-Yuho Nasahiri womens group, Vitune Welfare Association and Linahana womens group in EHP, and Agnes' group and Joseph's groups in WHP. Four more trainings groups are scheduled in Mt Hagen in coming months, including: (1) Mitnande Mama (Ellen's Group) in Kindeng, (2) Wahgi Flood CBO (VEW Renki) in Wahgi, (3) Tomba CBO (VEW Jeffrey) in Tomba, and (4) Orange Market. Each group consists of 20-30 participants.

**Impact assessment.** In August 2011, an impact assessment was conducted with the six groups which have been linked to NDB to see how financial literacy training and/or improved access to credit has worked for them. In particular, we were interested in finding out the following:

What they have learnt.

Whether they have put it into practice. If yes, in what way. If not, why not.

What impact did the training or loans from NDB (made through this project) have on them, both positive and negative?

### 5.1.2 Improving postharvest management and processing: the technical component

**Supply chain mapping - consignment trials.** Sweetpotato consignments were tracked from farm to market to determine where losses occurred. Tracking activities included local and long distance marketing supply chains. Seven supply chains were identified and three were examined in detail. Ten separate consignments (3 or 4 per supply chain type) comprising 3-8 100 kg sacks of sweetpotato were tracked from farms in the Highlands to Goroka, Lae, and Port Moresby. Temperature, humidity, and impact loggers were included in the bags to monitor the environment. At several transit points (field, farm collection point, highlands transport site, and the markets, roots were assessed for breakage, skinning, cuts and disease.

**Variety trials** Several varieties were evaluated for postharvest storage life, including weight loss, latex production, total soluble solids, and incidence of postharvest diseases. The selection of varieties included in this evaluation was based on market preferences and recommendations of PNG-based research and extension personnel. In all, 7 varieties were selected (Trimun, Wanmun, Waghi Besta, Gimane, Kerot, Okapa and Kiau). Product was sourced from a farm in Goroka, transported to Lae, and assessed during 4 weeks storage at the Lae NARI laboratory.

**Curing trials.** Trials were conducted to examine the effectiveness of curing in conjunction with appropriate harvesting practices to extend postharvest storage life. Curing enhances wound healing and reduces respiration rate, thereby potentially extending the storage life

of sweetpotato considerably. Optimum conditions for curing are holding roots at 25-32 °C under high humidity conditions (92-97%) for 4-7 days. Adequate ventilation is required during the curing process. A decommissioned cool store was cleaned, fitted with two 1000 W domestic oil heaters, a domestic oscillating fan for circulating the air, and a water hose that dripped water onto 2 jute coffee bags to maintain high humidity. The sweetpotato were given curing treatments at Mt Hagan (Alele Fresh Produce), and at an on-farm in-ground pit. The sweetpotato in onion bags were placed on wooden pallets on the concrete floor of the cool store with humidity and temperature loggers. The in-ground pit (1.3 m x 0.9 m x 0.9 m) was dug on one farm at Panga, near Mt Hagan. The bottom was lined with a jute coffee bag, and sweetpotato were layered 5 roots per rep per layer, and 5 layers (=reps), each separated with a coffee bag. Temperature loggers were included in the top and bottom, and two available cultivars were used. The pit was covered with a layer of plastic, then soil, then plastic to turn off rainfall. The controls were held at ambient temperature in a room adjacent the curing room at Alele. After 8 days, all sweetpotato from curing treatments were taken to the ambient storage room for 12 days to simulate storage. Weights were recorded at harvest, after curing, and after storage. Disease incidence was recorded after storage.

**Packaging trials.** Packaging alternatives (e.g. plastic or wooden crates, cardboard cartons, ventilated sacks) and small scale trials were undertaken to compare packaging options. Key requirements for the design of packaging alternatives were the local availability of materials, sufficient protection provided to the product, good airflow through the product, and cost-effectiveness. Packaging treatments developed were control – 100 kg poly bag, 100 kg poly bag with ventilation holes, 50 kg jute coffee bag with ventilation holes, 25 kg bag with ventilation holes, 20 kg carton, and 70 kg crate. Four consignments (replicates) were undertaken in May and August 2010 using product sourced from the highlands and assessed in Port Moresby. Assessment for numbers of broken roots, skinning, cuts, and disease were carried out on 100 roots from 2-5 bags or containers.

**Australian component - options for controlling *Erwinia* and *Fusarium* rot.** *In vitro* screening, using Australian essential oils of lemon myrtle (*Backhousia citriodora*), aniseed myrtle (*Anetholea anisata*) and tea tree (*Melaleuca alternifolia*), as well as the oil from seeds of caraway (*Carum carvi*), were screened *in vitro* for their ability to inhibit the growth of *Fusarium solani* (DAR 66102), *Fusarium oxysporum*, and *Erwinia carotovora* (now known as *Pectobacterium carotovorum* subsp. *carotovorum*). The inhibitory activity of compounds was tested by determination of inhibitory activity of compounds against spore germination, mycelial growth, and determination of inhibitory activity of compounds against bacterial growth. Gas chromatographic analysis was used to determine the fate of the volatiles during the experiments. *In vivo* trials were set up to assess the efficacy of selected biocontrols and essential oils against *Erwinia* and *Fusarium* rots on potatoes.

## 6 Achievements against activities and outputs/milestones

### *Objective 1: To map social, economic and physical components of sweetpotato supply chains*

no.	activity	outputs/ milestones	completion date	Comments
1.1	Activity 1.1: Establish a sweetpotato database	Preliminary sorting scheme established.  Baseline database (on production, consumption, prices, and marketable surpluses in key producing areas and markets) established.	November 2010  Nov 2008  June 2009  June 2011	Minimum quality requirements and benchmark quality were established Quantity data were collected at the Lae market  Costs of marketing from Kasena to Goroka, Lae and POM.  Price analysis completed using data from 1992-2009.
1.2	Activity 1.2: Understand social and economic components of sweetpotato supply chains	Interviews transcribed  Group discussions with women transcribed  Consumer survey completed.	November 2008  September 2008  February 2009	Interviews of farmer-marketers, wholesalers, institutional buyers and transporters completed Focus groups conducted in Goroka and Hagen  Norah Omot's PhD thesis submitted in February 2010
1.3	Activity 1.3: Map physical and technical components of the sweetpotato supply chains	Report on factors causing losses along the supply chain.  Report on disease surveys	April 2011  April 2011	Experimental work completed September 2009, with preliminary report delivery in Feb 2011  Final disease surveys undertaken in Lae and Port Moresby in Sept 2010.
1.4	Activity 1.4: Identify constraints and opportunities for improvement	Reports detailing survey results.	December 2008	

1.5	Activity 1.5: Progress review	Planning workshop	Feb 2008	Planning workshop
		First stakeholder workshop	January 2009 Various	
		Training provided.	May 2009	June 2008 (postharvest physiology, supply chain mapping, pilot consignment trial); June 2009 (survey methods); September 2009 (postharvest pathology, disease identification and disease surveys)
		Interim report to ACIAR.	As needed	Annual report, plus various trip reports
1.6	Activity 1.6: Develop social and economic evaluation models	Literature on impact assessment reviewed; templates developed	June 2009	Lit review of social and economic indicators and template for costs of marketing developed and examples provided.

**Objective 2: To develop locally appropriate postharvest handling and processing options**

no.	activity	outputs/ milestones	completion date	Comments
2.1	Activity 2.1: Evaluate 5-10 major sweetpotato lines for quality attributes and storage potential	Report detailing varietal characteristics.	June 2011	Initial trial work was completed in 2008. Following the stakeholder workshop in January 2009, this component was expanded with two further trials completed in 2011.
2.2	Activity 2.2: Conduct postharvest handling trials	Report packaging trials	April 2011	5 packaging trials were undertaken looking at alternative packaging options, which were completed in September 2010.
		Report on curing trial.	February 2011	Curing trials were undertaken in September 2010
2.3	Activity 2.3: Appraisal of household and village processing options	1-2 processed products selected based on market appraisal for future development Processing methods developed and tested using low-tech equipment.	July 2010	Evaluation of Sr Louisa's processing training activities
			February 2011	A sweetpotato fair was held in Minj where NARI and locals showcased their processed sweetpotato products
			April 2011	Processing training workshop was held in April 2011.
2.4	Activity 2.4: Progress review	Progress report		At least twice a year, regular project meetings with partners were held in PNG and Australia. Progress reports were included in various trip reports.

**Objective 3: To facilitate the development of stakeholder-driven strategies for improving the marketing efficiency and postharvest management of sweetpotato**

no.	activity	outputs/ milestones	completion date	Comments
3.1	Activity 3.1: Conduct first stakeholder workshop	Workshop held. Draft action plans developed.	January 2009 April 2009	
3.2	Activity 3.2: Form working groups for implementing strategies	Working group formed.	April 2009	Working groups were outlined in the workplans
3.3	Activity 3.3: Provide training to working groups	Training programs developed and working groups trained	Provided as needed  March 2011	June 2008 (consignment trials); July 2009 (Marketing skills for women's groups); Nov-Dec 2010 (Financial literacy for women's groups); March 2011 (Village level processing for women's groups)  Extension materials for postharvest management and disease control (fact sheets, posters and videos) were developed

**Objective 4: To assist stakeholders in implementing the intervention strategies identified in objective 3**

<b>Comments: Most activities in this objective were not implemented because of the change of direction as result of stakeholder workshops whereby different priority issues were identified and addressed</b>				
4.1	Activity 4.1: Implement women strategies	Networks established in key production areas. Minutes of meetings and action to be taken recorded and followed up by the research team.	On-going	Rather than establishing new networks, we worked closely with existing women's groups and networks in Minj and Banz, WHP. Regular meetings were held by those groups. The project had provided support and training in marketing, financial literacy and processing.
4.2	Activity 4.2: Pilot test preferred postharvest handling options	Report detailing trial results. Recommendation on best-bet postharvest handling practices.	NA	Activity removed (with PM's approval in September 2010)
4.3	Activity 4.3: Pilot test preferred household and village processing options.	Report detailing trial results. Recommendation on best-bet low-tech processing options.	NA	Activity removed from the project with PM's approval in September 2010

4.4	Activity 4.4: Evaluation of social and economic impact	Financial and economic impacts assessed.  Recommendation to policymakers on best bet practices for sweetpotato marketing Women's attitudes and sense of empowerment assessed.	May 2011  August 2011	Economic modelling activity removed (with PM's approval in September 2010)  Impact assessment on financial literacy training, linking farmers to credit and processing training
4.5	Activity 4.5: Conduct second stakeholder workshop	Workshop conducted. Final report to ACIAR, extension publications and conference presentations.	Nov 2009 June 2010 Nov 2011  September 2011	Economic component Technical component Final report  Three articles from this project appeared in Stewart Postharvest Review September issue and three more will appear in the December issue.

**Objective 5: Assist the Australian potato industry in developing effective supply chain solutions to reduce postharvest losses en route to export and distant domestic markets**

no.	Activity	outputs/ milestones	completion date	Comments
5.1	Activity 5.1: Industry consultation	Report detailing major postharvest quality issues and opportunities for improvement.	November 2009	
5.2	Activity 5.2: Evaluate the effectiveness of alternative control options	Report detailing antifungal properties for essential oils and biofungicides. Report detailing best alternative control options. Report detailing most effective concentrations and application method. Report detailing effectiveness of alternative control options against conventional control. Commercial feasibility of control options identified. Future research direction identified	March 2010  August 2010  August 2010  December 2010  March 2011  March 2011	Technical reports incorporated several of the milestones. Commercial feasibility could not be completed in time.

5.3	Activity 5.3: Undertake cost benefit analysis of new and existing control options	Report detailing major postharvest quality issues and opportunities for improvement.	June 2011	
5.4	Activity 5.4: Develop extension materials and conduct workshops and field day activities	Training manual and extension materials	June 2011	Some were showcased in March 2011 at the review workshop. More were completed in September and copies sent to PNG.

## 7 Key results and discussion

In this section, we discuss the results in the four thematic areas of this project, as reflected in the project title. They are: (1) improving marketing efficiency, (2) improving postharvest management, (3) improving value addition of sweetpotato in PNG, and (4) the Australian component.

### 7.1 Thematic Area 1: Improving marketing efficiency: the economic/social component

Major activities (or sub-projects) under this theme follow the cycle of participatory action research, i.e., research was followed by planning (through stakeholder workshops and action plans) and actions (through working groups). In the first round, supply chain mapping was conducted and research results were presented at the first stakeholder workshop, from which three priority issues (access to credit, transport, and market information), and recommendations for action, were identified and addressed through further research in the second round involving consultations with credit and transport services providers and a consumer survey. The results were again presented at the second stakeholder workshop, from which another set of priority issues and recommendations for action followed. Actions taken in the third round included (1) a case study looking at ways to improve transport, (2) providing financial literacy training to farmers groups and linking them to microcredit providers to improve credit, and (3) market analysis for generating market information and marketing workshops for improving communications between farmers and wholesalers. This thematic area was completed with an impact assessment looking at how participating farmers, especially women, have benefited from this project. All that had been learned about the sweetpotato sector in PNG was summarised in a 4x4 matrix following the analytical framework of a SWOT analysis.

Activities under each sub-project are outlined below.

Sub-projects	Activities	Reports
Supply chain mapping	Stakeholder consultations of farmers, wholesalers, buyers, and transporters.	Mapping the sweetpotato supply chains in PNG; and Sweetpotato marketing in PNG: a gender perspective”
<b>First stakeholder workshop</b>	<b>January 2009</b>	
Improving market information	Statistical analysis of prices, marketing costs and supply; consumer survey on consumer preference; and marketing workshops for farmers and buyers.	Market analysis of prices, marketing costs and supply; Improving women’s participation in sweetpotato marketing; and Consumer preferences and supplier responsiveness
<b>Second stakeholder workshop</b>	<b>November 2009</b>	
Improving transport	Literature review on collective action, consultations with transport service providers, and a case study	Improving access to transport for sweetpotato farmers in PNG; and A case study of Joe Kold’s sweetpotato supply chain
Improving access to credit	Literature review on microfinance, consultations with credit service providers, group profiling, linking farmers to microcredit, financial literacy training, and impact assessment	Improving access to credit for sweetpotato farmers in PNG; and Improving cooperation between smallholder farmers
<b>Project review/stakeholder workshop</b>	<b>March 2011</b>	
Overall assessment	A SWOT analysis and areas for further research	

## 7.1.1 Supply chain mapping

This activity involved a series of consultations with key supply chain operators (smallholder framers and farmer-marketers, wholesalers, transporters, and institutional buyers) through personal interviews and focus group discussions. It aimed to understand the workings of the sweetpotato supply chain and key issues and possible solutions from stakeholders' perspectives. The main results are presented in Table 1.1.

**Table 1.1 Results from supply chain mapping - stakeholder consultations**

	<b>Main issues</b>	<b>Possible solutions/comments</b>
Smallholder farmers and farmer-marketers	Lack of credit facilities in local communities; Upfront cash payments; Labour cost too high; Transport cost too high and limited availability; Poor roads; No storage facilities in Lae; Lack of regular buyers in their district; Lack of information on price and consumer preference.	Develop local processing facilities; Other ways of utilising sweetpotato; Training in book keeping, postharvest handling, and processing; Build storage facilities; Improve feeder roads; Establish microfinance in the district; Increase numbers of local buyers.
Women farmers	Same issues as farmer-marketers. <b>PLUS</b> Gender-specific issues: Personal safety; No safe accommodation in Lae; Can't open bank account; Laborious work (but no help from children); Harassment at the market; Markets were dirty with poor facilities; Low price and oversupply in local markets; Lack of business skills.	Gender training; Government build new markets and improves existing facilities; Need training on marketing; Need business training; New ways of cooking sweetpotato.
Wholesalers	Vehicles damaged due to overloading; Selling prices fixed for years; High fuel costs.	Comment: Most wholesalers have their own storage sheds and trucks, access to credit from commercial banks, regular customers, and secure contracts.
Institutional buyers	Supply shortage and cost increase due to landslides and roadblocks; Breakdown of cooking machines; Delayed payment from government; Limited budget; Student complaints (no variety, small servings, bad food, etc).	Comments: Institutional buyers use several regular suppliers to manage potential supply interruptions Price is more of a concern than quality due to set budget.
Kai bars	Source mainly from the open market	Comments: The volume of sweetpotato purchased is small compared with potato.
Shipping companies	Unreasonable compensation claims and harassment from farmers when spoilage occurs; Ship birthing problems (Consort in Lae, Bismark in POM); High costs of fuel and parts.	Statutory declarations; Sorting/better packaging /separate produce; Government improves port facilities.
Truck drivers	Poor feeder roads (can't go into the	A central pickup point/ a consolidation

	villages); Farmers not organised/no concept of time; Landslides/potholes; Police checkpoints and harassment; Holdups and roadblocks; Vehicle breakdowns; Tribal fights.	depot; Government improves road conditions; Farmers better organised.
Priority issues (as identified at the first stakeholder workshop): Improving access to credit; Improving access to transport; and Improving understanding of consumer preference for variety and product characteristics.		

