Australian Government

Australian Centre for International Agricultural Research

Final report

Project	**Promoting traditional vegetable production and consumption for improved livelihoods in Papua New Guinea and northern Australia**
project number	ASEM/2012/084
date published	1/6/2019
prepared by	Tania Paul
co-authors/ contributors/ collaborators	**Collaborators:** National Agricultural Research Institute Fresh Produce Development Agency The World Vegetable Center University of Queensland PNG Women in Agriculture Development Foundation World Vision PNG Charles Darwin University
approved by	Jayne Curnow
final report number	FR2019-90
ISBN	978-1-925747-66-9
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

This publication is published by ACIAR ABN 34 864 955 427. Care is taken to ensure the accuracy of the information contained in this publication. However ACIAR cannot accept responsibility for the accuracy or completeness of the information or opinions contained in the publication. You should make your own enquiries before making decisions concerning your interests.

Contents

1 Acknowledgments

We wish to acknowledge the contribution of Dr Rosa Kambuou to the conception of this project and the work she did on documenting and researching traditional vegetables in Papua New Guinea. We wish to highlight the valuable work she did in establishing a germplasm collection of aibika at Laloki research station and raising awareness of the importance and nutritional value of these traditional vegetables, and the need to conserve the genetic resources of PNG.

We wish to acknowledge the contribution of Willy J. Minala, who passed away during the last year of the project. Willy was an active and valuable team member with World Vision who was very much missed by the project team.

We would also like to thank the following people and organisations for the valuable contribution to the project:

- Farmers from the Nine Mile settlement in Port Moresby for their time, interest and hospitality.
- Staff and students of Alawa, Girraween, Belyuen, Howard Springs and Timber Creek Schools in the Northern Territory for allowing the project team to work with them in their school gardens.
- Staff and students at Mutzing High School for allowing the project team to work with them in their school gardens.
- Simon Smith from the Plantsmith Wholesale Nursery in Girraween NT for propagating and testing the sale of traditional vegetables to large retail nurseries.
- The Gardening Australia team from the Australian Broadcasting Commission for spreading the word and broadcasting and publishing information on aibika to a national audience.
- Food Ladder in Katherine for growing and disseminating planting materials and communication tools on our behalf.
- The Australian High Commission in Port Moresby for kind assistance in setting up cooking and taste testing demonstration events.

2 Executive summary

The overall aim of this research project was to understand the and increase the role of traditional vegetables for smallholder growers and household gardens in Papua New Guinea to diversify household incomes and improve livelihoods. The Northern Territory component aimed to promote the consumption and production of selected nutritious traditional vegetables in schools, community gardens and remote community food gardens with a nutritional education focus using vegetables such as aibika, rungia and pumpkin tips.

Focus areas of the project were urban and peri-urban Port Moresby with a small study in Lae, and in the NT, Darwin urban schools, Katherine, Timber Creek, Tiwi Islands, Nhulunbuy, Maningrida, and Jabiru.

This project took a collaborative, participatory approach working through grower's groups, women's organisations and NGOs, and provided opportunities for collaboration between schools and project activities. Activities included germplasm characterization, establishing germplasm collections of aibika, amaranth and nightshade in local and international gene banks, horticultural trials, supply and value chain mapping, consumer behaviour and preference studies, training in pest and disease management, seed harvesting and storage for key staff and farmers, and the development of educational and promotional tools to increase awareness of the nutritional benefits of traditional vegetables.

The project highlighted the economic importance of traditional vegetables to local economies, which had previously been neglected and poorly understood. In only one major market in Port Moresby, over K13 million is transacted in traditional vegetables per annum, and over K304,000 is sold to institutions per annum, with aibika topping the list in value and volume followed by choko tips and wild harvested bush fern and amaranth.

Outputs and benefits of the project included:

- Identification and understanding of behaviours, preferences and trends influencing consumption of traditional vegetables and comparison between rural and urban consumers. From these studies we were able to provide growers with information on the most preferred vegetables and traits, value adding opportunities, and understand the growing importance to consumers of nutritional information.
- Consumer studies identified a lack of knowledge on the preparation and cooking. In response, the project developed a series of recipes including nutritional information and held cooking demonstrations and taste testing at local markets and supermarkets.
- Maps of the formal and informal value and supply chains for traditional vegetables and constraints in each chain and where interventions could improve incomes for growers.
- Identification of potential areas for improving competitiveness and market opportunities for traditional vegetables.
- Establishment of market data collection, volume and value of trade, and information flows to growers on traditional vegetables.
- Identified and facilitated a successful new chain to a large catering firm in Port Moresby and increased volume of sales of traditional vegetables to institutional buyers for local farmers engaged in the project.
- Identification of suitable varieties and improved propagation and crop management strategies appropriate for PNG and the NT, with potential application more widely in the region.
- Extensive training for farmers and extension staff on pest and disease management, financial literacy, gross margin analysis, seed saving and storage, establishing nurseries, postharvest handling, and propagation.

- Exchange of germplasm between PNG and the World Vegetable Center in Taiwan,
- Characterisation, documentation and conservation of key traditional vegetables with new accessions into international gene banks and the establishment of living collections in Darwin, Port Moresby and Lae of aibika, amaranth, and nightshade.
- Harmonised nutritional data for the most popular traditional vegetables.
- Book of innovative and traditional recipes, factsheets and posters with growing information and nutritional information for a range of audiences for use by health clinics, schools, agricultural extension officers NGO’s and growers.
- Commercial sales of aibika and rungia in retail nurseries in the Darwin and Palmerston region and establishment of these crops in a local wholesale nursery as a regular line.
- Aibika successfully growing in school and community gardens throughout the Top End of the Northern Territory.

3 Background

This project extended the scoping work undertaken in the SRA HORT 2011/064 Indigenous vegetable consumption and production in Papua New Guinea: Opportunities and challenges, and linked to the SRA PC/2010/063 undertaken by the University of Adelaide and the Secretariat of the Pacific Community (SPC): Feasibility study on increasing the consumption of nutritionally rich leafy vegetables by indigenous communities in Samoa, Solomon Islands and Northern Australia, through shared findings and linkages with project activities in the Top End of the Northern Territory.

The project contributed to the actions arising from the Framework for Action on Food Security in the Pacific 2011-2015 under theme 3: Enhanced and sustainable food production, processing marketing, trading and use of safe and nutritious local food; and contributed to the progress towards the Sustainable Development Goals, particularly SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture and SDG 12: Ensure sustainable consumption and production patterns. The project contributed to the goals of the Framework for Action on Food Security endorsed by the Pacific Food Summit[1], particularly within the theme of Enhanced and sustainable production, processing and trading of safe nutritious local food.

The Scaling Up Nutrition (SUN) Framework and Roadmap[2] which evolved from World Bank and IMF priorities, highlights the need to improve nutrition through agriculture, and this project aligned with the SUN strategies of targeting nutritionally vulnerable groups such as poor women and children, investing in women, increasing access to nutritionally valuable food all year round, and creating enabling environments for good nutrition through knowledge and education.

Production and consumption of indigenous vegetables emerged as a priority issue for Papua New Guinea in the 2011 Country Consultation, and is considered essential for both food and nutritional security. This project aligned with this priority and the PNG Government priority of promoting growth in the rural sector and improving food supply and incomes for smallholder farmers[3].

At the time of commencement, the project sat within ACIAR's medium term strategy of securing improvements in food access and rural smallholder incomes, within several of the key areas: enhancement of smallholder incomes from vegetables and staples, and increasing household resilience and income sources through mixed farming systems – developing potential indigenous species.[4]

Food consumption patterns in urban areas have changed in recent decades[5] in Papua New Guinea (PNG), with an increasing consumer preference for imported foods such as tinned meats, rice, flour, and tinned fish[6]. Following this trend, micronutrient rich traditional garden foods are increasingly being replaced by store bought foods in both rural and urban diets which are energy dense but nutritionally poor.

---

[1]World Health Organisation Western Pacific Region Pacific Food Summit: Meeting Report, April 2010 Port Vila Vanuatu

[2]*FAO 2012. "Final Draft: Synthesis of Guiding Principles on Agriculture Programming for Nutrition." Rome.*[http://www.fao.org/fileadmin/user_upload/wa_workshop/docs/Synthesis_of_AgNutr_Guidance_FAO_IssuePaper_Draft.pdf.](http://www.fao.org/fileadmin/user_upload/wa_workshop/docs/Synthesis_of_AgNutr_Guidance_FAO_IssuePaper_Draft.pdf)

[3]Papua New Guinea Medium Term Development Plan 2011-2015

[4]Papua New Guinea – ACIAR Medium term Strategy 2012 http://aciar.gov.au/PacificRegion

[5]Special Issue: Papua New Guinea Nutrition Survey, 2005. *Pac. J. Med. Sci., 2011. 8(2).*

6 *Westwood, V. and V. Kesavan,* Traditional leafy vegetables of Papua New Guinea: aibika (Hibiscus manihot (L)), in Proceedings of the Second Papua New Guinea Food Crops Conference: Part Two*, R.M. Bourke and V. Kesavan, Editors. 1982, Department of Primary Industry: Port Moresby. p. 391-395.*

Increasing availability and access to traditional vegetables can improve food and nutritional security, particularly for communities that are remote and isolated, and also for poor urban communities where access to affordable, nutritional food can be problematic.

Traditional vegetables are superior in food value to globally popular vegetables with higher essential nutrients, and historically provided a large proportion of the daily protein, vitamin and mineral intake in the village diet[7] in Papua New Guinea (e.g. aibika, pumpkin tips, sweet potato leaves, rungia). Increased demand and consumption of traditional vegetables has the potential to contribute to higher potential incomes for growers and sellers, the majority of whom are women.

Communities in the Top End of the Northern Territory face similar problems with limited access to fresh vegetables and fruit, and an increasing shift towards energy dense, store bought food with declining consumption of traditional foods due to reduced access to homelands and bush tucker sources.

Many traditional vegetables are higher in essential nutrients than introduced vegetables[8]. For example, aibika (*Abelmoschus manihot*) has 12 times the beta carotene content, 20 times the folate content and 5 times the vitamin C content of tomato. The nutritional value of traditional vegetables over conventional vegetables in Papua New Guinea was recognised and documented as early as 1955[9]. They are superior in food value to introduced vegetables[10] and historically were known to provide a large proportion of the daily protein, vitamin and mineral intake in the village diet.