For smallholder farmers, their concerns centred on access to, and costs of, credit, and transport and availability of storage facilities (Table 1.1). Women faced additional gender-specific issues, such as personal safety, harassment, heavy workloads (no help from the children), poor market facilities, and low price and oversupply. For wholesalers, institutional buyers, kai bars and shipping companies, sweetpotato *per se* was not a main concern for them because it constituted a small portion of their business. Results summarised in Table 1.1 were presented at a stakeholder workshop and after considerable deliberations, three priority issues to be acted upon in the second round of planning cycle were identified. They were: improving access to credit, improving access to transport, and improving access to information for smallholder farmers.

The second round of research was all about addressing the priority issues and focused on getting the perspectives of service providers on credit and transport issues through personal interviews, and on understanding consumers' preferences for sweetpotato variety and product characteristics through a survey in Lae. The results are summarised in Table 1.2.

**Table 1.2. Interviews with transport and credit service providers, and consumers**

	Main issues	Possible solutions/comments
Transport providers	Farmers are not organised and do not keep to schedule; High costs of repair and maintenance due to bad roads; Big problem if there are shipping delays and can't unload; Compensation claims from farmers; Some containers carry chemicals and can't be used to carry fresh produce; Dealing with small farmers is time consuming and costly; Looting of containers.	Deliver to company's depot; Deal with one big supplier; One pickup point and one drop off point (with proper storage facilities); Curing and proper packaging to reduce losses and complaints; Use open-cut or chiller containers; Statutory declaration (to avoid liabilities).
Credit providers	Costly and risky to deal with small, individual farmers (no stable income, no collateral); Don't know how to manage money; Handout-mentality.	Financial literacy training; Group-based lending or community-based approach (as NDB).
Consumers	Prefer highland sweetpotato over coastal varieties; Know what they want but can't find it with ease; No information on varieties, where it is grown, and when it was harvested.	Improve quality; Lower price; Product labelling for highlands sweetpotato; Improve communication between farmers and buyers.

From Table 1.2, the key message from service providers, both credit and transport, is that doing business with smallholder farmers is high cost because they are unorganised, un-business-like and unprofessional.

### **Discussion**

**Consultations with credit and transport services providers -- smallholders are on their own unless ...** It is a common sentiment of the big companies involved in the sweetpotato marketing chain, including financial institutions, trucking companies and shipping companies, that the fresh produce sector (including sweetpotato) constitutes not only a very small portion of their total business, but also an unprofitable one. Therefore, the onus is on the smallholder farmers to show that they are worthy business partners if they want to do business with the big companies.

For credit providers, this would mean smallholder farmers being financially literate, learning how to manage money, and changing their attitudes towards loans, i.e., loans are not grants, but must be repaid according to set schedules. For transport providers, this would mean smallholder farmers organise themselves and consolidate their sweetpotatoes into container loads so they can be picked up from one central location and, preferably, from one responsible party who represents a group of smallholder farmers. Most trucking companies have contracts with their customers, mainly mining companies, and they are busy all year round. In addition, they have tight schedules, and therefore trucks must keep going and cannot afford to wait for farmers to deliver or pick up their sweetpotato bags. Back-hauling, although cost effective, is not allowed and is against trucking companies' policies because of potential problems with running behind schedule, and compensation and insurance claims from farmers when something goes wrong (such as cross-contamination).

To improve access to credit and transport, smallholder farmers must change their attitudes and behaviours, organise themselves into natural groupings, and work collaboratively to consolidate sweetpotato for transporting to market and to access group loans.

### **Understanding consumer preference: a consumer survey.**

The main finding from the consumer survey is that consumers' preferences for sweetpotato are quite specific in terms of variety, physical characteristics, and eating quality. Specifically:

*Karot* was by far the most preferred variety followed by *Wahgi Besta*, and then a number of varieties (*3-Mun*, *Korowest*, *1-Mun* and *Gimani*) that were equally preferred.

Characteristics such as yellow flesh, red skin, medium size, elongated shape, mature, sweet, firm and powdery were preferred by the majority of consumers interviewed.

There appears to be a price premium for *Karot* and a price discount for *Rachael*. But the relationship between price and other varieties are not clear.

The study also looked at farmers' perceptions of consumer preference for sweetpotato variety, physical characteristics, and eating quality, and how farmers responded to them. It found that sweetpotato suppliers from the Highlands were not fully aware of consumers' preferences, but because they thought they did, they could not, and did not, respond adequately to consumer demand. One possible reason why this happened is because farmers did not go to the market often enough (once or twice a year) to familiarise themselves with what consumers want, and when they did, they simply brought whatever they had grown. Misconceptions of consumer preferences can result in inefficiency in the supply chain and misallocation of resources because when unwanted products are being produced, there would mostly likely be low prices and product wastage. Education of farmers regarding consumer preferences, and providing consumers with product information (through, for example, product standards, labelling or advertising), will help improve marketing efficiency.

### ***Women in sweetpotato marketing.***

There are several gender-specific issues in the sweetpotato supply chain in PNG. The main ones are low prices and poor market facilities. Women often encounter low prices and oversupply at the local markets because (1), the majority of women in the highlands sell at the local markets near where they live (as opposed to men selling at the distant markets in Lae or POM) (2), women tend to go to the market together (they see each other as companions rather than as competitors) (3), women go to market when they need cash, especially for school fees or social obligations, as do others in their villages or neighbourhood, and (4), they tend to consistently grow the same produce either because it is easy to grow and requires no purchased inputs, e.g., watercress, carrots, cabbage, or sweetpotato, or because it is what is available from the local nurseries. To avoid low price and oversupply in the highlands, long distance marketing to the coastal markets must be improved.

Women dominate open markets. With very few exceptions, open markets are overcrowded, unsanitary, weakly policed, and without shelter, shade, water or toilet facilities (Brearley 2005). Poor market facilities are problems experienced only by women because selling food crops at the market is traditionally a woman's job. Men find it menial and embarrassing to sit and sell at the market for long hours with typically little returns. The very poor conditions of the open markets reflect a disregard for the struggle and hardship that women face and the marginalisation of women in PNG society by policymakers, despite the rhetoric to improve gender equality (Chang and Be'Soer 2011).

Since the local markets are where women maintain their livelihood, to encourage women to participate more fully in sweetpotato marketing, local transport to the market and the conditions of the market must be improved.

#### **7.1.2 Improving smallholder farmers' access to credit**

There are two parts to this section: the provision of financial literacy training, and the linking of farmers groups with credit providers.

##### ***Financial literacy training***

During the economic component stakeholder workshop in November 2009, an action plan was developed to improve farmers' access to credit by linking them with credit providers. Three farmers groups in WHP were organized in late November/December 2010, and National Development Bank (NDB) loan officers were invited to go the villages to provide financial literacy. However, we soon learned that the so-called "financial literacy training" provided by the NDB was nothing more but talking about NDB's microcredit scheme and the forming the groups into "community-based organisations" (CBOs) so that the group could take out group loans from NDB. There was no financial literacy training on budgeting, cash flow management, or debt management. This situation is challenging.

Financial literacy training is considered a pre-requisite for smallholders to access microfinance because without it, borrowers, who are often ignorant about money or loans, tend to default on their loans, intentionally or otherwise, simply because they don't know how to budget or manage their cash flows, or because farmers consider loans as grants that they do not need to repay. For this reason, we insist on providing literacy training to farmers prior to linking them to credit providers.

As soon as the project team realised that proper financial literacy training was not done by NDB, the FPDA team members sprang into action to fill the gap. The first basic financial literacy training by FPDA was conducted in February 2011 with Wayne Gorowe's group (Ambo Fresh Produce) at Kasena, EHP. The event was featured in the PNG Post Courier. The change in attitude indicator was captured in the training evaluation, as evidenced in the following written comments from the participants:

"I understand that money management is really about how you use wisely your income and manage your spending and by keeping good records of it" - Mary Daniel (Female).

"Of course I am now more confident that I can get a loan from National Development Bank to help me expand my tomato production and other income generating activities such as sweetpotato, carrot, coffee because I now know how to work out my cost of production and marketing expenses and come up with net incomes from which I can do my cash flow and forecast my family's financial goals"- Francis Runo (Male).

In May 2011, two more groups in EHP (Yahu-Yuho Nasahiri womens group and Vitune Welfare Association and Linahana womens group), and two groups in WHP (Agnes' and Joseph's groups), received their training from FPDA in September 2011. The latter two groups had already taken out loans from NDB without the benefit of the financial literacy training and, as to be discussed later, had borrowed more money than was necessary. After the training, they were made aware of the cost of borrowing and will now focus on savings, rather than loans, for the capitalization of their operations in the future.

FPDA has committed itself to continue the financial literacy training beyond the life of this project, and it has been incorporated into FPDA workplans in coming years. FPDA extension staffs are currently undergoing training to provide this additional service to smallholder farmers.

### ***Linking farmers to microcredit***

We began this activity in November 2010, and by March 2011, six groups (five in WHP and one in EHP) were linked to the National Development Bank (NDB) and subsequently four groups have taken out group loans with NDB. In August 2011, we talked to all six groups to assess the impact on their lives of improved access to credit.

In WHP, the first loans of K1000 per member were used for a range of activities, including purchases of inputs for vegetable production, day-old-chicks and feed to raise the chickens, buying coffee for re-sale, buying a pulp machine, generators or water pumps, purchasing land, building permanent houses, paying school fees, etc. The first loan was highly appreciated, and indeed, has been very helpful. For many, it is the first loan ever, and it enabled them to expand their vegetable production and made significant profits. Most borrowers used the money to buy seed, watering cans, sprayers, etc. In Minj, Agnes was able to buy these farm inputs in bulk for her group from Brian Bell at discounted prices.

However, we found that most farmers only required about K500 for inputs needed to expand their vegetable production. Some joined the group now (even they did not need the loan) so they could borrow the maximum amount of K10,000 later. Several reasons for borrowing more than necessary are that: (1) farmers do not budget or plan, so they don't know how much they need to borrow, (2) farmers do not fully understand interest rates or the cost of borrowing, and tend to borrow as much as they can, (3) in a group loan, everyone has to agree on how much to borrow and the amount decided on may be too big for some and too small for others, and (4) there is pressure from the bank to borrow more rather than less. During our visit in August 2011, both Agnes' and Josephs groups were in the process of making a second loan for K3000. We explained to the group the concepts of interest rate and costs of borrowing and advised them to re-consider having the second loan. Also, we stressed the fact that the purpose of the loans was to generate more incomes and savings to reduce the need to borrow in future.

In EHP, things did not go as smoothly as in WHP. In early 2011, the NDB Goroka Branch temporarily ceased its microcredit scheme because of problems with repayments. One reason for repayment problems, we thought, was that loans were often made in haste without proper screening, and that NDB did not provide financial literacy training to potential borrowers before they approved any loan application. This example suggests that both farmers and loan officers need training if microcredit schemes are to be sustainable.

Out of 6 groups that were linked to NDB, two decided not to borrow. These two groups (Lilly's and Wayne's groups) were also the only two groups that had received financial

literacy training prior to being linked to NDB. During the impact assessment, we were told that the groups would have appreciated having a loan, but they were cautious about it because the training had made them aware of the costs of borrowing and the responsibility associated with it. More importantly, they thought there might not be enough cash flows to repay the loan on schedule.

### **Discussion**

It is clear that the financial literacy training, when conducted properly, can be very effective in changing attitudes both towards farming (seeing it as a business) and borrowing (seeing it as a debt which needs repaying, not a grant). The exercises on budgeting and cash flow also make them think more about costs, prices, incomes, and expenses in dealing with their personal finances, and in contemplating a business venture. FPDA has tried for years to encourage farmers to record keep, mainly as part of the technical training on production, but to no avail. The financial literacy training conducted through this project may have provided the necessary motivation for record keeping and impetus further business because it relates more directly to their bottom line.

Access to credit is one of the major constraints to improving productivity and income for smallholder farmers. The provision of financial literacy training to women and farmers groups, and linking farmers with credit providers, have had significant and immediate impacts on both productivity and income. This is a significant outcome from this project because smallholder vegetable farmers, although facing serious credit constraints, did not have the opportunities to borrow from the formal sector because they were considered high risk and high cost. However, this is no longer the case. Being able to access credit from the NDB was considered a “breakthrough” by FPDA team members and all participating farmers.

More importantly, this activity will continue in future as FPDA has incorporated financial literacy training into its staff annual workplans, and will expand the activity to more groups and more communities in their jurisdiction. It is envisaged that the same groupings and networks will be used to provide further training and extension in vegetable production, postharvest management, marketing, and business skills. As the demand for fresh produce has been increasing substantially in recent months and is due to continue in the next few years as a result of the PNG LNG project, the timing of this project activity could not have been better in terms of setting farmers up to respond to demand increases. Significant economic and social impacts are expected in years to come, especially when suggested changes to postharvest management (cooling/packaging/handling) and marketing practices are implemented through FPDA's integrated extension program.

One important lesson learned from this exercise is that continuous monitoring and evaluation is absolutely crucial in ensuring that any glitches are picked up and rectified as soon as possible. Otherwise, good intentions can do more harm than good to smallholder farmers.

#### **7.1.3 Market analysis**

There are three parts in this market analysis: price analysis, volume assessment, and costs of marketing. The objective of the analysis was to understand the demand and supply conditions to derive marketing implications for smallholder farmers.

##### **Price analysis**

It was conducted using the Urban Market Survey data collected weekly by the Fresh Produce Development Agency at eight open markets. Therefore, these prices are to be treated as retail prices and not to be confused or compared with the price farmers receive when the produce is sold to intermediaries. Because many data points were missing, the weekly data were aggregated into annual data. The annual data from 1992-2009 thus derived were then analysed to understand changes over time and across markets in

prices and marketing margins, as well as price linkages between four markets (Mt Hagen, Goroka, Lae, and Port Moresby).

### **Annual prices.**

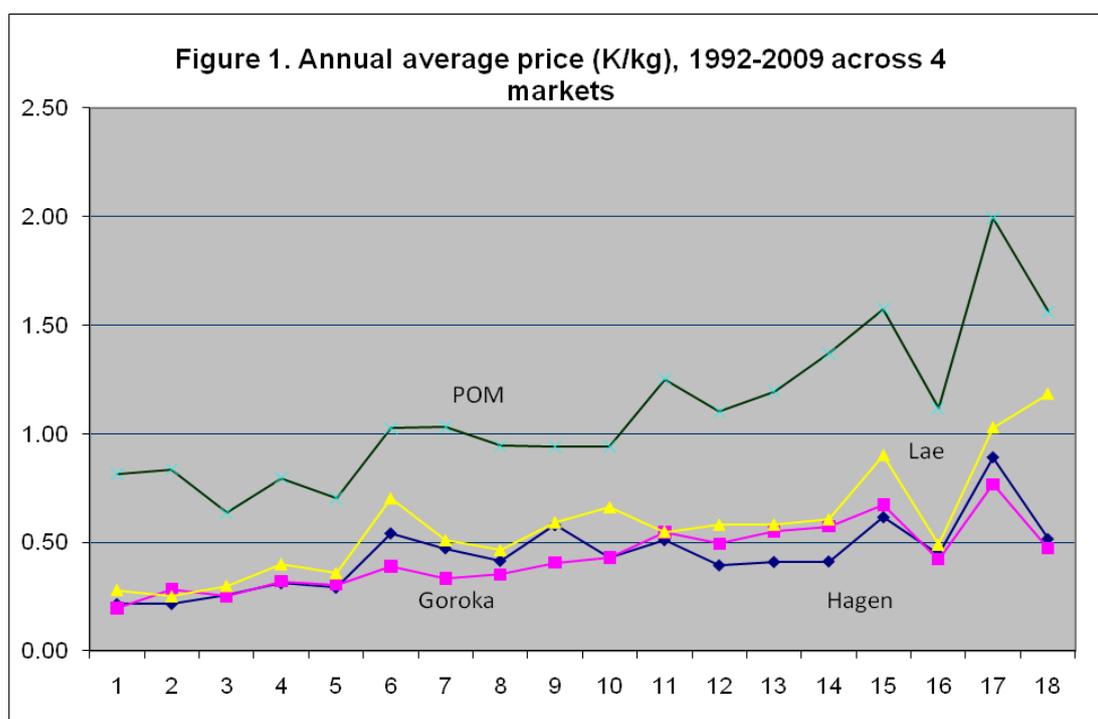
Sweetpotato prices did fluctuate quite significantly during the data period 1992 – 2009. Summary statistics of the four price series are presented in Table 3.1 and the mean prices for the four markets are: K0.44/kg in Hagen, K0.43/kg in Goroka, K0.58/kg in Lae, and K1.10/kg in POM over 18 years (second row). This means prices were similar for Hagen and Goroka, whereas the price in POM is much higher than the price in Lae. Price differentials (or margins) between Lae and Hagen and Goroka are K0.14 and K0.15/kg, respectively, and margins between POM and Hagen and Goroka are K0.66/kg and K0.67/kg, respectively. The margin for Lae-POM is K0.52/kg. Lae margins are important because when they are compared with the costs of marketing, they indicate whether a marketing endeavour is profitable or not.

**Table 3.1. Descriptive statistics for annual prices (in K/kg), 1992-2009**

	<b>Hagen</b>	<b>Goroka</b>	<b>Lae</b>	<b>POM</b>
Mean	0.44	0.43	0.58	1.10
Median	0.42	0.41	0.56	1.03
Standard Deviation	0.16	0.15	0.25	0.35
Minimum	0.22	0.20	0.25	0.64
Maximum	0.89	0.77	1.18	1.99
CoV	37%	35%	43%	31%

Next we looked at standard deviations and coefficients of variation (CoV) to assess variability of prices. CoV is arrived at by dividing the standard deviation by the mean value and multiplied by 100%. It is a relative measure and therefore can be used to compare price volatility across markets. As shown (bottom of Table 3.1), CoVs are 37, 35, 43, and 31% in Hagen, Goroka, Lae, and POM, respectively. This means that when averaged over 18 years, the average price in Lae is more variable than the price in POM, while the price in Hagen is slightly more variable than in Goroka. Note that because of the high level of aggregation, one can expect variability to be much higher on a daily, weekly, or monthly basis. Also, these differences in variability have not been tested for statistical significance. Therefore, they can only be used as a guide.

**Changes in prices and margins over 1992-2009 can be seen in Figure 1.**



It is clear that sweetpotato has become more expensive over time in nominal terms (i.e., not being adjusted for inflation) as prices have been trending upwards since 1992, despite a significant fall in 2007. There is no information on what happened in 2007, except that it was an election year. The highest price in POM occurred in 2008, being nearly K2/kg at the Gordons market, the same time as in Hagen (K0.89/kg) and Goroka (K0.77/kg). In Lae, the highest price (K1.18/kg) occurred in 2009.

When these prices are regressed against time, the results showed some differences in how fast prices have increased in different markets (Table 3.2). For example, POM prices increased by 5.51 toea/kg per year while the Lae prices increased by 3.82 toea/kg per year. For Hagen and Goroka prices, the increases were 2.15 toea/kg and 2.37 toea/kg per year, respectively. Moreover, the trend variable alone explained between 47% and 70% of the variations in prices, and the coefficients associated with the trend variable are statistically highly significant.

**Table 3.2. Regression results**

	Hagen	Goroka	Lae	POM
<b>Intercept</b>	-42.62 (-3.94)	-47.04 (-6.32)	-75.89 (-5.51)	-109.07 (-6.34)
<b>Time</b>	0.0215 (3.98)	0.0237 (6.38)	0.0382 (5.55)	0.0551 (6.40)
<b>Adjusted R<sup>2</sup></b>	0.47	0.70	0.64	0.70

\*The figures in parentheses are t-ratios.

### Monthly average prices.

To see whether a seasonal pattern existed in the sweetpotato market, the average price for each month over 1992-2009 was calculated. The summary statistics are presented in Table 3.3. Over the 12-month period, monthly average prices (over 18 years) in the Hagen market varied from K0.35/kg to K0.54/kg, with a mean value of K0.45/kg (second column, Table 3). For POM, the minimum is K0.95/kg and the maximum is K1.28/kg, with a mean value of K1.10/kg (fifth column, Table 3.3).

**Table 3.3. Descriptive statistics for monthly average prices (K/kg), 1992-2009**

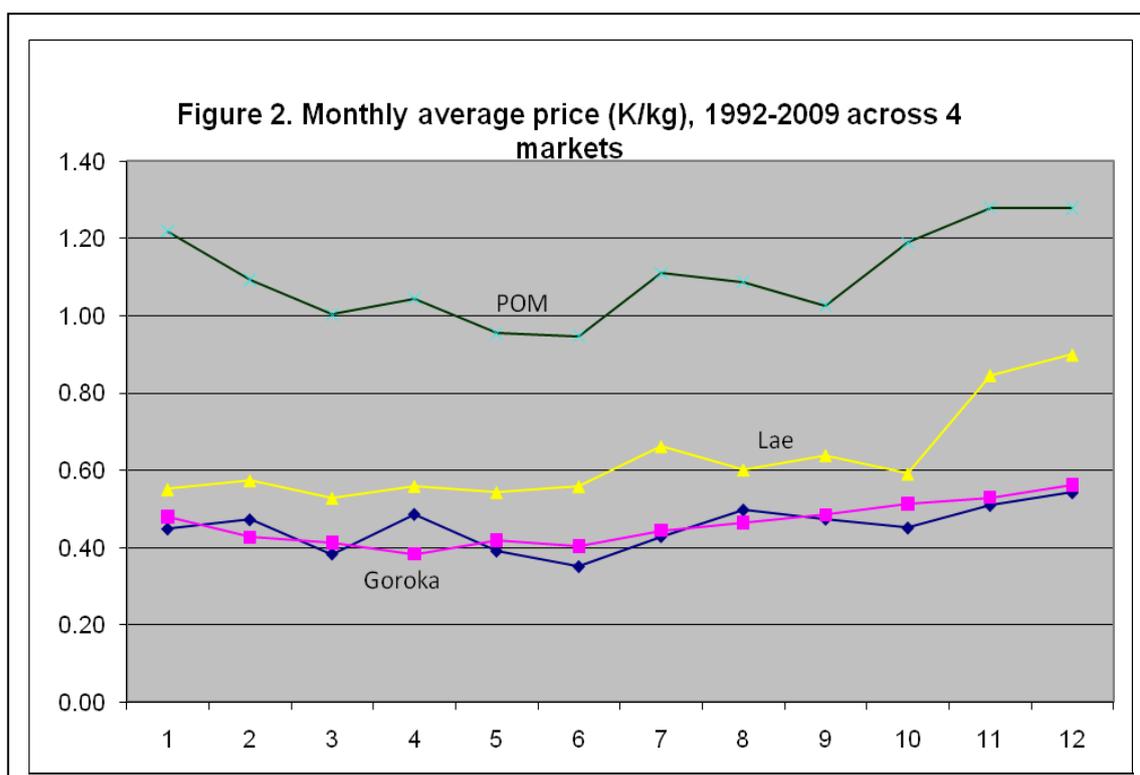
	Hagen	Goroka	Lae	POM
<b>Mean</b>	0.45	0.46	0.63	1.10
<b>Median</b>	0.46	0.45	0.58	1.09
<b>Standard Dev.</b>	0.06	0.06	0.12	0.12
<b>Minimum</b>	0.35	0.38	0.53	0.95
<b>Maximum</b>	0.54	0.56	0.90	1.28
<b>CoV</b>	13%	13%	19%	11%

In Figure 2, sweetpotato prices in POM were higher in October, November, December, and January and lower in May and June, and in Lae, prices seemed to jump up in November and December. Other than these highs and lows, there are no clear seasonal patterns in any of these four markets.

In terms of the variability in monthly average prices, the Lae price appeared to have had the greatest variation, with the CoV being 19%, followed by Hagen/Goroka (13%) and POM (11%). This might lead one to conclude that monthly price was most variable in Lae and most stable in POM, as were found with annual prices.

However, Figure 2 seems to tell a different story, which shows that average monthly prices in Lae were quite stable and were steadily increasing, except the hikes in November and December. By comparison, POM prices moved up and down without a clear pattern. Similarly, Goroka prices also appeared stable, rising gradually as the year progressed, while Hagen prices fluctuated quite a lot. The discrepancies between what is suggested by the statistics and what is seen in the graph may be explained by problems associated with non-stationary data, where the data series are trending upwards and do not have an “average” in the general sense. But, in general terms, we found no clear seasonality in the sweetpotato market.

Hagen



### Volume assessment

Three volume assessments were conducted at the Lae main market in 2008. Results on weekly volume counts and weekly disappearance and differences between the Lae and POM markets are summarised below.

#### Weekly volume counts.

Table 3.4 below shows the breakup of sweetpotato delivered to the Lae main market from various districts in Eastern Highlands Province (EHP) and Western Highlands Province (WHP). A total of 912, 974, and 1200 bags, respectively, arrived at the Lae main market in the three weeks surveyed (bottom of Table 3.4). These volumes do not include those destined for Port Moresby and other markets in the country or other bags sent directly to peri-urban markets within Lae city.

WHP farmers supplied almost twice as many bags as EHP. For example, in Assessment 1, 310 bags came from EHP while 574 bags came from WHP. Similarly, it was 355 bags versus 774 bags in Assessment 3.

**Table 3.4. Sweetpotato arrivals at the Lae Main Market during the week of assessment, by district and by province**

Province	Districts	Assessment 1 31.3 to 5.4 2008	Assessment 2 8-16.8.2008	Assessment 3 17-22.11.2008
EHP	Kainantu	15	6	5
	Okapa	43	6	6
	Bena	12	0	0
	Goroka	106	145	105
	Asaro	134	134	150
	Unknown district	NA	24	89
Sub-total		310	314	355
WHP	Anglimp/S. Wahgi	238	127	209
	North Wahgi	12	0	0

	Mul/Baiyer	168	0	100
	Hagen Central	96	119	325
	Tambul/Nebilya	3	0	10
	Unknown district	57	32	130
Sub-total		574	278	774
Unknown Province		29	382*	71
New arrivals		912	974	1200

**\*The origins of these bags' are not known because they could not be recorded in time.**

### **Weekly disappearance**

The beginning inventory was taken early Monday morning and the ending inventory in late Saturday afternoon. The beginning and ending inventories did not take into account bags that were already opened, or sweetpotato heaps that were on display, which could amount to 5-10 bags. The levels of inventories are listed below (Table 3.5).

**Table 3.5. Weekly disappearance of sweetpotatoes at the Lae main market**

	Assessment 1	Assessment 2	Assessment 3
Beginning inventory	96	168	261
New arrivals	912	974	1200
Ending inventory	149	211	238
Bags sold in Lae	859	931	1223
Bags shipped to POM	800-1000	800-1000	800-1000

The Lae market absorbed (or consumed) 859, 931, and 1223 bags of sweetpotato in each week surveyed. With an urban population of about 150,000, this is quite a substantial market for the highlands sweetpotato. The other observation is that the number of sweetpotato bags left in the market at the end of the week (i.e., the ending inventory) amounted to 150-250 bags. Some of these bags would have been exposed to the sun and the rain for 3-5 days before being disposed of. The negative impact on quality could be expected to be large. The lack of storage facilities in the Lae market was identified as a major concern for smallholder farmers during supply chain mapping. Given the large number of sweetpotatoes that passed through the market, the concern is well-justified and should be addressed if the lot of farmers is to be improved.

### **Comparing supply to Lae and POM markets.**

Consort and Bismark are two carriers that deliver sweetpotato from Lae to POM. Among the two, Bismark was the main carrier when the survey was taken because its rates were cheaper. According to Consort's shipping data, only a small volume of sweetpotato was shipped to POM during the three weeks surveyed (704kg/90kg=78 bags, 178kg/90kg=2bags, and 898kg/90kg=10 bags). To find out the total shipment, we needed data from Bismark. Unfortunately, shipping data for Bismark could not be obtained and had to be estimated. Personal communication with an informant in March 2011 revealed that on average, there had been 4-5 full container loads per week of sweetpotatoes heading for POM prior to the recent construction boom in POM (around late 2010). The shipments to POM since 2011 were 10-12 full container loads per week. This would mean an increase from 800-1000 bags/week to 2,000-2,400 bags/week at the turn of the year. The 90 kg/bag conversion was used here to convert from a weight to a bag basis, and vice versa. Note that the weight of sweetpotato has increased from an average of 70-75kg/bag a few years ago to the current 90-95kg/bag. Also, previously it was assumed that a full container load carried 350 bags, but now it is around 200 bags. This trend is worrying because of the damage caused by the ever bigger and more tightly packed sweetpotato bags.

To verify, we also looked at available historical shipping data collected by FPDA from Consort, at different aggregation levels. We found that based on the annual data from 1993-2006, the average number of bags shipped to POM per week was around 350 bags per week (about 1.5 full-container loads). Also, in the month of April, both 2006 and 2007, the volumes shipped to POM by Consort were 70-85 tonnes (i.e., about 1000 bags/month or 250 bags/week, or a little more than one full container load per week. These numbers seem to suggest that on average, the shipments from Lae to POM were about 1-1.5 container loads per week, but this is very low. We noticed anomalies in Consort's shipping data. We estimated the actual volume would be 3-5 times of the reported figures. When these bits and pieces of information were put together, we could conclude that the weekly shipments to POM from Lae during the survey period were likely to be around 800-1000 bags (or 4-5 containers). This means that the market for highlands sweetpotato is almost the same for Lae and POM. The important difference between the two markets is that the urban population in POM was around 500,000 in 2008, more than three times that of Lae (at 150,000). This would imply a possible supply shortage of highlands sweetpotato in POM and hence higher prices.

### Costs of marketing

Marketing costs from Kasena to Goroka, Lae and Port Moresby were estimated to identify major cost items and marketing strategies by which marketing costs could be reduced and returns to smallholder farmers increased. Costs of marketing considered included: costs of sweetpotato bags, packaging, loading/unloading, market entry fees, transport for both sweetpotato and the farmer-marketer (including return airfares from Goroka/Lae to POM), communications, living expenses when away from home, and product losses.