Horticultural production in PNG provides subsistence crops for consumption and substantial cash incomes for poor rural households. Around two-thirds of rural households depend on horticulture. Despite this, there are substantial gaps in the knowledge base about the nutritional, economic and social benefits from horticultural production of traditional vegetables, and this project aimed to fill some of those gaps. Over 85% of horticultural smallholders in PNG are women, improving incomes from traditional vegetables through better production and market access contributes to better nutritional and educational outcomes for these women and their families.

The findings from the SRA indicated an overall decline in the consumption of traditional vegetables, however there was a higher demand in urban markets for particular traditional vegetables, and an indication that consumption of traditional vegetables increased where consumers became aware of the nutritional benefits. Despite an overall decline in production, there is a reported increase in levels of backyard production in some areas. Factors contributing to the decline in production include difficulties with market access and continuity of supply, post-harvest losses and management problems, pest and disease management, and declining wild harvest sources in some areas.

The SRA identified key areas for further research including crop management, pest and disease management, post-harvest management, understanding market systems, market access and supply chains, increasing economic returns, declining wild harvest resources, and changing consumer attitudes resulting in declining demand.

Popular traditional vegetables in PNG include: aibika (*Abelmoschus manihot*) lowland and highland pitpit (*Saccharum edule* and *Setaria palmifolia*) winged bean (*Psophocarpus*

---

[7] *Bourke, R.M.,* Traditional vegetables of Papua New Guinea. Vegetables for the Hot Humid Tropics*, 1977. p. 33-6.*

[8] Chadha, M.L., Oluoch, M.O., *Home-based vegetable gardens and other strategies to overcome micronutrient malnutrition in developing countries*, in Food, Nutrition and Agriculture Series 2003, FAO: Rome, Italy.

[9] *Hamilton, L.,* Indigenous versus introduced vegetables in the village dietary. *Papua and New Guinea Agricultural Journal, 1955.* ***10****(2): p. 54-57.*

[10] *Bourke, R.M., Traditional vegetables of Papua New Guinea.* Vegetables for the Hot Humid Tropics, 1977. p. 33-6.

tetragonolobus), Rungia (*Rungia klossii*), tulip (*Gnetum gnemon*), water dropwort (*Oenanthe javanica*), amaranthus, bread fruit leaves, various fern tips, choko tips and pumpkin tips.

One of the main priorities of the Northern Territory Government outlined in the Northern Territory Health, Nutrition and Physical Activity Strategy 2015-2020 under Objective 1: *improve food security, particularly in remote communities*, is to increase the supply and consumption of fresh fruit and vegetables in remote communities, and to specifically promote and support the development of self-sufficiency in fruit and vegetable production[11]. The project activities tied in with the NT Government education and health promotion programs operating in schools and communities.

In remote communities of the Northern Territory, fresh fruit and vegetables are difficult to access and prohibitively expensive, and energy dense, nutrient poor food costs much less, driving a tendency towards diets that are associated with higher rates of preventable chronic disease.[12] The SRA Feasibility study on increasing the consumption of nutritionally rich leafy vegetables by indigenous communities in Samoa, Solomon Islands and Northern Australia, found that there are very few leafy green vegetables indigenous to the Top End and low levels of consumption of any greens, but that there was some interest in introduced traditional vegetables from Papua New Guinea such as aibika (slippery cabbage), rungia, and winged bean This project ran horticultural trials of aibika in Darwin, and used the findings of the trials to promote growing aibika in urban and remote community food gardens in the Top End indigenous communities and remote area schools.

[11] Department of Health 2015, NT Health Nutrition and Physical Activity Strategy 2015–2020, Department of Health Northern Territory available at: https://digitallibrary.health.nt.gov.au/prodjspui/bitstream/10137/672/1/NT%20Health%20Nutrition%20and%20Physical%20Activity%20Strategy%202015%20-%202020.pdf

[12]Brimblecombe, J.K & O'Dea, K. *The role of energy cost in food choices for Aboriginal populations in northern Australia,* MJA 2009; 190:549-551.

4 Objectives

The overall aim of this research project was to understand and increase the role of traditional vegetables in Papua New Guinea and the Top End of the Northern Territory for backyard and smallholder growers, for more diversified incomes and improved livelihoods. The objectives are aligned under each research question, and activities were planned against each objective to meet the outcomes of each.

Research Question: What are the factors influencing consumption of leafy traditional vegetables and what can be done to increase consumption?

Objective 1: To identify and understand factors in the decline in the production and consumption of leafy traditional vegetables in urban and rural markets of focus areas in PNG.

Research Question: What is the market potential and market demand for leafy traditional vegetables, what are the value chains and how can production and availability be increased?

Objective 2: To identify opportunities for increasing market demand, market potential, availability and consumption of leafy traditional vegetables in focus areas of PNG.

Research Question: How can current leafy traditional vegetable production practices be improved to increase quantity and availability, quality and safety?

Objective 3: To contribute to increased production, through improving production practices, demonstrations, community gardens, better seed and propagation material availability in PNG and Northern Australia.

Research Question: How can we increase the awareness of the nutritional benefits of traditional vegetables amongst consumers?

Objective 4: To promote the nutritional, social and economic benefits of leafy traditional vegetables in focus areas of PNG and Northern Australia

5 Methodology

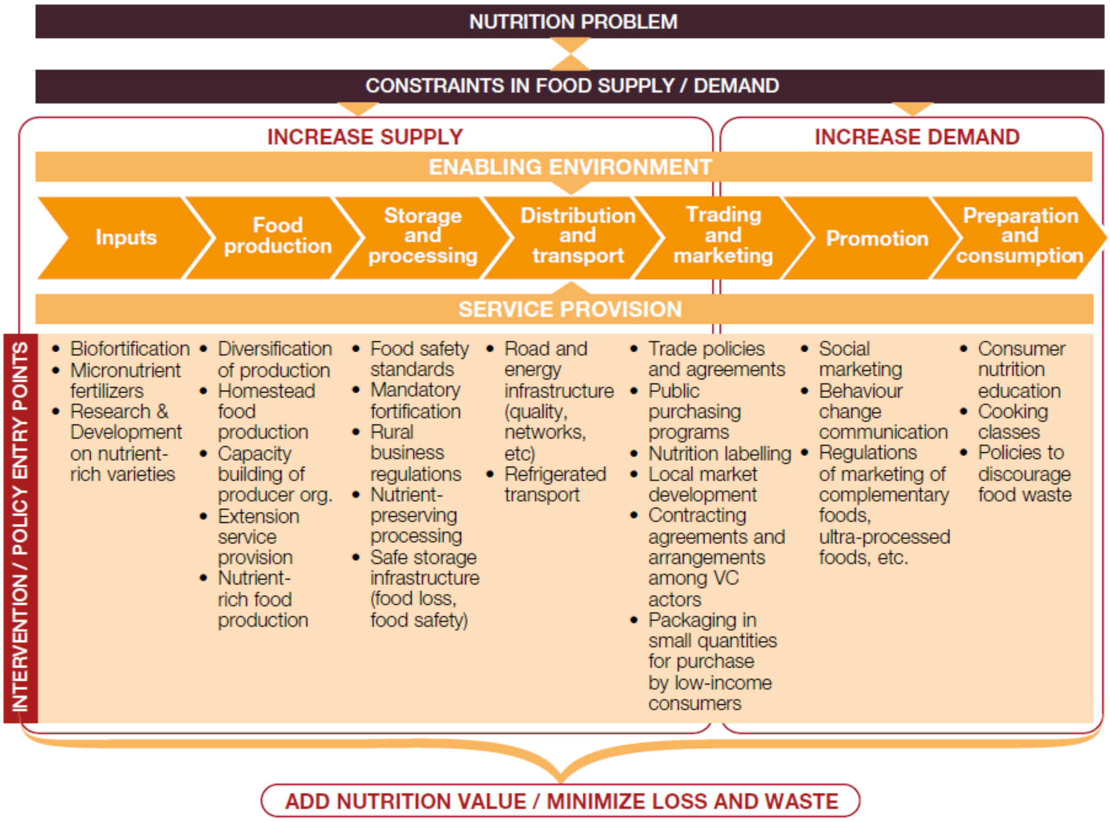
5.1 Research Strategy

The project sits within a conceptual framework of household food security comprising four pillars: availability, access, utilisation and stability[13]. It investigated the current and potential contribution of traditional vegetables to household food security for a range of household economies, including largely subsistence livelihoods in rural PNG, mixed cash and subsistence livelihoods in peri-urban PNG and state-supported livelihoods in the Top End of NT.

The project also aligned with a nutrition sensitive value chain approach as developed by IFAD through their work in Nigeria and eastern Indonesia. Studies suggest that developing, understanding and improving value chains for particular crops can provide important nutritional and livelihood benefits to smallholder growers and households.

Applying a nutritional perspective to the value chain provided a framework to identify research questions and intervention points where nutritional gains could be made in the chain.

Figure 1: Framework for understanding nutrition sensitive value chains and determining intervention points and potential impacts:



Source: IFAD 2018

Using the above framework with both a traditional production lens and a nutrition lens, the team investigated the steps on the chain where there were knowledge gaps, to try and determine where the most value and greatest impact could be gained. After the initial scoping, it was determined that the steps on the chain most likely to produce the greatest

[13] *FAO 2012*

impact and potential for change were the production, processing, marketing, promotion and consumption elements of the value chain.

Charles Darwin University and the National Agriculture Research Institute led and managed the project, in collaboration with the Fresh Produce Development Agency World Vision International in Port Moresby, and PNG Women in Agriculture for Development, local communities and the CDU Horticulture remote area program.

Collaborations with The World Vegetable Center were made for its expertise on germplasm characterisation, seed production, crop management, and nutrition. Working through on-ground partners and their networks encouraged better uptake of research outputs and help to ensure the ongoing usefulness of project outputs beyond the life of the project. For example, the education and awareness tools and recipes were developed and trialled in close collaboration with partners to build ownership and capacity, and integrate with other extension and communication activities.