- The numbers provided in Table 1 below are derived based on the following assumptions:
- Selling: in Lae and POM, 50% is sold in bags to re-sellers, and 50% in heaps by farmers themselves; in Goroka, all are sold in heaps
- Normally 5 bags/day are sold in heaps
- Accommodation: Lae (5 kina/night, 2 nights); POM (10 kina/night, 5 nights)
- Food: 20 kina/day when out of town in Lae or POM
- Gate fees: POM 3 kina; Lae 2 kina; and Goroka 2 kina
- Product losses: marginal losses in Goroka or Lae; 10% in POM (2 bags)
- One person can handle 20 bags of sweetpotato

The main results presented in Table 3.6 are the breakeven prices that are required to cover the total cost of production and marketing for selling at different markets. The breakeven prices per bag are: POM K133, Lae K57, Goroka K35, and Kasena K25 (bottom of Table 3.6). This means, for example, that unless the price in POM is more than K133/bag, there would be losses, and *vice versa*. The corresponding costs of marketing per bag are: K110, K37, K15, and K5, respectively. In percentage terms, marketing costs account for 83%, 65%, 43%, and 20% of the total costs, respectively.

**Table 3.6. Marketing costs and breakeven prices for Kasena Village, Goroka, Lae and POM**

Cost items	POM	Lae	Goroka	Kasena
Cost of bags	60	60	60	60
Packing	40	40	40	40
<b>Loading/unloading: Carriers-Goroka</b>	20	20	20	0
Carriers-Lae	40	40	0	0
Carriers – POM	40	0	0	0
<b>Transporting bags: Village to Goroka</b>	100	100	100	0

<b>(truck) (5 kina/bag)</b>				
Goroka to Lae (8 kina/bag)	160	160	0	0
Lae to POM (Bismark, K17.50/bag + tax +15 kina bill of lading)	435	0	0	0
Wharf to warehouse (5 kina/bag)	100	0	0	0
Order deliveries (5 kina/bag)	20	0	0	0
<b>Transporting one person: Village to Goroka (3k/one way)</b>	6	6	24	0
Goroka to Lae (25 kina one way)	25	50	0	0
Lae to Lae airport	4	0	0	0
Lae to POM (by plane)	268	0	0	0
Airport to POM home (10kina one way)	20	0	0	0
Home to Wharf (5 kina one way)	10	0	0	0
POM to Goroka (by plane)	268	0	0	0
<b>Living expenses: Food</b>	100	80	0	0
Accommodation in Lae	10	15	0	0
Accommodation in POM	50	0	0	0
Phone	50	50	0	0
Market gate fees (per bag)	30	60	40	0
Storage in POM (2 kina/bag)	40	0	0	0
Miscellaneous	100	50	20	0
Product losses in POM (10%)	2 bags	0	0	0
<b>Total costs of marketing</b>	<b>1996</b>	<b>731</b>	<b>304</b>	<b>100</b>
<b>Total costs of production</b>	<b>400</b>	<b>400</b>	<b>400</b>	<b>400</b>
<b>Total Costs</b>	<b>2396</b>	<b>1131</b>	<b>704</b>	<b>500</b>
<b>Costs of marketing/bag</b>	<b>110**</b>	<b>37</b>	<b>15</b>	<b>5</b>
<b>Break-even price/bag</b>	<b>133**</b>	<b>57</b>	<b>35</b>	<b>25</b>

**\*\* Because two bags were lost, the breakeven price per bag for POM is arrived at by dividing the total costs by 18, rather than 20. This was also done to determine costs of marketing per bag**

It is clear that the example provided here is a high cost scenario. That is, not that many farmers, especially in recent years when the novelty and excitement of going to POM “the city of light” wore off, would be sending only 20 bags to POM, or flying to POM to sell them themselves. Regardless, it does provide a good example of how costs of marketing can build up and how they can be significantly reduced.

## Discussion

**Why does price vary?** Farmers often remarked that when they went to the market, they never knew what price they would get and whether or not they would make a profit. Given that there is no form of intervention in the sweetpotato market, it is reasonable to conclude that price is determined by the balance between demand and supply at the local market. That is, the price in Lae is determined by the demand and supply conditions in Lae. Furthermore, because demand tends to be relatively stable, price is determined more or less by supply, holding other things constant (i.e., prices of competing products do not change). When there is a shortage of supply of highlands sweetpotato, the price goes up, and when there is an oversupply, the price goes down. Here is a good example. In 2009, we found the numbers of bags sold through the Lae market increased from 1200 bags in November 2008, to 2219 bags in the first week of April in 2009, and then to 4,422 in the first week of July 2009. As a result, prices were observed to drop from K90/bag in 2008, to

K60/bag in April 2009, and to K30/bag in July 2009. Another example is when landslides occur either in the villages or on the Highlands Highway, supply to the market can be reduced temporarily (i.e., a day or two) and price can rise on that event, other things being equal. This means that price may be more variable and higher during wet periods (January to March) when farmers cannot harvest or cannot get to the market as easily. In January/February or in June/July, supply tends to be more abundant because more farmers rush to the market to get cash for school fees, and price may fall, other things being equal. Annual festivities would have the opposite effect on supply, and hence price, when farmers stay home.

Despite concerns over the reliability of the data, some attempts were made to determine whether there was a relationship between sweetpotato prices in POM and the volumes of sweetpotato shipped from Lae to POM using simple regressions. The result showed that volume explained less than 8% of the variation in price. One possible reason was that the market share of highland sweetpotato in POM was small relative to other staples, such as rice, banana, taro, yam, cassava and local sweetpotato. Therefore, the price of highlands sweetpotato in POM was influenced less by its own supply but by the supplies of all other competing products. Unfortunately, the data did not permit a more thorough analysis.

**Why is price in one market (POM) less variable than the other (Lae)?** Given that demand is relatively stable, the price in one market will be more variable if supply to that market is more variable. This implies that the price in the POM market is more stable because the supply to POM is more stable, as compared to Lae. Similarly, we can expect supply in Hagen to be more variable than Goroka. Sweetpotato prices in POM are more stable than in Lae for three possible reasons. First, for most highlands farmers, when they take their sweetpotato down to the coast, they aim at selling it in Lae because it is the first available market and it is less costly. To go any further (Madang or POM) requires a lot more cash outlay and takes significantly more time. If most farmers stop in Lae, and without any form of planning on the part of individual farmers or coordination between farmers, it can be expected that sometimes there will be many bags, and at other times fewer bags, so prices will fluctuate as a result. Second, going to POM market is a big deal both financially and psychologically because not only is there additional transport costs (K17.50/bag plus other charges) but also one needs to know ones way around the city and have a place to stay.

Therefore, farmers who go to POM are regular suppliers and are more experienced and informed of demand and supply. They may regulate their supplies to maintain their margins, and this contributes to the stability of supply and hence price. Third, in the POM market, most sellers are “full-time” re-sellers, not farmer-marketers. Because these re-sellers are selling in the market day- in day-out, they are better able to match supply with demand, and hence help stabilise prices. Finally, POM prices could be more stable because the presence of competing products would put a limit on how much a price can rise before sweetpotato loses its competitiveness.

**Is there seasonality in sweetpotato?** As can be seen from Figure 2, sweetpotato prices during the year, especially in POM, were higher from October to January, and the highest price occurred in December whilst lower prices occurred from March to June, and the lowest occurred in May and June. In this section we discuss in some detail how these price variations can be explained, in particular in relation to seasonal supply, if it exists. Because this price pattern was observed using 18 years of data, the result can be considered robust. But how do we explain it?

In general terms, seasonality may be observed because (1), climatic conditions (especially rainfall and temperature) restrict when the crop can be grown more easily or exclusively (2), production is influenced by social and cultural factors, and (3), seasonality in supply reflects seasonality in demand.

**Coffee seasons.** It seems that the higher prices from October to January may be explained by coffee seasons. According to the data from CIC, the coffee season in the PNG highlands starts in April and runs through to August, with June-July being the peak coffee season. It was postulated that during the coffee season, more attention is given to coffee gardens and picking (either as owners or as casual labourers) and less attention, to sweetpotato. This could lead to supply shortages 6-8 months later, and hence, higher prices around December/January. This is indeed the case (as shown in Figure 2). Similarly, we can expect prices to fall in February-March, which is 6-8 months later after the coffee season and the start of sweetpotato planting in September-October. When planting actually starts would depend on weather and rainfall around the planting time, e.g., there may not be enough rainfall and the ground may be too dry or too hard for making raised beds.

**Climatic extremes.** Bourke (1991) examined a number of possible causes for variations in sweetpotato supply, and hence prices, including disruptions caused by the seasonal coffee harvest, the seasonal harvest of *kanuka* pandanus (an indigenous nut), pig killing ceremonies, and tribal fighting. However, he concluded that none of those factors was a major cause of supply shortages. Rather, it was climatic extremes. According to Bourke (1991), extended wet periods were the most common causes of severe yield reduction in the PNG Highlands, with a detrimental effect on sweetpotato yield manifested several months later after. This is because sweetpotato root yield is most vulnerable to very high soil moisture levels during the root initiation periods (2-8 week after planting). Extended wet periods usually occur during the wetter months, from January to March. This means the subsequent poor crop yields occur some six to eight months later. Periods of drier weather, or coffee and pandanus harvests did not explain variations in supply. Bourke rejected the suggestion that farmers' devotion of time to coffee production, particularly during the coffee seasonal harvesting (from May to September, with a peak in June-August), resulted in the neglect of food production and the subsequent low supply. He added that drought rarely caused large reductions in crop yields unless it was preceded by extended wet periods. The minor frosts that commonly occurred at these altitudes caused some damage to top growth, but the impact on root production was not serious. Other climatic extremes or natural disasters such as floods, hailstorms, and landslides, result in spectacular localised crop damage, but rarely widespread supply shortages.

Agnes (pers. comm.) indicated that the dry season in Minj is from April to July. There is less planting during this period because the ground is too hard for planting. If planting does not start until August, this would imply there would be a shortage of supply, and higher prices, in October-January, 6-8 months later. It appears that the dry periods seem to coincide with the coffee season and it is not possible to distinguish these two effects without more data. Although we are confident that sweetpotato prices are generally higher from November to January, and lower in from May to June, this price pattern is not sufficient to support the existence of seasonality. Bourke and Vlassak (2004) observed a tendency for sweetpotato to be more available at certain periods of the year, with the high supply occurring in March-July and the low supply in October-January. They noted that these periods vary between locations and between years, and as such, they recommended the long term pattern not be viewed as "annual seasonality".

## Marketing implications

This section on market analysis focuses on improving smallholder farmers' access to information by analyses of price, costs of marketing and supply of sweetpotato over time

(1992-2009) and across four markets (Hagen, Goroka, Lae and Port Moresby (POM)). The main findings are:

- (1) sweetpotato prices have been gradually increasing over time, with the price in POM being more stable and growing faster than the other markets;
- (2) prices tend vary significantly from week to week and from month to month, but no seasonality is observed;
- (3) in POM, there is a clear pattern that prices are at their highest from November to January and at their lowest in May and June;
- (4) marketing margins from Hagen to Lae and POM are K0.14/kg and K0.66/kg, respectively (these are equivalent to K13/bag and K60/bag);
- (5) costs of transport and loading and unloading alone from Hagen to Lae is K15-20/bag and from Hagen to POM is K40-45/bag;
- (6) for a smallholder with 20 bags of sweetpotato, the breakeven prices are K57/bag in Lae and K133/bag in POM; and
- (7) the Lae market is a substantial market for sweetpotato and perhaps more so than POM, with a weekly consumption of 1000 bags.

Comparing the average margin of K13/bag with basic transaction costs of K15-20/bag for selling to Lae and K60/bag with K40-45/bag selling to POM and the breakeven prices (K57/bag in Lae and K133/bag in POM) with average market prices (K53/bag in Lae and K100/bag in POM), the conclusion is that in most cases, farmers do not make a profit because costs are likely to outweigh returns, even before other costs (eg bus fares for farmers, market fees, food, etc) are considered. This means that farmers must be more vigilant about costs and must do things differently in order to beat the market.

The recommendations to smallholder farmers for improving marketing include the following: (1) farmers monitor the market closely and not go to make the journey until the market price is higher than the breakeven price; (2) farmers try to reduce the costs by hiring an agent in Lae or POM rather than going to the markets themselves; (3) farmers consolidate their bags with other farmers to take advantage of economies of scale in marketing; (4) farmers sell in bulk to re-sellers to avoid spending more time away from home than is necessary; or (5) farmers sell to local buyers and avoid all the costs associated with going to the market themselves. What is best would depend on individual circumstances, but whatever decision is made, it must be backed up by a sound analysis of prices and costs and other market conditions, such as consumer preferences for varieties and other product characteristics.

In the case study below, we show that the breakeven price was reduced to K90/bag by selling in container loads, and that sound supply chain coordination could reduce marketing costs and product losses.

#### **7.1.4 Best practice: a case study of Joe Kold's supply chain**

Joe Kold is a sweetpotato producer and seller operating from Kelowa Village, Mt. Hagen Central District, WHP. Over the course of the project, Joe Kold was consulted on several occasions and he was involved with the packaging trials and attended the project review workshop in March 2011. It soon became evident that Joe's supply chain is one that can be considered as "best practice" in the PNG context.

Based on our interviews with big transporters, the key requirements for them to work with sweetpotato farmers included:

- A minimum number of 200 bags to fill up a 20-foot container;

- One collection point at a central location for pickup; and
- Good road access to the pickup point.

Joe was able to meet these requirements.

Below is a summary of what sets Joe apart from other farmer-marketers of sweetpotato. They include:

- **Entrepreneurship.** We have talked to Joe probably half a dozen times. He is generous with his time and forthcoming with information, and unlike other farmers, he never asked for assistance. Another personal asset Joe has is social capital, which stems from his close relationships with the community and the social networks surrounding the church. His brother, Joshua, is the Pastor of the church and the leader of the community.
- **Professionalism and commitment.** He delivers regularly to ensure continuing supplies to his customers regardless of how prices fluctuate or whether he makes a profit or not.
- **Consolidation.** Joe sends only full container loads to POM (via Lae), which enables him to not only deal professionally with trucking companies, but also helps reduce transport delays and multiple rough handling often experienced by other farmers who have small numbers of bags and rely on PMVs and open-back trucks.
- **Supply chain coordination.** He plans and arranges for (1) delivery and consolidation into container loads; (2) communicates formally with trucking companies to ensure availability and timely pickup and delivery; (3) harvest and transport to coincide with Bismark's shipping schedules; and (4) regular delivery to his customers in POM.
- **Location.** Another marketing advantage for Joe is good road access, which is about 10 km from Hagen and linked to the Highlands Highway by sealed road. In addition, he is able to use the Kelowa church ground as a depot for consolidation. Good road access and a central collection point make it possible for him to arrange directly with the trucking companies in Mt Hagen to bring container trucks into his village for loading.
- **Quality products.** Joe selects the varieties that are hardy (Wunmun and Korowest); buys only mature roots (6-7 months old) that are grown in mounds; and does quality checks from garden to packing. He also tries to sell as quickly as possible to reduce spoilage.
- **Good relationships with his suppliers** (they are his wantoks in the same area) and customers (providing reliable supply, good quality product, credit and rewards to his buyers for bringing him new customers).
- **Market watch.** Joe monitors supply and demand situations before planting and harvesting. Because of this, he is able to buy and sell at the right prices, and hence, continue to supply from his farmers, and sustain demand from his buyers.

Joe is apparently doing extremely well, compared to other farmer-marketers. It is also clear that it requires a lot of effort on his part, as well as having a locational advantage, to achieve what he has achieved. However, there are areas that improvements could be made. They include:

- Diversify into higher-value market segments (e.g., hotels, restaurants and supermarkets), with grading and improved packaging.
- Improve business skills to deal with buyers in the formal market sector.
- Build a shed at the depot to protect sweetpotatoes from the elements and unnecessary damage.

- Expand its business, it is probably necessary to synchronise production among his suppliers to ensure consistency in supply all year round.
- Establish new supply networks to expand source of supply beyond his own communities.

### 7.1.5 Overall assessment: a SWOT analysis

In this section, the picture that has been formed of the sweetpotato sector in PNG from the research conducted over the project life is summarised in a 4x4 matrix (Table 6.1). Following the analytical framework of a SWOT analysis, strengths (S) and weaknesses (W) of the sector are derived from an analysis of internal environment (such as physical, human, financial resources and natural environment) and opportunities (O) and threats (T) of the sector are derived from an analysis of external environment (such as social-economic conditions, legal, political and institutional context, markets and competition).

As shown in Table 6.1, the strengths of the sweetpotato sector are the entrepreneurship of its people, an excellent product, and its natural environment (fertile soils and temperate climate). The main weakness is the social and cultural norms and beliefs that inhibit collaboration and better coordination of the supply chain, which are crucial for improving marketing efficiency and quality output. Another main weakness is the lack of information (or misinformation) on the workings of the market and on quality issues. The main opportunity is the projected demand increase from the PNG LNG project and associated economic growth in years to come. However, there is a serious threat from economic and socio-demographical changes that may reduce consumption of sweetpotato in favour of rice and other non-traditional foods.

**Table 6.1. SWOT analysis of sweetpotato supply chain in PNG**

<b>Strengths</b>	<b>Weaknesses</b>
<ul style="list-style-type: none"> <li>• Fertile soils are suitable for agricultural production, including sweetpotato;</li> <li>• Sweetpotato can be grown all year round; no apparent seasonality;</li> <li>• Many varieties to choose from</li> <li>• Consumers prefer highland sweetpotato (over coastal varieties).</li> </ul>	<ul style="list-style-type: none"> <li>• Sweetpotato is low value (per kg) and perishable, and markets are distant;</li> <li>• Poor packaging and postharvest handling, causing skinning and other damage);</li> <li>• Sweetpotato is priced by bags or in heaps (an arbitrary yardstick, does not provide clear price signal);</li> <li>• No quality standards; no price premium, no incentive for improving quality</li> <li>• Lack of business skills: not market-oriented (work for cash needs; irregular supply), no planning, cannot manage money</li> <li>• Lack of information and myths prevail: sweetpotato is strong; product loss is minimal; everything is marketable; middlemen rip farmers off</li> <li>• Social and cultural constraints to collaboration for marketing purposes</li> <li>• DIY: high costs due to diseconomies of scale</li> <li>• Handouts mentality: not proactive in initiating changes; always expect more help;</li> </ul>
<b>Opportunities</b>	<b>Threats</b>
<ul style="list-style-type: none"> <li>• Increased demand as a result of the PNG LNG project;</li> <li>• More local buyers/wholesalers are emerging;</li> <li>• Prevalence of mobile phones (market information; communication with buyers/suppliers);</li> <li>• Microcredit is more readily available (NDB,</li> </ul>	<ul style="list-style-type: none"> <li>• Climate change: weather becomes more variable and unpredictable (too wet or too dry for too long);</li> <li>• Economic and demographical changes do not favour sweetpotato; rich, younger, city, or working people prefer rice, bread and other foods;</li> <li>• Transport services becoming more scarce and</li> </ul>

<p>Nationwide, Alekano, etc);</p> <ul style="list-style-type: none"> <li>• Product differentiation/labelling for highland sweetpotato</li> <li>• Providing food security amidst climate change</li> </ul>	<p>expensive due to demand from the mining sector;</p> <ul style="list-style-type: none"> <li>• Feeder roads deteriorate further;</li> <li>• Labour costs go up (labour shortage and general inflation due to mining boom);</li> <li>• Law and order;</li> <li>• Poor facilities at the open markets (except Hagen)</li> </ul>
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Based on the SWOT analysis, strategic issues and areas for further research are identified as follows:

1. How to improve smallholder marketing? One realisation from the project is that given the stage of economic development in PNG, the sweetpotato marketing system is under-developed and smallholder farmers, as well as other supply chain operators, lack the necessary resources and skills to tackle those problems that are a result of an inherently deficient system. The problems and weaknesses identified in this research are no different from those in many other developing countries. As such, it seems more resources are needed for extension and development activities, in addition to adaptive research based on what have learnt elsewhere.
2. How to encourage adoption of cost reducing and quality enhancing technologies by smallholder farmers and other supply chain operators? Based on field observations and the results from the consignment and packaging trials, it is clear that there is little awareness and knowledge of quality issues and quality control options. Education of growers, wholesalers, transporters, storeroom staff, etc along the supply chain about quality is an important first step towards improving quality outturn through better practices.
3. How to improve marketing infrastructure (grades and standards, roads, market facilities, storage facilities, access to credit, insurance, market information), and what is the role of government and the private sector? A major source of competitiveness in agricultural value chains is access to physical infrastructure to enable produce to move rapidly and efficiently from farmgate to market. For the PNG sweetpotato sector, this means improving infrastructure for transportation and pre- and post-harvest storage, especially for the long distance marketing to Lae and Port Moresby. For women, the priority is to improve market facilities in the local market where they operate. Clearly, there is a role both for central government and the private sector to improve marketing infrastructure. Research is needed to identify the roles they can play, and areas and opportunities for public-private partnerships.
4. How to overcome social and cultural barriers to improve supply chain coordination? Supply chain mapping and consignment and packaging trials clearly suggest that to improve farmers' income and returns of their labour, postharvest management practices and value chain coordination must be improved by smallholder farmers and other supply chain players working collaboratively. However, social dynamics and cultural diversity in PNG offer significant challenges to collective action and the building of trusting, sustainable, business partnerships.

## 7.2 Thematic Area 2: Improving postharvest management: the technical component

The major sub-projects under this theme included a range of trials and surveys as outlined below. The research was focused on consignments of sweetpotato originating in the highland provinces (WHP and EHP) and terminating in the lowland markets of Lae and Port Moresby. The technical reports are presented in their entirety in an annex to this final report.

Sub-project	Activities	Outputs
Supply chain mapping	Mapping physical and technical components of sweetpotato supply chains, and undertaking disease surveys in the Lae and Port Moresby markets	Reports ('Sweetpotato supply chains – where does the damage occur?', and 'Survey of the postharvest diseases of marketed sweetpotato in Papua New Guinea (Lae and Port Moresby)', plus posters, a booklet, and a short video
Postharvest handling trials	Conducting trials with a range of package sizes and materials, and determining the feasibility and effectiveness of sweetpotato curing after harvest	Reports ('Developing alternative packaging options for sweetpotato in PNG', and 'Preliminary evaluation of some postharvest curing methods for kaukau grown in the PNG highlands') and posters
Varietal evaluation	Evaluating sweetpotato varieties for quality attributes and incidence of diseases	Report (Preliminary evaluation of some sweetpotato varieties for quality attributes and storage potential) and poster

### 7.2.1 Supply chain mapping – where is the damage occurring?

This activity tracked several consignments of sweetpotato in several supply chains (Figure 3) to assess instances of quality loss. The activities complemented other mapping activities including interviews and focus groups with supply chain partners, to gain a better understanding of the economic and social components of these chains.

During harvest, collection, and transportation to market in the supply chains studied in detail (Table 1.1), there were many instances where quality loss occurred. Whilst some skinning damage occurred at harvest and during transport to the packaging area, most took place during packing, with 45-83% of roots showing severe skinning following packing (e.g. Table 1.2). This damage was caused not only by over-packing of the bags (80-100+ kg) but also by the way the bags were packed. In contrast, significant damage due to root breakage was more likely to occur on the longer supply chain to Port Moresby, where more loading and unloading operations took place (Table 1.2). In consignments where there were large amounts of root breakage, disease incidence was also high, with 8-54% of roots being badly affected. Reducing impacts during loading and unloading operations through improved handling and packaging would therefore appear to be critical for reducing postharvest losses. Reducing delays in transit is also likely to reduce losses from disease development.

Skinning damage is a major cause of low quality sweetpotato. It results in poor visual appearance and increases in water loss, and hence loss of valuable weight, and it enables the entry of pathogens leading to disease. Packing and packaging are key points of concern.



### Figure 3. Sweetpotato supply chains

**Table 1.1. Supply chains selected for this study**

Supplier Type	Region	Transport Type	End Point
1) Village Entrepreneur	Highlands	Open back truck	Lae
2) Village Entrepreneur	Highlands	Container truck	Lae
3) Village Entrepreneur	Highlands	Container truck	Port Moresby

A number of disease surveys of market sweetpotato were conducted in Lae and Port Moresby during 2008-2010 (e.g. Table 1.3). Postharvest diseases caused losses of 10-14% at the Lae market, and more significantly, 57-78% at the long distant Port Moresby market. Although the disease incidence of surveyed sweetpotato was very high in Port Moresby, the disease severity was moderate-to-low, varying between 10 and 25%. The disease pathogens were visually assessed from their symptomology and morphology, and were identified to genus level. The most frequently occurring fungus diseases were Rhizopus soft rot caused by *Rhizopus spp.*, dry rot caused by *Fusarium spp.*, Java black rot caused by *Lasiodiplodia theobromae*, and scurf caused by *Monilochaetes infuscans*. *Penicillium spp.* were also often present as secondary infections. The main bacterial disease was soft rot caused by *Erwinia* (now *Pectobacterium*) *spp.*

**Table 1.2. Root damage (total score and percent roots with severe damage) for kaukau transported by container truck from the Highlands to Port Moresby**

Root damage	Consignment Number	Stage in marketing chain			
		Harvest	Collection point	Transport point	Port Moresby
Broken roots (max 200)	7	9 (4)	4 (1)	10 (2)	19 (9)
	8	13 (3)		6 (0.6)	54 (29)
	9	0 (0)	0 (0)		126 (64)
Skinning	7	44 (2)	67 (20)	109 (62)	112 (57)

(max 200)	8	43 (6)		91 (45)	151 (75)
	9	0 (0)	17 (0)		153 (84)
Cuts (max 80)	7	19 (14)	14 (11)	18 (12)	16 (6)
	8	9 (4)		14 (9)	15 (13)
	9	0 (0)	0 (0)		43 (34)
Disease (max 160)	7	0	0	0	0.4 (0)
	8	0		0	19 (8)
	9	0	0		102 (54)

Values represent the mean for each consignment (4 bags). Value in brackets is the percentage of roots with severe damage (a score of 3 or greater for broken roots, skinning, and disease, and a score of 2 or greater for cuts).

**Table 1.3. Assessment dates, location and number of kaukau roots assessed at each assessment during 2009-2011**

Date	Surveyed location	Number of total roots assessed	Disease incidence (%)
15.09.2009	Port Moresby markets	<sup>a</sup> 797	22
28.05.2010	Port Moresby markets	<sup>a</sup> <sup>a</sup> 1070	41
4.12.2010	Port Moresby markets	1246	62
2.2.2010	Lae markets	1321	5
14.4.2011	Lae markets	1348	74

*<sup>a</sup>The results reflect the assessment of only 3 bags of kaukau out of 5. The kaukau roots in the two unassessed bags were fully damaged due to rotting and unable to be assessed for disease incidence and disease severity index calculation and pathogen identification.*

*<sup>a</sup>The results reflect the assessment of only 4 bags of kaukau out of 5. The kaukau roots in the unassessed bag were fully damaged due to rotting and unable to be assessed for disease incidence, disease severity index calculation, and pathogen identification.*

## 7.2.2 Postharvest handling – packaging options and curing

Results from the consignment trials were presented at stakeholder workshops in February 2009 and June 2010. The damage to the sweetpotatoes were obvious, and stakeholders identified packaging as a priority research area, but curing may also help reduce damage.

Several packaging materials were used to assess the impact that they had on outturn of sweetpotatoes at the Port Moresby market. The results clearly showed that incidences of broken roots and skinning were significantly reduced when smaller and solid-walled containers were used (Table 2.1). Crates afforded best protection against broken roots (mean score: 6.6/100), followed by cartons (7.9) and 25 kg bags (9.4). The control 100 kg bags scored 15.4. Skinning was also reduced by using crates (mean score: 72.1/100), with cartons scoring 74 and the control 84.8. The crate and carton effects on skinning were statistically significant ( $P < 0.05$ ) but these differences may not be so important in practical terms. This may mean that movement within the containers during loading/unloading and transport contributes to skin damage that starts at the harvest and initial bagging. The incidence of cuts was not consistent, perhaps because most of these occur at harvest. Disease scores were not significantly influenced by packaging type. In addition to reducing damage, smaller containers are much easier to handle by workers.

**Table 2.1. Effect of packaging treatment on the level of sweetpotato damage**

Packaging Treatment	Broken Roots (Score/100)	Skinning (Score/100)	Cuts (Score/100)	Disease (Score/100)
Control – 100 kg bag	15.43	84.84	10.46	37.52
100 kg bag, packed less with ventilation holes	11.74	87.23	12.36	41.19
Coffee bag with ventilation holes	11.60	90.82	12.29	23.65

25 kg bag with ventilation holes	9.44	86.26	14.61	15.44
Carton	7.90	73.98	12.70	18.80
Crate	6.63	72.13	6.05	21.36
LSD (for any comparisons with treatment 2)	4.342	11.42		
LSD (for all other comparisons)	3.976	10.46		
P	0.004	0.008	Ns	Ns

High temperature (30 °C) and high RH (86-96%), conditions suitable for curing sweetpotato over 5-7 days, were maintained in a decommissioned cool room at the Mt Hagan markets, and in an on-farm in-ground pit sealed with topsoil. The pit idea was to test simple low technology methods for farmers to improve the resilience of their sweetpotato roots during postharvest handling. Suitable soil temperatures are needed to ensure high temperatures are maintained in the in-ground pit.

The high temperature curing treatment prevented the incidence of *Fusarium* spp. (Table 2.2), a most important cause of postharvest spoilage in the Port Moresby markets. However, *Fusarium* was prevalent in the in-ground pit where moisture inadvertently seeped in from the sub-soil. Fresh weight loss was still too high following the curing treatments, but a complication was the incidence of vermin damage that also resulted in some mass loss, and secondary *Penicillium* spp. infection.

Low technology facilities at the markets and modified in-ground pits, could be combined with field management (top removal) to improve skin resilience and further contribute to increased sweetpotato quality at the markets. These data reinforce the view that changes in packaging must be accompanied by changes in handling practises if the quality of sweetpotato at the Port Moresby market is to improve.

**Table 2.2. Incidence of *Fusarium* spp. in two varieties of kaukau following curing (8 d) and ambient storage (12 d)**

Treatment	Incidence of <i>Fusarium</i> spp. (%)	
	'Korowest'	'Rachel'
High temperature	0	0
Ambient temperature	5.7 ± 2.1	10.6 ± 2.8
In-ground pit	25.0 ± 3.9	7.3 ± 2.3

### 7.2.3 Varietal Evaluation

The final major activity in this section was the evaluation of sweetpotato varieties. Farmers are always keen to know what the best variety to plant and sell, so several varieties were sourced from farms and assessed for quality attributes and disease incidence. Attributes measured included fresh weight loss, internal and external disease incidence, cortex thickness, latex production, total soluble solids content, peel and flesh colour, and sprouting. Several varieties (Trimun, Wanmun, Wahgi Besta, Gimane, Kerot (sometimes written as Carot)) were evaluated over a 4 week period in October 2008, 2 varieties (Okapa and Kiau) were assessed for 1 week in November 2008, and 3 varieties (Marasonda, Wanmun, and Wahgi Besta) were assessed over 4 weeks in July 2011. There were a range of technical problems that beset these trials, including variable storage conditions, and variable disease pressures. As a result, it was not possible to nominate a 'winner'. However, most of the varieties performed as expected in most of the assessments (they were established market varieties after all), although the attributes were not always consistent. The trials pointed to the need to assess storage and quality in a uniform manner and in the absence of disease pressure. Resistance to disease can be studied with controlled inoculations. Most of this research should appropriately be undertaken within the breeding program prior to release.

This dilemma (of being unable to pick a winner) prompted the writing of an article for Stewart Postharvest Reviews (Irving et al. 2011) where we expressed the view that PNG is well endowed with sweetpotato germplasm, and although new varieties will continue to be necessary for future industry development, at the present time, transport, storage, and market infrastructure are far more pressing issues for the PNG sweetpotato industry.