The project commenced in several locations in PNG with differing priorities: peri-urban and rural sites in Port Moresby and Lae, and one rural site of Bougainville, as there appeared to be a divergence of issues between urban and rural areas. Port Moresby and Lae represented the largest current and potential markets for traditional vegetables, and the focus was on peri-urban growers and markets, and the value and supply chains for traditional vegetables. These networks were not well understood and included informal and formal markets, agents, 'black marketeers,' and grower/seller competition. The project commenced in all sites but due to changes in staffing in Lae and a shift in activities with partners in Bougainville, the project focused more intensively on urban and peri-urban sites around Port Moresby from 2016 on, and concentrated on implementing Objective 4 in Bougainville.

The project investigated supply chains to better understand the push-pull dynamics and determine which approach would be most effective. Findings from the SRA indicated that the markets for traditional vegetables were mostly demand-pull with demand outstripping supply for some vegetables at certain times.

We worked with grower groups engaged in previous ACIAR projects in Port Moresby and linked with growers around Central Province through our partners. In the Top End of the Northern Territory, activities were initially focused in Darwin and then extended to indigenous communities throughout the Top End of the Northern Territory.

Table 1: Summary of activities and partners engaged in each of the project sites

Site	Objectives	Activities	Main partners	No. families/ communities directly involved
Central Province	1, 2, 3 & 4	Factors in consumption and production Market demand, and potential Horticultural trials Education and awareness	NARI, World Vision, World Vegetable Center (WorldVeg), PNGWIAD	245
Bougainville	4	Education and awareness	World Vision, NARI	30
Darwin/Arnhem Land	3 & 4	Horticultural trials on aibika Education and awareness	CDU	2 community gardens

Within Central Province, and the National Capital District surrounding Port Moresby, the project worked in the following communities: a mixture of rural, urban and peri-urban sites:

Table 2: Communities involved in the project

District	Village	Distance from POM (Estimate)	Number of farm families
Rigo	Karekodubu	60Km	25 farm families
Rigo	Manugoro	40km	25 farm families
Rigo	Deugogo	45km	25 farm families
Rigo	Geresi	100km	20 farm families
Rigo	Ibunato	200km	40 farm families
Hiri	Kuriva	80km	30 farm families
Hiri	Seme	30km	20 farm families
Peri-urban	9 mile	4Km	10 farm families
Peri-urban	ATS site	10 Km	30 farm families
Hiri	Doromokoi	75km	*20 farm families – withdrawn due to communal clash*

The species targeted for horticultural field trials under objective 3 were determined by the findings in objective 2, and final findings of the SRA which was completed in March 2014. Trials were conducted at NARI research sites in Laloki in Port Moresby. Seeds and propagation materials were obtained locally and samples were sent to the World Vegetable Center (WorldVeg) in Taiwan for morphology and DNA analysis, to characterise the germplasm and comparison with accessions held by WorldVeg.

In remote areas of the Northern Territory there are very few traditional green leafy vegetables consumed, and fresh introduced vegetables are expensive and usually low quality with unreliable supply. This is not a decline in consumption or production but a factor of culture and environment. People traditionally derived important nutrients from other sources, e.g. carotenes from turtle fat and pollens. Because of changing lifestyles and reduced access to homelands, these traditional food sources are increasingly difficult for people to access. There are very few locally occurring greens due to the long dry season and the heavy wet season, and there is very little commercial production of vegetables in remote communities.

The project tested education and awareness tools to stimulate demand using healthy eating and nutritional benefits as the foundation. Traditional vegetables are known to be more nutritious than introduced vegetables, and the intention of the project was to integrate the spectrum of knowledge about these vegetables into targeted packages for a range of groups who could benefit from increased availability and consumption of traditional vegetables.

There has been investment by the NT Government and other agencies in establishing community gardens to promote the production and consumption of fresh vegetables and fruit. The project tested the introduction of aibika (*Abelmoschus manihot*) into community food gardens, where it can be introduced into the school feeding programs and promoted as a healthy food choice. Research has shown that introduction of novel vegetables into school gardens is one of the most effective behaviour change approaches in encouraging healthy eating.

Aibika is thought to have been introduced to Croker Island in Arnhem Land from Kiribati by missionaries over 60 years ago. It is still actively cultivated by the community there and is a popular vegetable, which presented an opportunity to trial the acceptability of aibika/pele in other communities. Aibika was selected for several reasons for the NT component: it is a highly nutritious green vegetable, it is easily grown and propagated, and we can draw on the knowledge and skills of the PNG team for assistance. It is already present in the NT in Croker Island, and in a few local gardens in Darwin, and so overcomes any quarantine problems associated with importing planting materials, and it has a track record of acceptability in local diets in and around Croker Island and therefore is a good candidate to pilot the method of introduction of greens into community gardens.

The project put out a call over the local radio for any Darwin locals already growing aibika to get in contact. This resulted in the NT team establishing a collection of four aibika varieties in the CDU Horticulture compound which were then used for propagation and dissemination of cuttings to schools and community gardens.

Linkages to other ACIAR projects

This project linked with several other ACIAR projects:

HORT/2012/020: *Integrated Crop Management in the Philippines and Australia*, which commenced in December 2013, through sharing findings and information.

ASEM/2010/052 *Improving women's business acumen in Papua New Guinea: working with women smallholders in horticulture.* We provided training in seed saving, human nutrition and vegetable growing skills to families and farmer groups that participated in this ACIAR project.

SMCN/2008/008 *Increasing vegetable production in Central Province to supply Port Moresby markets, Papua New Guinea* by linking with grower groups engaged in this project and investigating the supply chains these groups were involved in.

This project made use of the learnings and materials developed in the ACIAR project: PC/2006/106 *Screening and field trials of high-carotenoid sweet potatoes in Solomon Islands and Papua New Guinea to improve human vitamin A status*, which encouraged the production and consumption of carotenoid rich sweet potato varieties in Papua New Guinea and the Solomon Islands.

We shared data with the SPC project: 'How an indigenous vegetable can contribute to sustainable development" which conducted horticultural and social research on aibika in PNG New Caledonia, Fiji, Vanuatu and Solomon Islands.

The AusAID Public Sector Linkage Program project: *Capacity development in leadership and decision-making for women in the agricultural public sector in PNG* provided training in areas of leadership, communications and media to staff of partners from participating public sector organisations in the project, and participants used their training to disseminate information and findings from this project.

The National Agricultural Research Institute provided overall coordination and leadership of the project in collaboration with Charles Darwin University. On ground activities in PNG were undertaken through World Vision International in Port Moresby and the Fresh Produce Development Agency (FPDA) in Port Moresby.

We focused primarily on production and education activities in Darwin and the Top End of the Northern Territory. In each site in PNG we aimed to work with groups of around 25-

30 growers, and through the networks of partners in each site to reach maternal and child health programs for the educational aspects.

Initial aibika trials in Darwin were conducted through the School of Horticulture at CDU, and included student research projects. Once the best cultivation methods were established, the trials then moved into local community food gardens in urban Darwin, and extended out to remote indigenous communities through the School of Horticulture and the food garden networks in the Top End, which links with NT Government programs relating to health and nutrition already operating in these communities. We propose to work with two urban and two remote communities. The aibika trials and the extension to communities will be a pilot for future work on promoting leafy greens and other vegetables in communities and schools in the Top End.

We used the extensive network of PNGWIAD for developing and piloting recipes and educational materials for community audiences, promotional activities and taste testing trials. The University of Queensland worked with partner country collaborators on market analysis and supply chain mapping, supply chains and understanding market access, assessing value adding and processing potential.

The project drew on expertise and research in social science, horticulture, economics, and agricultural extension, taking an overall mixed methods approach. Both qualitative and quantitative research tools were employed to address the research questions. Detailed methods are listed within the activity descriptions in the next section.

5.1.1 Methods

A combination of qualitative and quantitative methods was used to carry out the research activities listed below. A mixed methods approach was necessary for the qualitative aspects of the project including: structured and semi-structured interviews, email surveys, market surveys of consumers, supply chain mapping, informal focus group discussions, taste testing trials, behavioural analyses, questionnaires and focus group discussions.

Some of the work required desktop literature reviews and searches, such as the analysis of recent Household Income and Expenditure surveys of food diaries and recent Demographic and Health surveys for similar information.

Horticultural trials were undertaken using action research in research farm trials to ensure that grower considerations were included in the trial designs taking a low technology approach. We worked with existing grower groups who had participated in previous ACIAR projects in focus areas.

Behaviour change communication methods to promote the awareness of the nutritional benefits included linking with remote communities and kitchen garden programs to provide opportunities for school children to grow, see and taste these vegetable, posters, recipes and information cards were distributed through our partner networks and maternal and child health centres, taste testing and cooking demonstrations, cooking competitions at rural shows and using local celebrities and project members to engage with the media to raise the profile of these vegetables.

Specific details of the method for each activity are included with the key results and discussions, but generally the methods included:

Objective 1

1. Surveys and informal focus group discussions to understand the factors influencing the consumption of traditional vegetables in urban and rural areas and recommend strategies to reverse the decline in consumption and production.

2. Behavioural analysis: investigate current eating habits of target population, preferences in urban and rural areas (stratified based on income, education status etc.). Using interviews, surveys, food diaries, and matrix ranking on preferred traits of traditional vegetables, conjoint questionnaire to investigate willingness to pay surveys.
3. Reviewing what has been done elsewhere to reverse the trend in declining consumption and production, such as work done in Micronesia, Tanzania and Zimbabwe and future directions in community level and national level seed systems.

Objective 2

1. Mapping the formal and informal supply chains of traditional vegetables to determine consumer sources of traditional vegetables; for example: store bought, market, home grown or bush collected using surveys and understanding the flow of market information to growers for target areas, which will inform suppositions about wider scale trends.

Table 3: Formal and informal supply chains identified with potential for mapping

Site	Chain
Central Province	Pacific Adventist University - producer and supplier to local super markets (large supplier) Communities growing and supplying into local markets or road side markets (rural and urban) Settlement communities that have limited access to physical resources (peri-urban)
Lae	Producers to supermarkets (large supplier) Communities growing and supplying into local markets or road side markets (rural and urban)

2. Identifying existing and potential market opportunities. We used lessons and information from earlier work by Chambers, Spriggs and Newman on vegetable chains in PNG.