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### **7.3 Thematic Area 3: Improving value addition**

The one sub-project under this theme included a review of sweetpotato processing options, an evaluation of the training methods of a rural trainer (Sr Louisa Miugle), a sweetpotato village fair in Minj (near Mt Hagan) where locals and NARI staff showcased their processed sweetpotato products, and a processing training session that emerged from the food fair. There were a range of activities undertaken, and the full reports are presented in their entirety in an annex to this final report ('Improving value addition of sweetpotato in Papua New Guinea: a literature review', 'Evaluation of Sister Louisa's training program', 'The Mt Hagan (Minj) Food Fair 2011', and 'Sweetpotato marketing and processing project: organising training of trainers on sweetpotato value addition processing Minj, Anglimp South District, Jiwaka province, 12-14 April 2011').

#### **1 Appraisal of household and village processing options**

Processing options for sweetpotato were appraised in a review of the literature. Various processed products are possible for domestic household manufacture and use, including noodles, sauces, cakes, buns, and bread. The main constraints to use of sweetpotato for processing are the chipping, drying and milling into flour. In addition, the flour does not contain the dough strengthening proteins that wheat has. Access to equipment and costs of purchase, operation, and maintenance must be addressed before wider scale adoption of processing is possible in rural communities. Most families do not have the time and inclination to manually slice, dry, and mill sweetpotato when imported rice and wheat products are becoming increasingly available and affordable.

Sr Louisa Miugle provides village level training as a way of increasing social cohesion, employment, and use of sweetpotato in rural villages. Her training program was evaluated over three days with focus groups of her trainees to see what had worked and what had not, and to identify areas where the present project could contribute.

#### **2 Sweetpotato fair**

The Sweetpotato Fair was held in the village of Minj on 3 February 2011 to showcase products which could be made with sweetpotato and to see which of them were more acceptable to fair participants. The latter results were used to devise a training program for sweetpotato processing training in April. The event was well-publicised and attracted more than 1000 people. Some came from as far as Chimbu and Enga Provinces. The success of the day may mean it could become an annual event for the community.

The Fair had a number of components: speeches from local governments and village dignitaries, information sessions organised by FPDA, NARI and farmers and extension officers involved in various ACIAR research projects on sweetpotato, taste panel for six sweetpotato products developed by NARI, and a competition with prizes for the best local sweetpotato products. The Fair was a community event as well as a venue to promote outputs and outcomes from ACIAR-funded projects.

Due to Lilly Be'soer's excellent organisational and networking skills, an awareness campaign was carried out a week prior to the fair through two Radio Broadcasting Stations operated by the Catholic Mission, the Western Highlands Provincial Eagle FM and the Radio Light FM. In addition, Mr Jim Umin, Chairman for the South Wahgi Peace Mediation Committee informed the public daily about the event using the Public Announcement system. Flyers were also put up in all major venues such as the markets,

trade stores, and schools, and were given to community leaders and councillors to take to their communities to inform their people about the event. Invitation letters were distributed to community-based organizations, churches and leaders of the province informing them about the event as well asking them to get involved.

A number of key people attended the event and were impressed with what they saw. Among the guests was the Director of the Jiwaka Transitional Authority, Mr Nicolas Kuman, the Deputy Chairman of the Jiwaka Transitional Authority, Mr Roger Palme, the South Wahgi District Administrator, Mr Kimin Gokumi, other public servants from the South Wahgi District Office, the Minj District police officers, teachers and village leaders such as magistrates, councillors and peace officer. The Deputy Chairman of the Jiwaka Transitional Authority, Mr Roger Palme in his key note speech indicated strongly of his government's interest to develop agriculture in Jiwaka Province. He was impressed with the outcome of the show and thanked NARI, FPDA, RWDI and ACIAR for taking the initiative to organize such a successful event focusing on the main staple food (sweetpotato) for the highlands region. In his speech, he encouraged the people of Jiwaka to work closely with NARI and FPDA to develop their land. He indicated his government was committed to agricultural development as priority number one. The new government will work with people who are working on their land. He called for such a show to be hosted bi-annually.

On the day, a total of 18 groups took part in the Sweetpotato Fair and showcased their sweetpotato products. Eleven were Sr. Lousia's groups that were trained in general food processing. The products displayed were all made from sweetpotato, some mixed with other ingredients such as flour, banana, cassava, yeast, sugar, eggs and some artificial colourings. The products displayed included buns, bread, thick and thin chips, pies, stock feed, pancakes, biscuits, crackers, sweetpotato balls, and sweetpotato juice. All of these products were made by hand using simple village level technology, e.g. baking was done in 44-gallon drums and using firewood as a source of heat.

A lot of information and brochures related to sweetpotato were also made available to the public at the Fair by our team from NARI and FPDA and extension workers and farmers who have participated in sweetpotato-related ACIAR projects. For example, Mr Joseph Kuru and his group of farmers, who have been involved in the ACIAR sweetpotato soil fertility project, showcased good quality sweetpotato roots, and demonstrated how improving soil fertility can increase the yields of sweetpotato. Ms Agnes Jonah, a village extension worker with FPDA, and her group of farmers displayed and distributed pathogen-tested (PT) planting materials and relevant information to interested public. Ms Roselyn Walep, an extension worker with the Rural Women's Development Initiative, and her team displayed stock feed made from sweetpotato and silage, as well as roots harvested from the soil improvement project, and sweetpotato products (cakes, buns, and chips). One significant achievement of the Sweetpotato Fair was that it brought all stakeholders together informally, but it was able to disseminate information most effectively. Indeed, not only did the Sweetpotato Fair provide an opportunity for farmers to hear and learn about research being conducted on sweetpotato through ACIAR projects, it provided an opportunity to link and integrate ACIAR projects in production with our project in marketing, post-harvest and value addition of sweetpotato.

### **3 Sweetpotato processing training workshop**

Training needs were identified through an assessment of sweetpotato training programs to determine what further support or training was required in August 2010. An evaluation of sweetpotato product preferences for possible adoption was conducted at the Sweetpotato Fair in Minj, in February 2011. The three day training course on sweetpotato processing was attended by 15 participants, including four males. The training included some theory, but it was participatory and involved lots of hands-on experience making crispy chips, muffins, strips, cakes, buns, flour balls, pancakes, and juice. The sessions also covered food storage and handling, personal hygiene, and health issues. The workshop was completed with an evaluation of expectations and achievements. Several

recommendations emerged from the workshop that would improve further offerings, and they included better equipment and access to resources and support.

## 7.4 Thematic Area 4: The Australian component: alternative control options for controlling rots and sprouting

There was a considerable delay in appointing a researcher to conduct this research, and as a result, research objective did not advance as far as intended. The major sub-projects under this theme included a range of trials and surveys as outlined below. The research was focused on postharvest diseases and sprouting of Irish potato, a crop of interest to the Australian potato industry. The research reports are presented in their entirety in an annex to this final report.

Sub-project	Activities	Outputs
Australian industry consultation	Interviews with NSW potato growers to assess the major industry problems	Report ('The Australian Potato Industry – stakeholder consultation')
Evaluating essential oils from native plants for their disease control potential <i>in vitro</i>	Conducting experiments with essential oils in the laboratory using plant-pathogenic fungal and bacterial cultures	Report ('In vitro screening of alternative control options for dry and soft rot diseases of potatoes') plus scientific articles
Evaluating essential oils from native plants for their disease control and sprout-inhibiting potential <i>in vivo</i>	Conducting experiments with essential oils for their ability to inhibit postharvest fungal and bacterial diseases, and sprouting, when applied to stored potatoes	Report ('Summary of in vivo screening of alternative control options for dry and soft rot diseases, and sprouting of potatoes')

### 1 Australian industry consultation

The Australian potato crop is grown by a small number of farmers owning large tracts of land. Although the end-use of the produce varies from state to state, farming practices and quality issues are uniform across the country. For this reason, the NSW Riverina district growers were chosen as representatives of Australian potato growers, to be interviewed to identify where major losses were occurring, and where modifications to current supply chain practices may lead to improvements in quality outturn through better management of these diseases. Although a participatory approach was intended for the program, the small numbers of farmers involved meant that interviews were more appropriate. The interviews revealed that the fresh potato market has declined but that the processing industry has remained stable, exports were minimal (about 7%), mainly to South East Asia and South Korea, the bacterium *Erwinia* (now *Pectobacterium*) seed-piece breakdown was a major production issue, all growers sent potatoes to the market/processor within 24-48 hours of harvest, and that *Erwinia* soft rot and sprouting are the major postharvest issues. The program was subsequently expanded to investigate the efficacy of possible alternative control treatments (Australian essential oils) on diseases and sprouting in potatoes.

### 2 Evaluating Australian essential oils – *in vivo* experiments

Increasing concentrations of carvone alone (1.5-3.5%) for *F. solani* and 0.5-3.5% for *F. oxysporum* significantly ( $P < 0.05$ ), and incrementally, reduced culture growth when compared with the control over 6 d (over 40% reduction with 3-3.5% for both fungi). Spore germination was inhibited at concentrations of 1.5% or higher (*F. solani*) or for all concentrations (*F. oxysporum*), but 90-94% and 82-90% respectively, of spores still germinated. When oil combinations included carvone, and especially LM+TTO+AM, there was a significant reduction in culture growth (17-33% for *F. solani*, and 24-44% for *F. oxysporum*). Spore germination was also reduced, but only to a maximum of 3% below the control.

All treatments of oils and combinations at 2%, except aniseed myrtle (AM), inhibited growth of the bacterium isolate *P. carotovorum ssp. carotovorum*. At this stage, the inhibition is recorded qualitatively. Where aniseed myrtle was used in combination with other oils, it had a negative, or antagonistic effect on pathogen inhibition, whilst lemon myrtle combined with tea tree oil had a synergistic or complementary effect. Based on these results, further investigations used lemon myrtle, tea tree oil, carvone, LM+TTO, and TTO+carvone as treatments for growth control of *P. carotovorum ssp. carotovorum*. Whilst other treatments were able to inhibit growth to a similar level, it was decided that the combinations were not sufficiently effective enough compared to the single oil treatments to be economically viable as a commercial treatment. LM and LM+TTO treatments provided the greatest control over *P. carotovorum ssp. carotovorum* of the treatments tested. LM at 1.5%, or LM+TTO at 2.0% each give similarly effective control as higher concentrations of these treatments, and so are the most feasible treatments of all tested for control of *P. carotovorum ssp. carotovorum*. Concentrations near 3.0% are required for TTO, TTO+carvone, and carvone treatments to achieve similar levels of control to low concentrations of LM or LM+TTO, reducing their economic viability as a commercial treatment.

Peak concentrations of volatiles in culture dishes were found over the 7 days after application of lemon myrtle oil. Neral and geraniol components of LM oil peaked at 45 ppm on day 4, then decayed, indicating that repeated applications will be necessary for a postharvest treatment. Lower concentrations (30 ppm) were found when the pathogen (*F. solani*) was present. The tea tree oil component terpen-4-ol volatilised slowly until a peak of 120-160 ppm was obtained. This remained steady for 7 days, but, in contrast,  $\Omega$ -terpinene accumulated immediately (3400 ppm) and then decayed. Concentrations of all major oil components did not individually or in sum reach the concentrations theoretically applied (20,000 ppm or 2%), indicating that effective activity against the pathogens was occurring at very low concentrations. In summary, for the fungi *F. solani* and *F. oxysporum*, inhibition of spore germination is not likely to be a mechanism for control by the essential oils tested. Mycelial growth was inhibited by around 30-40%, and this level of growth inhibition together with the observations on inhibition of the bacterium *P. carotovorum ssp. carotovorum*, are encouraging enough for the oils to be used in *in vivo* tests on Irish potatoes. Nevertheless, it is proving to be difficult to ensure suitably high concentrations of volatile ingredients can be supplied in the treatments.

### **3 Evaluating Australian essential oils – in vitro experiments**

The *in vivo* trials to assess the efficacy of selected biocontrols and essential oils against *P. carotovorum ssp. carotovorum* and *Fusarium* rots on potatoes have established that some of the selected alternative control options have potential to commercially control postharvest losses of potatoes. Selected treatments were able to significantly reduce sprouting, but dry rot development was able to be only minimally affected for one of the tested pathogens. As very little research has looked at alternative control options for postharvest potato diseases and breakdown, and particularly the use of Australian essential oils, these are important findings.

Both *Fusarium solani* and *Fusarium oxysporum* were able to cause dry rot to develop in the *in vivo* setting. Thiabendazole, the industry standard postharvest fungicide treatment, was unable to cause a reduction in disease development, except for lesion width at week 7 for *F. oxysporum*. BioSave was also unable to reduce disease development in inoculated potatoes compared to the control sample, despite being registered for control of dry rot in the U.S. The lack of disease control exhibited by the Thiabendazole and BioSave treatments suggests an inability of these two products to treat wounds penetrating into the flesh of the tuber, and may contribute to pesticide resistance issues for Thiabendazole – particularly when used in seed potato. The lack of control could also be an effect of the high inoculation load each tuber was subjected to - this high inoculation load was required to guarantee infection within the experiment for assessment. It is a real

possibility for BioSave, and expected for Thiabendazole that significant levels of control would be seen in more natural infection loads.

Although carvone was able to inhibit the *in vitro* mycelial growth of *F. solani* and *F. oxysporum* by 32% and 47% respectively, no significant effect was seen on disease development *in vivo*. Again, this could be an inoculation load issue, or it could be a penetration issue relating to parameters such as hydrophobicity of the essential oil components affecting absorption through the tuber, and/or volatilisation rate being decreased at the tested temperatures. There are variations in susceptibility across species of *Fusarium*. This same susceptibility difference was noted for the lemon myrtle treatment - disease lesion length was able to be significantly reduced for *F. oxysporum* at 7 weeks, but for *F. solani*, an increase in lesion width was observed. Again, this is despite significant effective control in the *in vitro* experiments. Based on these results, the tested alternative control options can neither be discounted nor confidently recommended for dry rot disease control in potatoes. Further research into pathogen species susceptibility, reduced pathogen load, and treatment penetration through the wound site is required.

Thiabendazole was effective in controlling *Pectobacterium carotovorum* subspecies *carotovorum* in potato tubers if applied at the recommended label dosage. The biopesticide BioSave and the essential oils did control the growth of *Pectobacterium carotovorum* subspecies *carotovorum* in potato tubers. In the inoculated tubers, disease development occurred following wounding, and disease development remained moderate following fumigation. These results provide an indication that essential oil fumigation is more protectant rather than curative. The use of biological control is being explored worldwide, but much more needs to be done before the scientific community can definitively say how successful it will be.

In the preliminary assessments (Experiments 1 and 2), it became evident that neither Thiabendazole nor BioSave had any effect on sprout production. However, carvone and lemon myrtle essential oil showed significant promise in controlling sprout numbers. Carvone completely inhibited sprouting in one preliminary trial, while lemon myrtle essential oil significantly reduced the number of tubers expressing sprouts, and the number of sprouts present on the remaining tubers. Whilst the anti-sprouting effects of carvone are known (Hartmans *et al.* (1995), Baydar and Karadogan (2003/4), Eshel *et al.* (2009), Elsadr and Waterer (2006)), this is the first study to our knowledge which demonstrates the anti-sprouting effects of lemon myrtle essential oil. Subsequent testing (Experiment 4) confirmed the potential to control sprouting parameters at reduced rates, although the rates tested were too low to cause complete inhibition. The ideal rate therefore remains between 8,000 - 20,000 ppm. As the afore-mentioned researchers have already established the application dosage range for carvone (approx. 100 mL/tonne in the first application, then 30-50 mL/t each 6 weeks thereafter), optimum application rates need only be further refined for the lemon myrtle essential oil treatment. Equally importantly, when sprouting had already been initiated, both treatments were able to destroy the growing shoot, thereby reducing the total number of sprouts. This provides an invaluable tool for the potato farmer and marketer. Eshel *et al.* (2009) also observed damage to the developing sprouts after treatment with spearmint oil. The results also showed that potato variety has an effect on the efficacy of the treatment. This may well require further research before commercial use commences.