3. Data collection on levels of production of traditional vegetables at a local level, particularly peri-urban levels of production and estimated revenue generated from production for Port Moresby and Central Province.

The findings of this objective informed the activities in Objective 3.

Objective 3

1. Interviews, surveys, site visits and key informants to understand constraints that growers are facing in producing traditional vegetables. Insect pest and disease samples were collected for identification by NARI entomologists and WorldVeg.

2. Characterising locally utilised germplasm to select elite varieties for better consumer acceptance and higher nutrition value and recommend locally adopted seed saving and propagation methods.

   Designing horticultural field trials to address constraints and issues identified by growers, e.g. trial the production of wild harvested vegetables.

Trialling growing aibika at CDU Horticulture compound in Darwin, then extending trials into community food gardens in both urban and remote areas of the Top End after any production problems are identified and best practice methods are established for the Top End environment. We will grow the aibika through two wet seasons in Darwin to determine the pest and disease problems that are more likely to occur in high humidity and rainfall.

Initial proposed trials on popular traditional vegetables included:

Amaranthus sp.

- Collect, evaluate and document genetic diversity
- Trial varieties for performance, pest and disease incidence, yield and yield attributes.
- Investigate problems and solutions for reliable seed supply
- Investigate seed marketing options

Karakap or nightshade (*Solanum nigrum*)

- Collect, evaluate and document genetic diversity
- Trial varieties for performance, pest and disease incidence, yield and yield attributes

Aibika *(Abelmoschus manihot)*

- Identify and document existing gardens in the NT
- Trial propagation and growing in the NT climate
- Trial cultivation of aibika/pele varieties for best performance in NT community and school gardens
- Establish in situ germplasm collection in Darwin of locally collected varieties of aibika

Objective 4

1. Developing communication tools on production tips, recipes, picture cards for use in Papua New Guinea, Northern Australia in easy to understand formats.

2. Promotion of traditional vegetables through television and radio programs e.g. “PNG Gardener”, the Saturday morning garden show on ABC Darwin NT, local kitchen/food garden and sustainability programs. Hold booths at exhibitions and shows – taste tests, cooking demonstrations, cooking competitions using traditional vegetables in both Papua New Guinea and the Northern Territory.

3. Evaluating and reviewing communication and extension materials based on findings, results and feedback from growers and the community.

6 Achievements against activities and outputs/milestones

Objective 1: To identify and understand factors in the decline in the production and consumption of traditional vegetables in urban and rural markets of focus areas in Papua New Guinea.

No.	Activity	Outputs/ milestones	Comments
1.1	Surveys & focus group discussions to identify trends and factors influencing consumers.	Report on factors with comparison between rural and urban consumers in focus areas.	**Data analysis and report writing for POM and Buka Surveys** Rural and Urban Consumer surveys completed
1.2	Behavioural analysis of target populations	Recommendations on strategies to reverse any decline adapted to PNG	Urban and rural consumers – target institutions, networks, developed methodology, cultural context, reporting; • Institutional market surveys determined the 5 most popular vegetables: aibika, pumpkin tips, choko tips, amaranth, karakap/nightshade. • Food Diary: The collation of raw data for the wet and dry season of rural and urban survey was completed and the final report completed. • Food habit questionnaire was delivered at 9-mile in peri- urban Port Moresby surveying 7 family groups.
1.3	Review what has been done elsewhere to reverse the trend in declining consumption and production	Report, literature review	Completed and scope expanded in light of grower feedback and needs to focus on seed saving, seed systems and community- based seed banks for traditional vegetables and other important vegetable crops

PC = partner country, A = Australia

Objective 2: To identify opportunities for increasing market demand, market potential, availability and consumption of traditional vegetables in focus areas of PNG

No.	Activity	Outputs/ milestones	Comments
2.1	Map and assess formal & informal supply chains.	Assessment and clearer understanding of supply and any value chains, information flow and markets.	2.1a Mapping formal and informal supply chains • Data collection completed and included: ▪ Surveys of formal and informal supply chains ▪ Formal supply chains through institutional markets and restaurants ▪ A map of the supply chain ▪ Surveys of informal supply chains ▪ Surveys of wet markets 2.1b Market information through market officers – • Assessment on bags brought to market and number of bags bought by vendors – main markets • Data collection complete including ▪ Bag sizes and grading system with a focus is on Traditional Vegetables ▪ The data collected calculates the volume locally available compared to price and how it fluctuates with volume
2.2	Data collection on levels of production and estimated revenue generated.	Analysis of significance of traditional vegetables to the agriculture sector in Central Province	2.2a Assessment of bags sold to market by different grower groups Data collection completed. • FPDA's work with grower groups established volumes weighed and compared with price and where it's being sold • A tracking record achieved through providing training on record keeping 2.2b Baseline information – all sites community questionnaires for growers Baseline information on all sites is completed. Report submitted in 2016.

2.3	Assess potential traditional vegetables for value adding and assess value adding opportunities		2.3. Data collection completed for assessing potential traditional vegetables for value adding and assess value adding opportunities. NARI's Jeromy Kavi presented at a seminar in Bubia on the willingness to pay. • A report was compiled and presented at a seminar for review.

Objective 3: To contribute to increased production, through characterising germplasm, improving production practices, increasing availability of seed and propagation material in focus areas of PNG and Northern Australia

No.	Activity	Outputs/ milestones	Comments
3.1	Gather data to understand production constraints, including pest diagnosis.	Report on the constraints to production.	Surveys and report completed to understand constraints including pest and disease diagnostics, IPM strategies.
3.2	Conduct morphological and genetic characterization and develop seed saving methods.	Report on germplasm diversity and seed saving methods	• Completed morphological characterization of Amaranth & Blackberried nightshade (karakap). • Documentation of passport data completed. • Seed saving methods produced, disseminated through farmer trainings, videos, Toktoks, other extension materials. • Genetic characterization not achieved in the project however done through a master's project by Philmah Seta Waken from NARI. • The seeds to be morphologically characterised passed PNG's biosecurity and the Taiwan BAPHIQ (Bureau of Animal and Plant Health Quarantine) at the end of 2018 and were listed as accessions into the World Vegetable Center genebank in Taiwan. • As an alternative the accessions were characterized in PNG by Ms Philmah Seta-Waken according to the WorldVeg descriptors after her training in WorldVeg. Philmah Seta-Waken prepared a catalogue with the results.

3.3	Design and conduct field trials to address constraints and issues identified by growers in PNG	Improved propagation, pruning and other techniques identified and documented	Cultivar evaluation trials of selected traditional vegetables completed. • Preliminary amaranth & nightshade trial (1st season)- completed • Nightshade confirmation trial (2nd season)– completed • Amaranth confirmation trial (2nd season) – completed – see Appendix for report “the Agronomic Evaluation study of Amaranth (Amaranthus species) in PNG conditions” • Amaranth & nightshade (3rd season) Identification of pests & disease of amaranth & nightshade completed Training was then developed based on this and the following training rolled out: • Seed saving training was provided at 9 Mile kitchen gardens by World Vision staff. The participants included 20 school children, 20 men, and 20 women. The seed saving You-Tube videos designed by NARI and WorldVeg were displayed on the projector as a teaching tool • NARI provided grower training in Bougainville early 2018 • The World Vegetable Entomologist, Dr Srinivasan Ramasamy trained 22 participants from various institutions gained knowledge and skills on various aspects of identifying and diagnosing pests and diseases

3.4	Trial growing aibika in Horticulture compound in Darwin- (2 wet seasons)	Identification and resolution of production problems in the Top End.	3.4.1 Aibika field trials completed at the CDU Horticulture compound 3.4.2 Aibika successfully incorporated into schools including: • 5 Urban Schools - Students were trained on examining propagation and growing methods, as well as cooking demonstrations and nutritional information • 2 Rural schools – Students were trained on examining propagation and growing methods, as well as cooking demonstrations and nutritional information • Flyers collated by CDU providing growing and nutritional information, recipes, and educational activities appealing to children were distributed at each school. 3.4.3 Trials in Rural communities • Aibika introduced into 2 rural schools in the Top End. CDU following up with teachers to monitor the growth of plants under different conditions. • Food Ladder, Katherine. A Community Development Employment Program (CDEP) site where mainly indigenous participants learn to grow Aibika as well as Rungia and Winged bean. • Some feedback received from Food Ladder in Katherine indicated that a major pest - the Giant Termite (*Mastotermes darwiniensis*), was feeding on the aibika. Foodladder commenced trials to control the pest using different manual and chemical controls, with soil improvement and planting away from moist areas giving the best results.

3.5	Distribute into community gardens and school gardens in urban and remote areas of NT	Aibika growing successfully in two urban and two remote community gardens	Aibika cuttings and flyers containing growers guide and nutritional information have been distributed at various community gardens, school gardens, and remote areas. These included: • 5 urban schools • 2 rural schools • Aibika distributed to Jabiru and to a school garden at Timber Creek • 2 community gardens – Alawa community garden and the Mulch Pit, Nightcliff. • Food Ladder, Katherine – a work for the dole program training mostly Indigenous participants Community based activities: In the Northern Territory, cuttings and growing and nutritional information were distributed at more community events. • Botanic Gardens Open Day • CDU Nursery Open Days and Sales, 2015, 2016, 2017, and 2018 • Permaculture classes run at Nightcliff and Alawa. • Food Ladder, Katherine – who now sell TV produce at the markets and in produce boxes sold in across the region • Darwin Agricultural show each year CDU targeted the following community events: • CDU Open Day 2018 • Nightcliff and Rapid Creek Markets

Objective 4: To promote the nutritional, social and economic benefits of traditional vegetables in focus areas of PNG and Northern Australia