Based on these results, the tested alternative control options, carvone and lemon myrtle essential oil are recommended for development as sprout inhibitors for the Australian potato industry.

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## 8 Impacts

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### 8.1 Scientific impacts – now and in 5 years

One of the strengths of this project was its multidisciplinary approach, bringing together economic and biophysical scientists. This was particularly apparent in the supply chain mapping undertaken in Year 1 where the technical team (led by Suzie Newman) and the economics team (led by John Spriggs) worked together to determine the best approach to understand all aspects (social, economic and technical) of the sweetpotato supply chain in PNG. The supply chain mapping was an important first step in our approach to participatory action research (PAR). To the extent that it was successful, it provided further support of PAR as a successful tool for development research. Bringing the two teams together in this way had led to a more thorough analysis of the sweetpotato supply chain. Through the exchange of ideas and perspectives it had also resulted in greater appreciation of each other's disciplines and the benefits that each could bring to the table. Results from the mapping of the sweetpotato supply chain were well-received by all participants at the stakeholder workshop held in February 2009 and hence provided a good foundation for our work in year 2. Subsequent stakeholder workshops also produced excellent outcomes in terms of identifying priority issues and implementing locally appropriate intervention strategies.

The sweetpotato disease surveys have also provided insight into the importance of different postharvest pathogens. Information gained on this project will not only be useful in developing effective control strategies for postharvest diseases in sweetpotato, but will also enable PNG researchers to design control strategies to manage postharvest diseases in other crops.

Cost and price analysis for sweetpotato, which has never been done before because of lack of capacity in economic analysis, contributed significantly to better understanding of sweetpotato market, and it elucidated how farmers returns could be improved. It has brought to light the need to improve the methods by which data are collected, stored, retrieved and analysed, and to build capacity in economic and policy analysis, especially in FPDA.

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### 8.2 Capacity impacts – now and in 5 years

This project has a significant capacity building component, including research training of a PhD student, two postgraduates, and the training of PNG project team members in survey methods, postharvest management, and disease surveys.

PNG members of the economic research team received instructions from John Spriggs on how to conduct semi-structured interviews and focus groups, how to prepare and give PowerPoint presentations, and how to write reports. Training was also provided by Suzie Newman on postharvest physiology, and how to conduct consignment trials using data loggers and other instruments. During womens focus groups, gender training was provided by Lilly Be'Soer and Cathy Wali, to highlight inequality in income distribution and division of labour and ways for women to speak out for themselves. Team members and stakeholders also learned about participatory action research and consensus decision-making from taking part in the planning and stakeholder workshops.

We were also involved in the ACIAR scholarship programs and NARI's cadet program, and helped with economics training. In particular, Norah Omot, funded by a John Allwright Scholarship, completed her PhD research on understanding consumer preference for sweetpotato in March 2011, under the supervision of Christie Chang and John Spriggs from the University of Canberra. We were also involved in NARI's cadet program with Eleo Dowa and the ACIAR Postgraduate Scholarships program with Mr Leonard Kipi at

Unitech. Eleo submitted his report in November 2010 and Leonard graduated in April 2010. The training on survey methods in June 2009 also included an undergraduate student from Vudal University who was doing his professional experience at FPDA at the time. Thomas helped with the farmer survey on credit issues and presented the results at the stakeholder workshop in November 2009. He graduated from Vudal in December 2009. During the project review workshop in March 2011, extension officers from FPDA expressed the view that they appreciated the experience of organising farmers groups and linking them to credit providers and the immediate impact on farmers' income.

On the technical side, much of the emphasis of the pathology component of this project had been on capacity building. This has been achieved through training and study tours. A Disease Survey Training was held in Port Moresby, 14th – 16th September 2009 for both research and extension personnel at NARI and FPDA (16 officers attended the training). In it, Dr Lazar-Baker covered both theoretical and practical aspects, with the major emphasis being on giving the team the skills to recognise particular disease symptoms in the field (a disease assessment key was provided to assist with this). Hands-on training was also provided in how to undertake the disease survey (assessing disease severity and taking samples for identification).

A Plant Pathology Training session was held in Lae on 17–21 September, 2009. It provided a more in-depth training in plant pathology. The first two days of the training were allocated to lectures on fundamental principles of plant pathology for agricultural producers, and sweetpotato diseases in PNG. The remaining three days of training were laboratory or field based. The laboratory training was conducted in the microbiology laboratory at the University of Technology, Lae, while the postharvest trials were undertaken at NARI. The training covered basic microbial techniques such as making agar plates, general aseptic techniques, inoculating plates with the primary culture, and sub-culturing of pathogens, and also they improved their skills in using the autoclave, the biological safety cabinet, and the microscope. The postharvest/field work component focussed on putting their skills into practice, with further re-enforcements and opportunities to practice what they had learned during the disease survey training.

A group of PNG team members visit Australia for a study tour during 29 November – 3 December 2010 under the guidance of Dr Donald Irving. The tour focused on seeing best practise crop production, harvest, grading, packaging, cooling, transportation, and marketing of fresh produce and sweetpotato. The information and impressions gained will help the members implement the essential elements of good postharvest handling of sweetpotato in PNG.

It is anticipated the relationships established within the project will be used in future to assist extension staff and researchers to improve their knowledge and skills in research methodologies.

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### **8.3 Community impacts – now and in 5 years**

The project started making its impact as soon as it was started, with the planning workshop in February 2008 and during the supply chain mapping. On both occasions, project team members visited many communities, talked to many farmers, and explained to them how this project could help remove some of the constraints they faced in marketing sweetpotato. Key issues were to reduce marketing costs and product losses, and to show the immediate benefits they stood to gain from supporting and participating in the project.

Two of the project activities that had an immediate impact on the communities was the provision of financial literacy training to women's and farmers groups, and linking them to credit providers. We began this activity in November 2010. Since then, five groups (with 30-50 members in each group) have taken out loans with the National Development Bank.

With an initial loan of K1000 for each member, many of them were able to increase their vegetable production and make significant profits in 3-4 months (the returns could be as high as 200-300% amidst increased demand for high quality vegetables). This was a significant outcome, because vegetable farmers had until now not had the opportunities to borrow because they were considered high risk and high cost. However, things have changed (it is a “breakthrough” as one team member put it). It is well-documented in development literature that access to credit is one major constraint for resource-poor smallholders to improving farm productivity and access to markets. With credit, they can hire extra labour, purchase high-quality inputs (seeds, fertilisers, packaging materials), invest in labour-saving technology, and pay for transport. This is exactly what has happened. FPDA has played a significant role, and will continue the work as part of FPDA’s work plan. In fact, since early 2011, FPDA has taken the initiative to provide basic financial literacy training to farmers groups as a pre-requisite for linking them to microfinance providers. The training ensures farmers not only make money, but also manage their earned money more wisely.

As the demand for fresh produce will continue to increase substantially in the next few years, especially as a result of the PNG LNG project, the timing of this project activity could not have been better in terms of setting farmers up to respond to demand increase. Significant economic and social impacts are expected in years to come, especially if suggested changes to postharvest management (cooling, curing, and packaging) are implemented.

The other area we had made a significant impact was the work on costs of marketing and linking farmers to local buyers. In June 2009, Wayne, a local sweetpotato buyer, was kind enough to talk to our workshop participants about his costs of marketing from Kasena to Port Moresby. The presentation was well received because it was the first time farmers were given a detailed account of marketing costs, something they had been wanting to know. It helped a lot in clarifying the myth of the role of middleman in marketing. The data from Wayne had since been made into a template and used to show the different costs of going to Goroka, Lae, and Port Moresby. The analysis showed that the breakeven prices were close to 140 Kina/bag for Port Moresby, 60 Kina/bag for Lae, and 25 Kina/bag in the village. Since then, we have shared the results with as many farmers as possible, and the template has been used by FPDA in its VEW training programs.

An excellent outcome is that fewer farmers are venturing down to Lae or Port Moresby without thinking about the costs and risks of doing so. We believe that the middleman, or wholesaler, is the key to improving marketing efficiency in the sweetpotato supply chain. When sweetpotato and other fresh produce are consolidated through local buyers or wholesalers, it avoids multiple handling and hence physical damage to produce, as well as reducing high transaction costs due to diseconomies of scale of marketing in small lots. The real challenges now are to identify and train local entrepreneurs to be professional marketers, and to convince smallholder farmers to trust them.

A kaukau fair was held in February 2011 in Minj where NARI and the locals showcased their processed sweetpotato products and prizes were awarded to those products judged by a panel to be the best. In addition, the event was used to disseminate information on all things sweetpotato, including other ACIAR projects on PT planting materials, soil improvement, etc. The event was strongly supported by local government officials and communities, and drew a huge crowd. The success of the day may mean that it could become an annual event, and if well-coordinated, could be used as a venue for disseminating information on ACIAR projects and gaining recognition for ACIAR’s contribution to PNG agriculture.

### **8.3.1 Economic impacts**

Marketing cost analysis and linking farmers to credit have already had a positive impact on farmers’ returns. From the supply chain mapping and subsequent curing and packaging trials and diseases identification, it is clear that substantial reductions in

skinning, cuts and breaks, and resulting disease incidents, could be achieved if recommended changes (reducing the size of current bags, using cartons or crates instead of large polyethylene bags) could be extended to more farmers. Due to time limitations and staff shortages, we did not have time to do much extension on the ground. However, useful extension materials have been produced and passed on to FPDA and NARI for their own use. We are confident that there would be measurable economic benefits from improved postharvest practices within 5 years.

### **8.3.2 Social impacts**

One of the objectives of the project was to improve women's participation in the sweetpotato supply chain. To achieve that, we have kept in constant contact with women's groups in Minj, through workshops and informal meetings, with the help from our collaborator Lilly Be'Soer. At those meetings, we tried to teach women some basic skills in marketing, as well as discussing gender issues. For example, we talked about the costs of selling to different markets, how to avoid low prices and take advantage of high prices, what to grow, when to go to the market, the ideal selling spots, and how to protect and promote their produce at the market (bring small change, greet customers, be friendly, offer volume discounts, etc). According to Lilly Be'Soer, women are taking note and have put some ideas into practice. Importantly, women have talked to one another to avoid going to the market at the same time with the same produce. They also tried to get to the market early when there would be fewer sellers, and hence less competition. This is not rocket science, but every little idea seems to be helpful to some in some way. And it is most rewarding.

Lilly's group in Minj has formed a savings group whereby members put their small earnings regularly into a joint bank account at ANZ Bank and they can borrow from it. The group has received two financial literacy training sessions facilitated by this project. The savings and loan facilities, along with the financial literacy training it received, have motivated women and helped build their confidence in taking on a number of income-generating activities. Some women have increased their incomes and are able to meet their daily needs. In general terms, women in the areas have been empowered, and are more hopeful and optimistic about their future.

### **8.3.3 Environmental impacts**

There are no significant environmental impacts from the PNG component of the project because the focus is on marketing and postharvest management, not on-farm production. If packaging recommendations were adopted, systems for recycling fibre board or crates would need to be implemented to reduce the accumulation of waste. For the Australian component, the use of essential oils such as lemon myrtle, tea tree oil, and soft chemicals for control of postharvest diseases, would have some positive impact on the environment and personal health.

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## **8.4 Communication and dissemination activities**

Because of the very nature of participatory action research (participation, collaboration, empowerment, capacity building, and socio-economic change), most research and development activities conducted in this project involved, to varying degrees, the stakeholders (policymakers, researchers, farmers, marketers, and consumers) mapping the marketing system to identify key issues, develop strategies, and engage in the change process. This means that communication and dissemination are concurrent with research and development, and continue throughout the project. Through their involvement in the planning and stakeholder workshops and the supply chain mapping activities, key stakeholders along the sweetpotato supply chain (farmers/marketers, transporters, institutional buyers and wholesalers) were well aware of our project activities and the potential (and some immediate) benefits to them. During our various field visits to farms and villages, we took every opportunity to inform the farmers and villagers about what we

were doing ,and voiced our views on, for example, quality issues. We also had strong support from community leaders, such as Dot Kawagla, Lilly Be'Soer and Wayne Gorowe, who have been informing farmers in their villages about our work.

Our project activities and results have also been publicised through stakeholder workshops, research reports, FPDA and NARI newsletters and field days, and PNG newspapers, as well as at the kaukau fair in Minj which attracted nearly 1000 people. To reach more stakeholders, extension materials in various forms have been prepared and will be passed on to FPDA and NARI for extension and dissemination. Some of our publications so far are listed in Section10.2 of this report, and there will be more in coming months. We also plan to convert our research reports into publications.

On the Australian side, the earlier farmer survey has led to considerable interest in the project. In addition the inclusion of two I&I NSW extension staff on the project team, Mr Tony Napier and Mr David Troidahl, has ensured that the project maintains a relatively high profile in the farming community. These links will pave the way for future engagement with the industry.

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## 9 Conclusions and recommendations

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### 9.1 Conclusions

During the life of the project, we have done a lot and have also learnt a lot. The main lessons learned are:

**On Methodology.** Participatory action research is a useful tool for user-oriented research and development projects. However, we found that a year-long research-plan-action cycle, although appropriate for a general review, was too long for many of our sub-projects, which would benefit from having their own smaller planning cycles. In addition, we learnt that although it is important to focus on issues that are important to stakeholders (e.g., access to credit, costs, and returns), there is also a need to make sure that strategic issues, for example institutional innovations in grading schemes, pricing mechanism and market information system, are also addressed because of their longer-term impacts on the competitiveness of the industry.

**On supply chain coordination.** The market analysis clearly showed that it was very costly for individual farmers to take on long distance marketing on their own and there is little profit in it. One viable alternative is to sell to local buyers. Local buyers and wholesalers, being the link and intermediaries between farmers and customers, appear well-suited to be chain leaders who can play a key role in consolidating produce, as well as exerting influence on grading, quality control, and appropriate postharvest management. However, distrust between farmers and middlemen and resellers must be resolved to promote such a new business model. More research is needed to see how a wholesale model can work in the PNG context.

**On women's issues.** Women face additional marketing issues that are gender-specific as a result of their social status and marginalization in PNG society. We are most concerned about the problems of local transport and poor facilities at the open market where women make their living. More research can be afforded to local marketing for women, in addition to long distance marketing for men.

**On variety preference.** Both PNG consumers and farmers are passionate about their sweetpotatoes and have strong preferences for some particular varieties and physical characteristics. However, there appears a gap between what consumers prefer and what is supplied. Better understanding of consumer preferences will help strengthening suppliers' responsiveness to meet consumer demand and hence to increase sales.

**On quality.** It seems from the suppliers' point of view, product losses are "minimal" (between 0-5%) because "everything gets sold". This is different from our research which indicated product losses were significant, especially in terms of skinning and breakage. Consumers also found quality to be an issue. Without a grading scheme to separate what is marketable and what is not, and what is good quality and what is not, there would be little interest in quality issues and little incentive to improve postharvest management.

**On project administration.** One serious problem that we encountered was frequent staff turnover and loss of project staff. At the end of the first year, we lost half of the team members. Since then, it had been a struggle to find qualified people to complete project activities and we had to constantly train new, but often temporary, staff. In hindsight, revisions to the project document could have been pursued more rigorously as soon as the problems surfaced. The other problem was the lack of mid-management level personnel on the PNG side. While we were happy to work closely with junior research staff in most cases, it would be preferable that there were senior research staff who could be a main contact person, have a mentoring role, help monitor progress on the ground, and rectify problems as soon as they occurred.

## 9.2 Recommendations

### **Recommendation 1**

The participatory and the stakeholder workshop approach have worked very well for this project. It brought all stakeholders together to interact and to build relationships which will foster future supply chain collaboration. It was extremely effective in narrowing down a long list of issues to a small set of priorities. The support the project received from the industry has been phenomenal. We highly recommend taking a similar approach in ACIAR projects, especially in PNG where the culture and social structure are diverse and complex. However, there should be some built in flexibility in terms of budget, milestones, and outputs to be delivered in Schedule 5.2. This is so because the outcomes from the stakeholder workshops do not always coincide with what was envisaged at the time of preparing the project document. For example, the project had budgeted for 2 stakeholder workshops and we ended up having 5. Another example is that access to credit was not part of the proposal, but was identified through the stakeholder workshop. It turned out that improved farmers' access to credit has had the greatest and most direct impact on their income. In addition, to benefit fully from the participatory action research approach, the research-planning-action-reflection cycle will need to be incorporated into all the action plans, but with much shorter planning cycles and in smaller groups, as well as having local facilitators on the ground to monitor progress and see things through.

### **Recommendation 2**

Conduct surveys on consumers' preferences and buyers' requirements for sweetpotato be conducted in Port Moresby to identify market segments and their respective quality requirements. The surveys may include: consumers at open markets and supermarkets, institutional buyers (schools, universities, defence force, mine sites, etc), supermarkets, hotels, restaurants, Kai bars, catering services, etc). This information can be used to develop more effective marketing strategies aimed at increasing farmer returns and improving customer satisfaction, as well as linking farmers more directly to these markets.

### **Recommendation 3**

Improve the development, and adoption of, locally appropriate practices and technologies by better understanding the social and cultural constraints that may hinder the adoption of new ideas and new technologies. Given PNG's unique social and cultural environment, more research is needed to find the best-fit practices that take into account the local conditions, rather than "best practices" that are unlikely to happen. More research is also needed to find out the ways by which new information and best-fit practices can be promoted to smallholder farmers given their different levels of education and of exposures to new ideas.

### **Recommendation 4**

More attention should be given to improving market information and communications along the supply chain and providing price signals to address demand and quality issues. This will require research into the development of locally appropriate quality standards and grading schemes and the pros and cons of a bag-based pricing mechanism versus weight-based. These institutional changes are necessary for providing an enabling environment for farmers to respond to market signals. In addition, more attention should be given to the development and maintenance of a workable database on sweetpotato. The current information systems maintained by FPDA, NSO, Customs, etc must be improved to allow proper market research. FPDA will need assistance in cleaning up its vast, but fragmented, database and in data analysis.

### ***Recommendation 5***

For the packaging trials, concerted effort was given to provide some costing. However, due to the small scale of the trials, the incremental changes were too small to be measured more precisely. It is recommended container load trials be considered. By repeating the packaging trials based on container loads (through perhaps working with wholesalers), we will get a better understanding of total savings in time and cash costs from packing, loading and unloading, and the impact on quality outturn. The packaging trials could also incorporate further testing of field and postharvest curing methods to compare results between cured and uncured sweetpotato.

### ***Recommendation 6***

More research into issues related to local marketing for women, such as low prices, oversupply, poor market facilities, transporting sweetpotato from gardens to home, poor feeder roads, access to PMVs, protecting produce while in transit, workloads, etc.

### ***Recommendation 7***

More effort be devoted to dissemination of research outputs by assisting extension officers at FPDA, NARI, RWDI, DAL and NGOs in providing training to lead farmers, and local buyers, on (1) marketing planning, record keeping, and costs and returns analysis; (2) grading, packaging and postharvest handling; and (3) linking farmers/groups to markets.

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## 10 References

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### 10.1 References cited in report

Baydar, H., and Karadogan, T. 2003/4. The effects of volatile oils on in vitro potato sprout growth. *Potato Research* 46: 1-8.

Brearley, T. 2005. Increasing the autonomy of women as a means to improving community well-being and facilitating development: An exploratory study in Papua New Guinea. Report for ACIAR Project ASEM/2001/037 entitled Improving the Marketing System for Fresh Produce from the Highlands of PNG.

Bourke, R., Camarotto, C., D'Souza, E.J., Nema, K., Tarepe, T.N. and Woodhouse, S. 2004a. Production patterns of 180 economic crops in Papua New Guinea. Coombs Academic Publishing, Research School of Pacific and Asian Studies, The Australian National University, Canberra.

Bourke, R. and Vlassak, V. 2004b. Estimates of food crop production in Papua New Guinea. Land Management Group, Australian National University, Canberra.

Chang, C. and Be'Soer, L. 2011. Sweetpotato marketing in Papua New Guinea: a gender perspective. *Stewart Postharvest Review*, December issue.

Elsadr, H. and Waterer, D. 2006. Efficacy of natural compounds to suppress sprouting and Fusarium dry rot in potatoes. University of Saskatchewan, Canada. [<http://www.usask.ca/agriculture/plantsci/vegetable/resources/student/potatosprout2006.pdf>]

Eshel, D., Orenstein, J., Tsrer, L. and Hazanovsky, M. 2009. Environmentally friendly method for the control of sprouting and tuber-borne diseases in stored potato. *Acta Hort.* 830: 363-368.

Hartmans, K.J., Diepenhorst, P., Bakker, W. and Gorris, L.G.M. 1995. The use of carvone in agriculture: sprout suppression of potatoes and antifungal activity against potato tuber and other plant diseases. *Industrial Crops and Products* 4: 3-13.

Irving, D.E., Newman, S.M. and Ramita, I. 2011. Sweetpotato varieties for the Papua New Guinea highlands – a postharvest perspective. *Stewart Postharvest Review* 7(2), 1-9.

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### 10.2 List of publications produced by project

#### *Journal articles*

Kylie Crampton, 2010. Controlling postharvest losses of potato using biocontrol products and essential oils – an Australian perspectives. *Stewart Postharvest Review* 6 (3), 1-7.

Christie Chang, 2011. Quality management in the Papua New Guinea horticultural sector. *Stewart Postharvest Review*, December issue.

Christie Chang and Lilly Be'Soer, 2011. Sweetpotato marketing in Papua New Guinea: a gender perspective. *Stewart Postharvest Review*, December issue.

Irving, D.E., Newman, S.M. and Ramita, I. 2011. Sweetpotato varieties for the Papua New Guinea highlands – a postharvest perspective. *Stewart Postharvest Review* 7(2), 1-9.

#### *Conference papers*

Chang, C., Spriggs, J. and Newman, S. 2008. Improving sweetpotato marketing in PNG highlands, *Acta Horticulturae* 794, 2008.

Chang, C., Be'Soer, L., Wali, C., Anjan, J. and Ramita, I. 2010. Women in sweetpotato marketing in Papua New Guinea. Conference paper presented to AARES Annual Conference in Adelaide, February 2010.

Omot, N., Spriggs, J. and Chang, C. 2010. Consumer preferences and supplier responsiveness. Conference paper presented to AARES Annual Conference in Adelaide, February 2010.

Crampton, K.A., E.E. Lazar-Baker, L.J. Spohr and A.M. Harris 2011. Australian essential oils as potential biocontrol agents for potato storage diseases. Australasian Plant Pathology Conference, Darwin, 25-30 April.

Irving, D., S. Newman, I. Ramita, E. Lazar-Baker, C. Anton, A. Mais and K. Crampton 2011. Curing sweetpotato in the PNG highlands – Poster. Joint conference of the Australasian Postharvest Horticulture Conference Organising Committee (APHC), the Australian Society for Horticultural Science (AuSHS) and the New Zealand Institute of Agriculture and Horticulture Science (NZIAHS) at the Mantra Erskine Beach Resort, Lorne, Victoria, Australia, September 18 - 22.

Lazar-Baker, E., Crampton, K.A., Kenny, B., Finau, K.A., Gangai, S. and Ramita, I. 2011. Postharvest disease management of horticultural produce in the Pacific Island Countries: a brief overview. Stewart Postharvest Review 2:3

Newman, S., I. Ramita, J. Spriggs, K. Crampton, G. Ortiz, R. Pam and C. Anton 2011. Mapping sweetpotato supply chains in PNG – Oral Presentation. Joint conference of the Australasian Postharvest Horticulture Conference Organising Committee (APHC), the Australian Society for Horticultural Science (AuSHS) and the New Zealand Institute of Agriculture and Horticulture Science (NZIAHS) at the Mantra Erskine Beach Resort, Lorne, Victoria, Australia, September 18 - 22.

### **Reports on stakeholder workshops**

Report on January 2009 Stakeholder Workshop - Christie

Report on November 2009 Stakeholder Workshop - Christie

Report on June 2010 Stakeholder Workshop - Suzie

### **Trip Reports**

June 2008, consignment trials – Suzie

September 2008, women's focus groups in Goroka and Hagen-- Christie

August 2009, economic component and marketing training workshop, Goroka – Christie

June/July 2009, industry consultations in POM with NDB and ARDSF – John

September 2009, disease survey - Elena

September 2010, curing trials - Donald

October 2010, progress review in Lae – Christie

Dec 2010, study tour and technical training in Australia – Donald

## **10.2.1 Technical Reports**

### **Social-economic component**

Mapping the sweetpotato supply chains in PNG, John Spriggs, John Kewa, Donald Hehona, Jesse Anjan and Eleo Dowa.

Improving access to market information for sweetpotato farmers in PNG: a market analysis of prices, marketing costs and supply volumes, Christie Chang, Jesse Anjan and Eleo Dowa.

Improving access to market information for sweetpotato farmers in PNG: consumer preferences and supplier responsiveness, Norah Omot, Christie Chang and John Spriggs

Improving access to credit for sweetpotato farmers in PNG, Regina Mali, Eleo Dowa, Iga Anamo and Peter Dekene and Conrad Anton

Improving access to transport for sweetpotato farmers in PNG, Eleo Dowa, Debra Bubun and Conrad Anton

Improving women's participation in sweetpotato marketing, Lilly Be'Soer

Improving cooperation between smallholder farmers: collective action and profiling farmers' groups in PNG highlands, Regina Mali, Conrad Anton, Iga Anamo, Peter Dekene and Debra Bubun

Best practice: a case study of Joe Kold's sweetpotato supply chain, Christie Chang, Eleo Dowa and Conrad Anton

Framework and example for analysing costs of marketing, Christie Chang.

*These reports are available upon request.*

### **B. Technical component: postharvest and value addition**

Sweetpotato supply chains – where is the damage occurring? Suzie Newman, Isidora Ramita, Kylie Crampton, Guinevere Ortiz, Ronald Pam, Conrad Anton, and Sarah Misiel

Survey of the postharvest diseases of marketed sweetpotato in Papua New Guinea (Lae and Port Moresby), Elena Lazar-Baker, Lorraine Spohr, Samantha Gangai, Gend Bagle, Isidora Ramita, Kylie Crampton, Sarah Misiel, Debra Bubun, and Birte Komolong

Postharvest pathology training (powerpoint presentation), Elena Lazar-Baker and Kylie Crampton

Disease assessment scale and scoring system (powerpoint presentation), Elena Lazar-Baker

Preliminary evaluation of some sweetpotato varieties for quality attributes and storage potential, Donald Irving, Suzie Newman, Isidora Ramita, Samantha Gangai, Elena Lazar-Baker, and Kylie Crampton

Developing alternative packaging options for sweetpotato in PNG, Suzie Newman, Isidora Ramita, Conrad Anton, Sarah Misiel, Poela Utuma, Amanda Mararuai, and Lorraine Spohr

Preliminary evaluation of some postharvest curing methods for kaukau grown in the PNG highlands, Donald Irving, Suzie Newman, Isidora Ramita, Conrad Anton, Samantha Gangai, Elena Lazar-Baker, Anton Mais, and Kylie Crampton

Improving value addition of sweetpotato in Papua New Guinea: a literature review, Anton Mais

Evaluation of Sister Louisa's training program, Anton Mais, Ronald Pam and Lilly Besoer

The Mt Hagan (Minj) Food Fair 2011, Anton Mais and Lilly Besoer

Sweetpotato marketing and processing project: organising training of trainers on sweetpotato, Anton Mais and Lilly Besoer

Value addition and processing in Minj, Anglimp South District, Jiwaka province, 12-14 April 2011, Anton Mais and Lilly Besoer

Report on travel to Australia November 29-December 13, 2010, Anton Mais and Donald Irving

Caring for kaukau after harvest. A pocket guide to disease identification and quality maintenance (extension and farmer resource, bilingual): Part 1: When and how does damage occur? and Part 2: What disease is this?

Identification of the common postharvest diseases of kaukau (extension poster)

Sik bilong kaukau em i wanem kain stret (extension and farmer poster)

Identification of the common postharvest diseases of kaukau (researcher poster)

Improved postharvest practices for quality outturn of kaukau (extension and farmer poster)

Oi rot bilong lukatutim kaukau bihain long yu kamautim long gaden (extension and farmer poster)

Quality kaukau for market (extension and farmer poster)

The Australian Potato Industry – stakeholder consultation, Kylie Crampton, Tony Napier, and Stephan Wade

In vitro screening of alternative control options for dry and soft rot diseases of potatoes, Kylie Crampton, Elena Lazar-Baker, Mike Russell, Lorraine Spohr, Anne Harris, and Honorine Laplace

Summary of in vivo screening of alternative control options for dry and soft rot diseases, and sprouting of potatoes, Kylie Crampton, Elena Lazar-Baker, Lorraine Spohr, and Anne Harris.

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## 11 Appendixes

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### 11.1 Appendix 1:

“Technical Reports for ASEM/2006/035 Improving marketing efficiency, postharvest management and value addition of sweetpotato in Papua New Guinea”, which is part of this Final Report, is attached as a separate document because of its size (a PDF file with 289 pages). The document is a collection of the following reports and outputs:

Sweetpotato supply chains – where is the damage occurring? Suzie Newman, Isidora Ramita, Kylie Crampton, Guinevere Ortiz, Ronald Pam, Conrad Anton, and Sarah Misiel

Survey of the postharvest diseases of marketed sweetpotato in Papua New Guinea (Lae and Port Moresby), Elena Lazar-Baker, Lorraine Spohr, Samantha Gangai, Gend Bagle, Isidora Ramita, Kylie Crampton, Sarah Misiel, Debra Bubun, and Birte Komolong

Postharvest pathology training (powerpoint presentation), Elena Lazar-Baker and Kylie Crampton

Disease assessment scale and scoring system (powerpoint presentation), Elena Lazar-Baker

Preliminary evaluation of some sweetpotato varieties for quality attributes and storage potential, Donald Irving, Suzie Newman, Isidora Ramita, Samantha Gangai, Elena Lazar-Baker, and Kylie Crampton

Developing alternative packaging options for sweetpotato in PNG, Suzie Newman, Isidora Ramita, Conrad Anton, Sarah Misiel, Poela Utuma, Amanda Mararuai, and Lorraine Spohr

Preliminary evaluation of some postharvest curing methods for kaukau grown in the PNG highlands, Donald Irving, Suzie Newman, Isidora Ramita, Conrad Anton, Samantha Gangai, Elena Lazar-Baker, Anton Mais, and Kylie Crampton

Improving value addition of sweetpotato in Papua New Guinea: a literature review, Anton Mais

Evaluation of Sister Louisa’s training program, Anton Mais, Ronald Pam and Lilly Besoer  
The Mt Hagan (Minj) Food Fair 2011, Anton Mais and Lilly Besoer

Sweetpotato marketing and processing project: organising training of trainers on sweetpotato, Anton Mais and Lilly Besoer

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Improved postharvest practices for quality outturn of kaukau (extension and farmer poster)

Oi rot bilong lukatutim kaukau bihain long yu kamautim long gaden (extension and farmer poster)

Quality kaukau for market (extension and farmer poster)

The Australian Potato Industry – stakeholder consultation, Kylie Crampton, Tony Napier, and Stephan Wade

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Summary of in vivo screening of alternative control options for dry and soft rot diseases, and sprouting of potatoes, Kylie Crampton, Elena Lazar-Baker, Lorraine Spohr, and Anne Harris