No.	Activity	Outputs/ milestones	Comments
4.1	Develop communication tools on production tips, recipes, picture cards for use in Papua New Guinea, Northern Australia in easy to understand formats.	• Posters, & factsheets on crop management, • Easy to prepare recipes using traditional vegetables that maintain nutritional content - Posters and factsheets with comparative nutritional values of common and popular traditional vegetables	4.1. Recipe Book • A Recipe Book called "A Taste of PNG Greens" is complete and in the final stages of editing before release. • The book emphasizes PNG cooking traditions, new ways of preparing select vegetables, and some emphasis on why traditional vegetables are important to PNG culture 4.1.b. Marketing tools for appealing to children: • An Activity book containing colour in and games is complete. The book has been distributed at marketing events both in Darwin and PNG • Illustrations complete of popular traditional vegetables 4.1.c. Plant Files: • Plant Files are complete containing growing and nutritional information as well as recipes • The plant files were trialled at various activities including at a training activity in Bougainville and Botanic Gardens open day in Darwin 4.1.d. Youtube videos of seed saving are being used as training materials. The videos are in simple English and PNG pidgin • 4.1.d Facebook page and Website were used to promote traditional vegetables containing pictures, growing information, and recipes. • See the Facebook page at https://www.facebook.com/Promoting-PNG-Traditional-Vegetables-897906590297596/?ref=bookmarks • The Website: http://traditionalvegetables.cdu.edu.au/

4.2	Promotion of traditional vegetables through television and radio programs. Hold booths at exhibitions and shows.	Communication materials available on website and Facebook Taste tests, cooking demonstrations in PNG and NT	The website http://traditionalvegetables.cdu.edu.au/ contains links to marketing materials including the Recipe Book, kid's activity book, and the Plant File series. Promotional events have included: PNG • APEC conference in Port Moresby to promote PNG traditional vegetables hosted by Maria Linibi from PNGWIA • Another APEC booth to promote TV's is planned for August 2018 • NARI Open Day – PNGWiA and NARI held Traditional Vegetable Booths. The children's' activities and recipes books were distributed • PNGWiA formed a MOU with the Kangaroo Foundation – Training was provided to remote communities in the Highlands on how to grow and cook traditional vegetables • NARI family farmer training in Bougainville – Gena from NARI delivered training on growing traditional vegetables. As a trial, the Plant File series was used as part of training tools • World Vision ran a seed saving training activity at the 9 Mile Kitchen Garden. The training was in May 2018 and included a mix of participants including 20 children. The YouTube seed saving videos were put on the projector

			Northern Territory • Aibika and rungia have been provided to wholesale and retail nurseries and are stocked at Bunnings in Darwin and Palmerston • Food Ladder, Katherine is now commercially growing Aibika, Winged Bean, and Rungia. Food ladder is a Community Development Employment Program (CDEP) training mainly indigenous participants. There are plans for the vegetables to be grown in Arnhem Land when Foodladder expand their operations in early 2019. For more information: https://www.facebook.com/foodladder/ • Food ladder has started selling produce and disturbing marketing materials to local Katherine buyers including a local café. • Radio talks were delivered including Territory FM, Radio National, the ABC Country Hour which can be heard at http://www.abc.net.au/radio/programs/nt-country-hour/nt-country-hour/9411846 • Botanic Gardens Open Day – plants files, cuttings, and plants were distributed along with taste tests. The draft Recipe book was on display – over 50 people requesting copies of the book. • CDU Nursery sales – PNG vegetables including rungia, aibika, and winged beans were distributed • ABC Gardening Australia TV segment on growing and cooking with aibika. Ten videos on seed saving methods for PNG and northern Australia were prepared in PNG local language Tok Pisin and English. The video links are: • Wei bilong kamapim Karakap Sid na lukautim bilong bihain taim (How to save nightshade seeds) • Wei bilong kamapim Tomato Sid na lukautim bilong bihain tain (How to save tomato seeds) • Wei bilong kamapim pamkin sid na lukautim bilong bihain taim (How to save pumpkin seeds)

			• Wei bilong kamapim Aupa Sid na lukautim bilong bihain taim (How to save amaranth seeds) • Wei bilong kamapin Ekplen Sid na lukuatim bilong bihain taim (How to save eggplant seeds)
4.3	Evaluate & review communication materials	Revised and updated communication and extension materials	The recipe book, activity book, and plant files were distributed to growers in PNG, and to the general public during various promotional events.

7 Key results and discussion

Overview

Traditional vegetables were found to be valuable in terms of nutritional value, their economic contribution to farmer incomes and cultural significance, to potential climate change mitigation strategies, and in terms of their unique biodiversity value.

The perceptions around traditional vegetables were found to be that people considered them as backward, unsophisticated village food that is only eaten by poor people, driving a shift in preference towards more modern store-bought foods, and an increasing market demand for introduced crops. There was also found to be a perception among women growers that introduced vegetables were better and more nutritious than traditional crops such as aibika. A consequence of these consumer and grower perceptions is an increasing market demand, and an increase in planting of cash crops near villages pushing out traditional home gardens to less accessible and arable land.

Interestingly people also considered some of these vegetables as culturally significant and important components of ceremonial occasions, and there was a reported loss of these food traditions among the growing urban population.

The most common ad popular traditional vegetables were ranked according to five criteria to determine which were the most important:

Table 4: Ranking of relative importance of the main traditional vegetables of PNG

Crop	Market Availability	Nutritional Value	Ease of propagation	Consumer Preference	Profitability	Score
Aibika	5	5	5	4	5	24
Choko	5	3	5	5	5	23
Pumpkin Tips	5	5	5	4	4	23
Watercress	4	5	5	4	5	23
Amaranth	5	5	5	3	4	22
Rungia	5	4	4	4	5	22
Lowland Pitpit	4	3	4	5	5	21
Water dropwort	4	3	5	4	4	20
Fern	5	5	2	3	3	18
Karakap	3	4	3	4	4	18
Too-lip	4	4	1	4	4	17
Winged Bean	1	4	3	4	5	17
Fig Leaves	2	3	1	4	4	14

Highland pitpit	1	1	5	3	4	14
Walangur	1	3	5	3	2	14
Breadfruit	3	3	1	3	3	13
Bamboo shoots	1	1	1	3	3	9

Research Question: What are the factors influencing consumption of leafy traditional vegetables and what can be done to increase consumption?

Figure 2: Framework for Objectives 1 and 2

Objective 1: To identify and understand factors in the decline in the production and consumption of leafy traditional vegetables in urban and rural markets of focus areas in PNG

Methods

Activity 1.1 Surveys and focus group discussions to identify trends and factors influencing consumers

Activity 1.2 Behavioural analysis of target populations

Over 200 surveys were conducted to understand the drivers of consumer, grower and market preferences and demand for traditional vegetables in urban, peri-urban and rural areas. Quantitative surveys were used to measure:

- Purchasing decisions
- Consumer and grower demographics
- Consumer motivations and expectations
- Loyalty segments

Food diaries were used to record consumption of traditional vegetables over a period of seven days, recording all meals taken in both urban and rural consumers. The sites for this activity was conducted with 33 families, and over a dry season and wet season period. These were followed up with semi-structured interviews.

Table 5: Urban Consumer Surveys and Income Strata

Income group/Strata	Assumed shopping locations as proxies for income grouping
High Income Earners (more than 3000 Kina/fortnight)	Boroko Food World and Water Front (Super Markets)
Middle Income Earners (1500 Kina/fortnight)	Vision City (Super Markets)
Low Income Earners (less than 300 Kina/fortnight)	Open Markets -Gordons, Koki, Maloro and Gerehu

In Port Moresby where urban consumer surveys were conducted, questionnaires were pre-tested at Boroko Food World, Vision City shopping centres, and Gordon's open market. The pretesting highlighted some gaps in understanding and the following improvements were made:

- Photos of each vegetable were included
- The approach of the enumerators was modified to set the team up at tables in supermarkets and open markets
- Information posters and materials were developed to include in a display about traditional vegetables where they surveys were being conducted

The Port Moresby surveys were further divided into the following cohorts:

- 100 respondents from open markets – Gordons, Maloro, Koki, Gerehu
- 50 respondents from supermarkets – Boroko Food World, Water Front, Vision City
- 41 respondents from institutions – Gerehu Seventh Day Adventist Church, NARI, NAQIA, PAU, UPNG
- Gender breakdown: 114 female / 77 male

For rural consumers, over ten villages in two districts were surveyed, Kairuku-Hiri and Rigo districts. Two hundred consumers were targeted in these areas, with the criteria that respondents be over the age of 18 years and consuming vegetables or farming vegetables.

Table 6: Rural consumer and grower surveys locations, numbers and gender

Villages	Number of Respondents
Saroa Keina- Magi Highway	35 (25F + 10M)
Karekodobu – Magi Highway	41 (23F + 18M)
Ibunato – Magi Highway	16 (10F + 6M)
Kwikila Station- Magi Highway	33 (20F + 13M)
Seme – Magi Highway	19 (10F + 9M)
Kuriver- Hiritano Highway	16 (10F + 6M)
Kerea – Hiritano Highway	26 (12F + 14M)
Vemauri, (Akuku & Lalako) Hiritano Highway	25 (18F + 7M)
Total	211 (128F + 83M)

Results

The most commonly consumed traditional vegetables for the Port Moresby respondents on a weekly basis were:

- Pumpkin tips 86%
- Aibika 73%
- Aupa (amaranth) 68%

All income range consumers preferred pumpkin tips, aibika and amaranth, where taste was the most important factor. A lack of familiarity was cited as a common reason for people not purchasing traditional vegetables, and not knowing how to prepare them. The surveys indicated that an increased understanding of the nutritional benefits of these vegetables would increase the likelihood of people buying these vegetables. Respondents cited Gordon's open market as the most preferred place to buy vegetables.

The most commonly consumed traditional vegetables for Buka – Bougainville respondents on a weekly were:

- pumpkin tips and choko tips 66%
- aibika 64%
- karakap (nightshade) 54%

The vegetable being the main ingredient in a common dish was the most important factor, while lack of availability and lack of familiarity were the two main reasons for not purchasing traditional vegetables.

The results of the rural surveys showed that the most commonly consumed traditional vegetables were:

- pumpkin tips 100%
- aupa (amaranth) 98%
- aibika 98%
- lowland pitpit (88%)
- fern tips (87%)
- tulip (83%)
- fig leaves (74%)

For rural consumers taste was the most important factor, and the same issues as for the urban consumers for not purchasing or consuming traditional vegetables, that is a lack of familiarity with cooking and preparation. The rural surveys also indicate that people would consider consuming a wider range or more frequently if they thought the vegetables had a higher nutritional content.

Overall there was no significant difference in the perceptions and attitudes of urban and rural consumers, however the levels of consumption appear to be higher in the rural respondents, and a wider range of traditional vegetables consumed more frequently.

Other findings from this objective indicated:

- a lack of knowledge among growers on post-harvest handling, packaging and transport of soft leaved vegetables;
- high costs for transporting vegetables from farm to market;
- unreliable transport connections in rural areas and long timeframes to get produce to market or institutional buyers.

The findings from this objective were then used to select the pumpkin tips, aibika, and amaranth supply and value chains as priorities for further study. The results also confirmed the need to increase awareness of the nutritional value of traditional vegetables and a need for cooking demonstrations, taste testing and recipe development.

The project initially commenced working in Buka Bougainville and collected data on consumer preferences and traditional vegetables from local consumers and markets. The results of these surveys are included here. The project was not able to continue working in Buka as our partners World Vision withdrew from activities there. The project team followed up with training and linking with the ACIAR family teams project on Women's Business Acumen.

Activity 1.3 Review what has been done elsewhere to reverse the trend in declining consumption and production

The initial scope of the literature review was expanded to focus on seeds and seed systems as a result of the findings and feedback from Objectives 1 and 3; which highlighted the need for seed security, conservation of indigenous germplasm and the establishment of local and national systems to secure access and availability of quality planting materials.

Feedback from growers, team members and other collaborators highlighted the lack of access to quality seed for both traditional and introduced vegetables as a major constraint to sustainable crop production, and a risk in times of drought, disease outbreaks, conflict and market failures. Many growers currently rely on imported seed which is unreliable in supply and often with low seed viability. Establishment of local seed production would provide more reliable and more easily accessible seed sources, enable small business opportunities and build a higher degree of food security. The safe collection, storage and conservation of a diverse variety of vegetable and crop germplasm through seed saving systems is essential for improving national and local food security, technology development and conservation of genetic diversity while contributing to protecting local livelihoods.

Research Question: What is the market potential and market demand for leafy traditional vegetables, what are the value chains and how can production and availability be increased?

Objective 2: To identify opportunities for increasing market demand, market potential, availability and consumption of leafy traditional vegetables in focus areas of PNG.

Methods

With reference to the framework developed for Objectives 1 and 2, activities under this objective included mapping the value chains for selected traditional vegetables identified in objective 1, surveying and interviewing buyers, sellers and middlemen in the chains, surveying and interviewing growers to better understand their strengths, weakness and points where interventions could have an impact to improve incomes and livelihoods.

Before these studies were conducted, the supply and value chains for traditional vegetables were not understood, and the volume of traditional vegetables sent to markets and transacted in the markets was not known.

Activity 2.1: Map and assess formal and informal supply and value chains

Activity 2.2 Data collection on levels of production and estimated revenue generated

The methods and data collection overlapped for these two activities and are presented here as a combined summary.

Semi structured interviews were conducted to map the chains to identify the main activities and the key actors in each chain and who performs these activities, and the links to each other step in the chain and their interdependence on each other. It involved mapping each chain from the grower all the way to the final consumer of the product, and mapping the key people involved in each specific value chain.

Eight formal institutions were surveyed and interviewed:

- CPL group – City Pharmacy Ltd, a leading wholesale and retail organisation in PNG
- RH Hypermarket – Rimbunan Hijau wholesaler with more than 50 retail outlets across PNG
- Boroko Food World – supermarket and shopping mall
- Green Fresh - wholesaler
- Jmart – supermarket chain
- Papindo – supermarket and department store retail chain
- NCS – catering services for mining companies, airlines, educational institutions and government agencies

Three Kaibars (take-away food bars) were interviewed:

- Michina restaurant
- Feyang restaurant
- Jmart Kaibar

Surveys were conducted at four informal open markets around Port Moresby:

- Gordons
- Waigani
- Koki
- Malaoro
- Mini - one roadside market in Waigani

Market surveys were designed to understand the reasons behind any shortfalls and dissatisfaction of consumers according to service providers and business owners/retailers. This would also serve to evaluate the need for training in post-harvest handling and business skills to improve income generation opportunities.

Consumer surveys were designed to determine the level of availability and satisfaction with traditional vegetables on offer in the marketplace, and to identify areas in the market where there was an unfulfilled demand or that could be improved with additional support or training.

Data collection forms were used to gather information from growers and sellers at local urban markets, from growers on their farms, and weighing scales were introduced and used to standardise weights when growers and sellers were discussing the volume of produce transacted.

Extra work was done to collect data on the market prices for a range of traditional vegetables where the Fresh Produce Development Agency staff conducted wider price and market surveys. This information was gathered to compare prices achieved in markets in different locations.

Results

Table 7: Market survey results to determine sources of dissatisfaction and potential interventions

Source of dissatisfaction	Opportunities for intervention	Project intervention
Lack of supply	Increase in demand for Aibika is recorded in the institutional markets study Demand for Aibika and Kangkong is high during dry seasons No formal arrangements made with buyers but once agreed majority farmers supplied the produce.	Karekodubu farmers have informal agreement to supply Aibika twice a week to NCS. Facilitation to maintain commitments to supply.
Lack of understanding on the volume, price and business	Record keeping of production and sales Weighing scales to record the volume sold to the wholesaler	Training provided on financial literacy. Continuous mentoring to use weighing scale to record volume of produce.
Lack of understanding of packaging for specific volumes	Market study conducted to identify various packaging bags and their weights	Standardised the weights when growers mentioned volume of produce transacted.
Lack of understanding on pest and disease management	Training on pest and disease management.	Training on pest and disease management provided to farmers in selected sites.
Spreading of pests and diseases through seed exchange	Seed saving techniques	Training conducted on seed saving techniques and nursery management skills.
Lack of understanding of the nutritional value of produce	Awareness on nutrition value of traditional vegetables Cooking demonstrations. Community kitchen garden.	Awareness on nutritional value provided in most sites. Cooking demonstrations conducted in most sites. A community food garden was established at 9-mile site.

Photo 1: Community food gardens established at 9 Mile, Port Moresby

Photo 2: Intervention of drip irrigation method in community garden in 9 mile.

Figure 3: Mapping traditional vegetables flows in informal systems

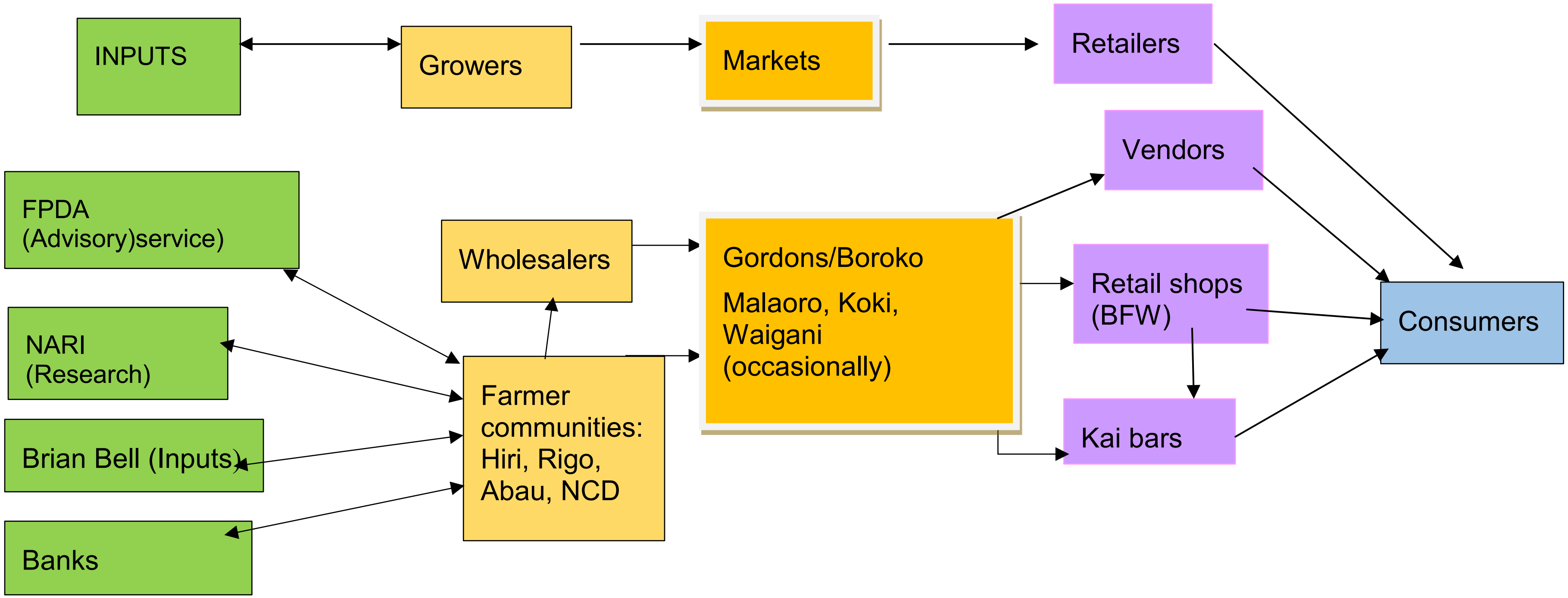
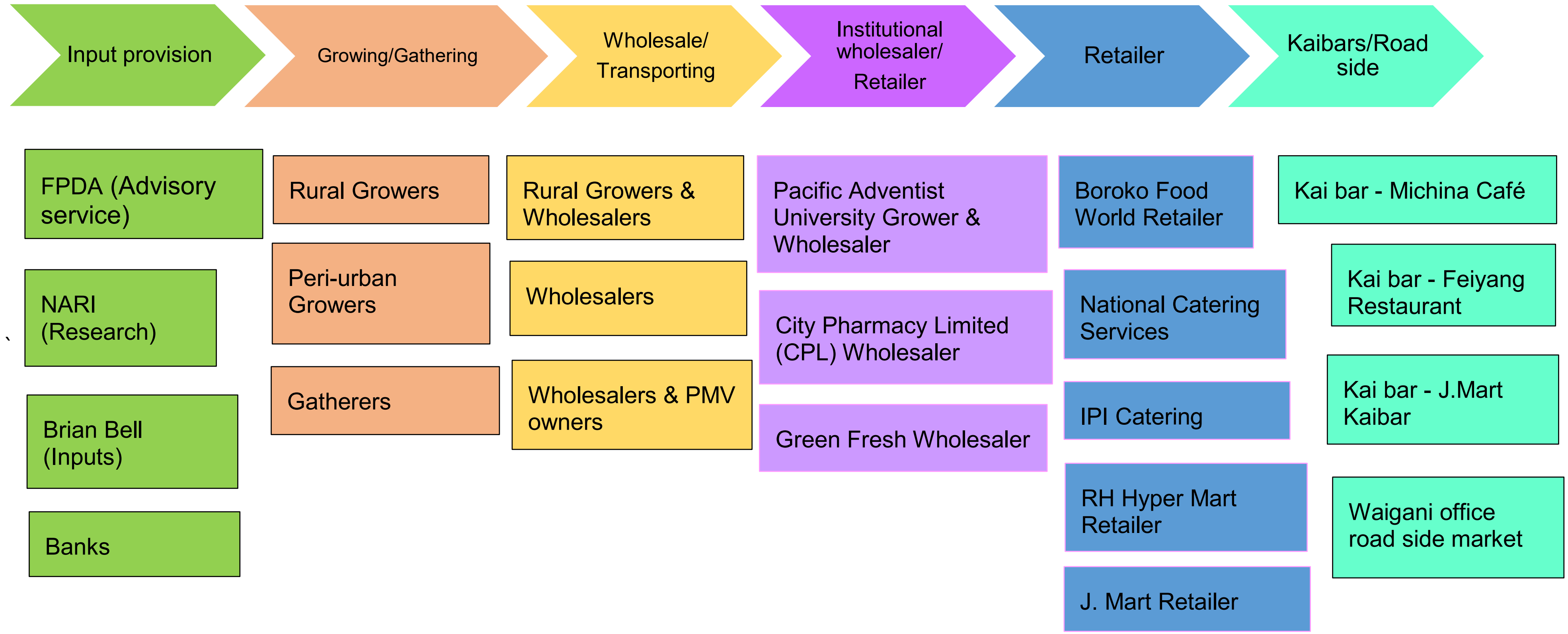


Figure 4: Mapping traditional vegetables flows in institutional markets (formal)



The surveys and interviews conducted found the following volumes and values for traditional vegetables

- *Formal institutions*: 1.83 tonnes of traditional vegetables were supplied each week to the eight formal institutions, primarily aibika, amaranthus (aupa), Kangkong, and choko tips. This equates to 95.2 tonnes annually supplied into the formal chain, with an estimated value of PGK 376,800.
- *Kaibars:* Weekly supply was 0.07 tonne of aibika, amaranth (aupa) and kangkong, with an annual volume of 3.64 tonnes at a value of PGK 14,400.
- *Informal open markets*: Weekly supply was 84.7 tonnes of aibika, amaranth, kangkong and bush fern, with an annual volume of 4,406 tonnes with an estimated value of PGK 17,4000
- *Roadside market:* weekly supply of amaranth was 0.02 tonne, with an annual volume of 1.04 tonne and an annual value of PGK 40000.

Table 8: Summarised total volumes and values for each crop

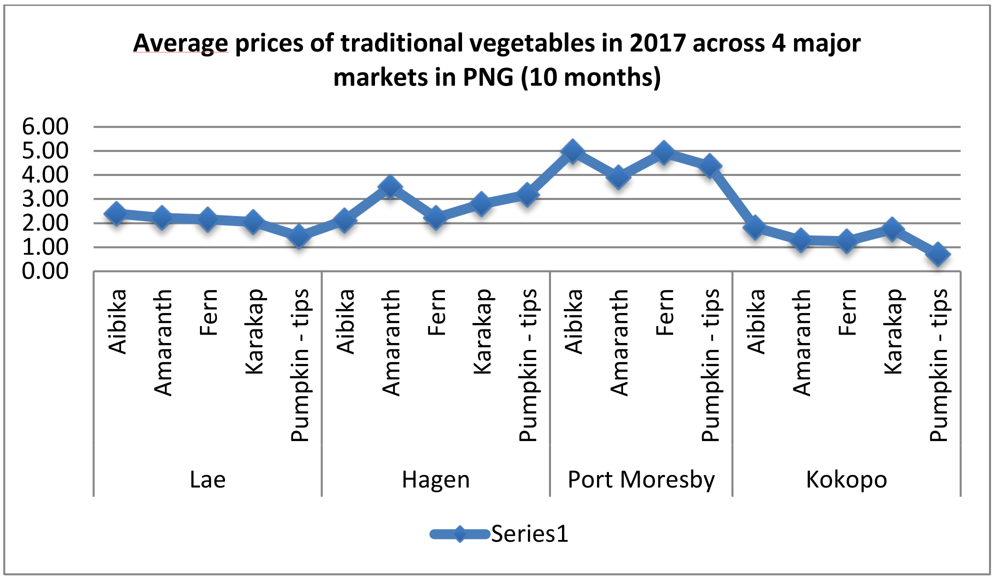
Crops	Estimated weekly volume (Kg)	Estimated Annual Volume (t)	Estimated Annual Income (Kina)
Aibika	40,300	2,097	6,287,800.00
Amaranthus	2,830	147	441,480.00
Bamboo shoots	No data	No data	No data
Bush Fern	8,187	426	1,277,172.00
Fig leaf	No data	No data	No data
Kangkong	4,100	213	639,600.00
Pumpkin tips	9,640	501	1,503,840.00
Tulip	No data	No data	No data
Water cress	No data	No data	No data
Total Volume	**105,357**	**3383**	**10,148,892.00**

Table 9: Annual volumes and income generated for farmers around NCD

Farmer*	Volume(Kg)	Unit Price	Traditional vegetables	Value (Kina)
1	51,464	K3.3	Aupa, Kangkong, Aibika	169,831.20
2	17,160		Fern, Tulip, Aibika	43,350.00
3	4,800		Aibika	6,400.00
4	19,200		Aibika	24,000.00
5	9,200	K2.0	Aibika	18,400.00
6	4,800	K3.3	Aibika	15,840.00
TOTAL	**106,624**			**272,821.20**

**grower identities removed*

Figure 5: Results from market price surveys of traditional vegetables in key markets in PNG



Discussion

Prices are highly dependent on the level of supply which is largely influenced by the wet and dry seasons. Prices of traditional vegetables are relatively higher in Port Moresby than in the three other centres where price surveys were conducted. Aibika appears to be the highest value traditional vegetable for coastal markets, whereas amaranth appears to achieve relatively higher average prices in the Highlands (Mt Hagen). Aibika is the leading indigenous vegetable with the highest demand and production levels.

There are communication barriers between growers and middlemen (often women) or aggregators, and these aggregators/vendors in the informal and open markets are very aggressive with growers to pressure them to sell at the most advantageous prices for the aggregators. There is a level of resentment among growers who often prefer to try and sell in the market themselves and risk a lower return rather than sell to the middlemen (called ‘black marketeers’).

Transactions with the formal institutional buyers are based entirely on verbal agreements, and payment is on a cash basis or direct bank deposit, although NCS pays by cheque 2-3 weeks after receipt of produce. There are no formal agreements or contracts between institutional buyers and sellers, and therefore growers sometimes miss out on selling their produce if they are not the first ones at the door in the morning. Growers are often disadvantaged by poor transport systems, if the local PMV’s are full, late or broken down then growers miss out on the opportunity to take their produce to the buyers.

In one of the research sites, Karekodobu, there is one dinghy to transport produce across the river to the roadside for five growers, meaning a long timeframe each morning to get the produce to the buyers.

There have been successes out of this project. The Karekodobu farmers have been supplying traditional vegetables to the institutional buyers on a fortnightly basis since January 2017. They are now primarily supplying NCS with 200kg of aibika, 100kg of amaranthus, and 100kg of kangkong each fortnight.

Training on agronomic practices, post-harvest, and financial literacy and gross margin analysis have led to higher levels of production and improved quality and consistency, and consequently better incomes for these growers.

The NCS buyers commended the project team for assisting the Karekodobu growers to meet their requirements of volume, quality and consistency which had been ongoing constraints for the growers.

Further work needs to be done on supporting and developing the commercial production and marketing of aibika and other traditional vegetables.

Through this project the Fresh Produce Development Agency commenced regular collection of market information and prices of traditional vegetables and have committed to continue monitoring these vegetables across the five major markets as part of their service to growers, with a view to expanding surveys and data collection on traditional vegetables into more markets.

Activity 2.3 Analysis of potential traditional vegetables for value adding and assess value adding options

This study focused on the potential of choko tips for value adding. Choko tips are time consuming to clean, peel and prepare for cooking. They are a very popular vegetable, however feedback from consumers was that the time need to peel and prepare the vegetables was a deterrent.

The aims of this study were to:

- determine the amount and quantity supermarkets/institutions are willingness to pay for pre-cleaned choko tips including willingness to accept the process carried out by farmers.
- determine the priced based amount willing to be paid, the quantity demand and develop understanding of the margins between each players in the chain.
- determine the current demand and supply situation, factors affecting production and marketing and to find out if pre-cleaning and peeling could increase demand for choko tips.

Method

The team used the 'Willingness to pay' method for this study. Willingness to pay (WTP) for a product is defined as the amount of money an individual or household is willing to pay for the purchasing of a product given her/his income, risk preference and other characteristics.

WTP is generally analysed using the Contingent Valuation Method (CVM) and it helps to estimate the value an individual places on a good, usually an intangible good.

CVM was initially designed to value public goods and services like environment and health care programs however it has now been widely used to value private market goods and services including organic agriculture food products. CVM is now increasingly being used to value private market goods and services (Lusk and Hudson 2004); it also has been applied to value organic food products and indigenous vegetables. The study was broken into two phases:

Phase 1: Willingness to Pay Study

- Location of the Study: Lae, Morobe, PNG.
- 9 Institutions were selected non-random selection (Purposeful sampling)
    - 4 Supermarket, 4 Hotels, 1 Catering Company
    - Data Collection instrument used: Interview Questions (Pretested)
    - Data Analysis: descriptive Analysis using excel- institutional WTP

Phase 2: Trials

- Trials to be done with Institutions willing to participate
- Analysis of supply chain in Mumeng Districts (and Markham farmers)
- Data collection (observations, interviews, FGD and value chain analysis)
- Contingency Valuation (Individual WTP/WTA) using SPSS

Results

- Catering Companies: e.g. IPI-Unitech does not use choko tips
- Hotels: Some serve traditional dishes occasionally while others don't serve them.
- Educational Institutions: Choko tips quite impossible to deal with large quantities because it is laborious and when cooked it loses its form and shape.
- Supermarkets: Willing to pay and are the only ones buying and reselling

- Supermarkets are willing to pay for pre-cleaned choko tips at a market margin of 50t
- Farmers change of practice specifically on post-harvest allows a profit of 30 to 40 toea per bundle of choko tips.

Discussion

There was a lack of awareness at supermarkets and catering companies and individual consumers on the potential for pre-cleaned and peeled choko tips. Some businesses were not willing to share their market data on the amount of choko tips used or transacted. Another issue was the sample size (institutions) is very small for this very specific data analysis.

Pre-cleaning and marketing has never been done at the supermarket level before, and so is potentially a way forward to promote choko tips. Pre-cleaning add value needs further negotiation and promotion to be accepted by the supermarkets and other institutions. Understanding of price margin is important to be able to work out the amount willing to be paid to be paid by supermarkets.

Research Question: How can current leafy traditional vegetable production practices be improved to increase quantity and availability, quality and safety?

Objective 3: To contribute to increased production, through characterising germplasm, improving production practices, demonstrations, community gardens, better seed and propagation material availability in focus areas of PNG and Northern Australia.

Activity 3.1 Gather data to understand production constraints, including pest diagnosis

Method

Interviews with growers, surveys, site visits and field surveys were undertaken by the team to understand constraints that growers are facing in producing traditional vegetables. Insect pest and disease samples were collected for identification by NARI entomologists and WorldVeg.

A staff member of the entomology team from the Department of Agriculture and Livestock undertook one month of training in vegetable pest and disease diagnosis, including survey methods, rearing insects for identification, and integrated pest management at the World Vegetable Center in Taiwan.

Results

The team undertook field surveys and pest and disease sampling to establish a list of economically important pests of aibika, amaranth and karakap (nightshade), and entered reference specimens of pests from aibika, amaranth and nightshade into the PNG National Agricultural Insect Collection and database. The results of this activity summarised

- More than 1200 insects recorded over the month of November 2016
- Most abundant – weevils (*Hypolixus* sp.) & brown coreid bugs mostly observed copulating.
- Greatest damage to plants caused by – leaf chewing & shot holes.
- Other minor diseases– leaf curling, burning at leaf edges, leaf mines, leaf rust (scales 1 – 3).
- Beneficial insects (wasps, bees, assassin bugs) observed in the mornings.
- All 27 accessions showed good tolerance of P&D (scales ranging from 1-3 / 5)

- Establish economically important pests of amaranth so appropriate IPM can be sought.
- All trialled amaranth accessions tolerant to amaranth pests & diseases (scoring scales between 1 – 3).
- Addition of reference specimens to National Agricultural Insect Collection for future amaranth work

The team then collaboratively developed participatory IPM strategies for growers of amaranth and nightshade and trialled these with growers. When the IPM strategies were finalised, the team then held training for growers on pest and disease monitoring and identification, integrated pest management strategies and how to implement it on farm.

Five key steps in selecting treatments for pest management were recommended to growers:

1. Seedling monitoring
2. Monitoring in field to watch for changes
3. Cultural practices such as hand-picking pests, allowing chickens to roam, selecting tougher/resistant varieties, reduce stress on plants by regular water where possible, increase soil organic matter and apply fertilisers
4. Bio-pesticides
5. Chemical pesticides as the last choice

Two treatments for fungal/bacterial/viral diseases of crops were recommended to growers:

- Control/avoid the vectors, or
- Plant resistant/tolerant crop varieties.

The team followed this up with a training for extension workers and trainers on pest and disease diagnostics and applying integrated pest management for aibika, amaranth and nightshade.

Discussion

The outcomes of these activities were exposure to new technologies and skills of pest diagnostics and integrated pest management for NARI staff, extension staff and growers themselves and a clearer understanding of the economic pests of key traditional vegetables. The IPM approach emphasises a shift away from chemical pesticides and incorporates the idea of working out the cost of the damage against the cost of treatment and control, and choosing the best methods for the situation.

Exposed to different approaches of entomological research and types of help that can be sourced from the World Vegetable Center and other experts. A good outcome of this activity was learning of the resources and assistance available to FPDA and NARI staff to assist them to provide accurate and appropriate advice to growers on pest and disease treatments and controls.

The NARI staff member who attended the one-month training at World Vegetable Center gained new skills and knowledge on insect rearing techniques for pest diagnostics and improved ability to recognise some common plant diseases. She also gained exposure to laboratory protocols in the entomology, mycology & bacteriology, and virology laboratories at the World Vegetable Center in Taiwan.

Activity 3.2 Conduct morphological and genetic characterisation for key traditional vegetables and develop seed saving methods

The purpose of this activity was to characterise locally utilised germplasm to select elite varieties for better consumer acceptance and higher nutrition value and recommend locally adopted seed saving and propagation methods.

One staff member from NARI undertook a 3-month placement at the World Vegetable Center in Taiwan to be trained in morphological and genetic characterisation from March to June 2016. This work was carried out in Taiwan and PNG using local varieties successfully sent to Taiwan. The genetic characterisation was not able to be completed due to time constraints in sending shipments of seeds to Taiwan, however the genetic characterisation work has been continued on by Philmah Seta-Waken as part of her studies at the University of Queensland as part of this project and results are expected mid-2019.

Method

Seeds of 4 crops collected from the Highlands, Autonomous Region of Bougainville (AROB) & Central Province (CP) and sent to the Wold Vegetable Centre in Taiwan for further work on genetic and morphological characterisation. Seeds were collected by NARI Staff at Aiyura & Laloki and World Vision International staff in AROB and stored at the agricultural research station in Laloki, Port Moresby.

1. Amaranth
2. Nightshade
3. Winged bean
4. Pumpkin

Further detailed work was undertaken on amaranth and nightshade. Aibika has already been the subject of much research as it is the most widely eaten, grown and sold traditional vegetable in PNG and the Pacific. There is an existing in situ germplasm collection of aibika in the Sourthern Regional Research Station of NARI in Laloki and other sites in PNG. To date there had been no work done on amaranth (aupa) or nightshade (karakap).

Amaranth seeds were grown out and flowers were collected from amaranth accessions at flowering stage. Flowers were examined and photographed using an Olympus CMOS Camera SC30 mounted on an Olympus light microscope. A descriptor list and taxonomy key list developed by the World Vegetable Center Gene Bank Unit list was used to identify different species depending on position of the tepals on the tower of the flower.

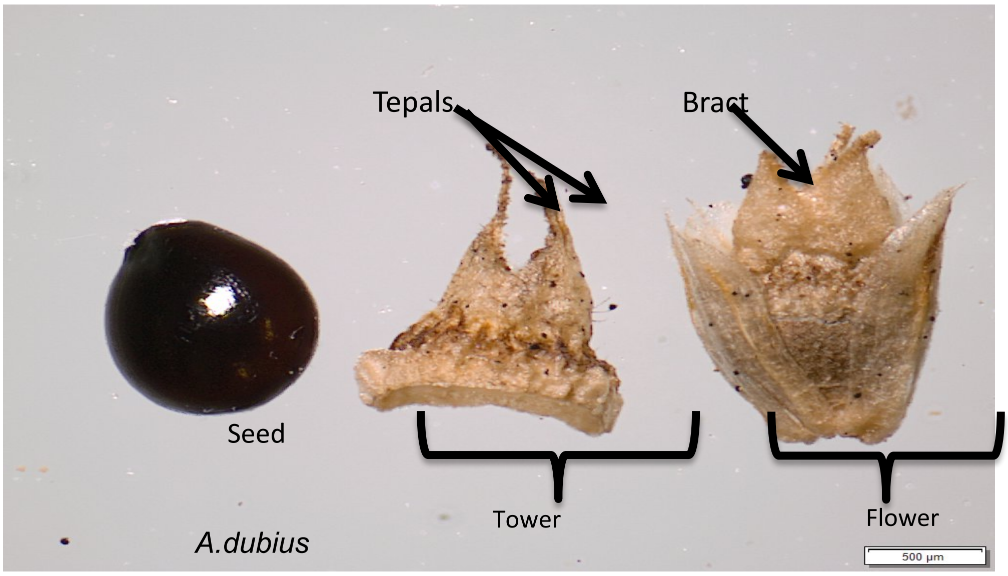


Figure 6: Morphological species identification of *Amaranth* sp.

Seeds of nightshades were also cultivated and multiplied. Morphological characterization was conducted to identify and confirm species of nightshade collected from two provinces.

Results

A total of 25 accessions of amaranth were collected.

- 13 accessions from the Eastern Highlands Province.
- 3 accessions from the AROB.
- 9 accessions from the Central Province.

A total of 3 Nightshade accessions were collected.

- 1 accession from the Central Province.
- 2 accessions from the AROB.

A total of 18 accessions of winged bean were collected.

- 1 accession from each of Central Province, AROB, Morobe Province
- 15 accessions from the Eastern Highlands Province.

A total of 39 accessions of pumpkin were collected.

- 26 accessions from the Eastern Highlands Province.
- 4 accessions from the AROB.
- 8 accessions from the Central Province.
- 1 accession from the Morobe Province.

Documentation of passport data for amaranth and nightshade was completed. Seed saving methods were developed for each and disseminated through grower training, extension officer training, videos in Tok Pidgin and other extension materials.

For the amaranth specific work, 18 out of the 25 local accessions were characterised and morphological differences documented, with five different species identified and resulting in the establishment of a PNG amaranth species list:

1. *Amaranth blitium* – 2 accessions
2. *Amaranth caudatus* – 3 accessions
3. *Amaranth cruentus caudatus* – 3 accessions
4. *Amaranth dubius* – 2 accessions
5. *Amaranth hypochondriacus* – 3 accessions

For nightshade specific work, all three accessions collected from Central Province and AROB were confirmed to be of the one species: *Solanium nigrum.*

Discussion

This activity resulted in the establishment of a PNG amaranth characterization database, which has been included in the World Vegetable Center database, and confirmed the presence of many different amaranth types in PNG. There were no PNG accessions of amaranth, nightshade and pumpkin in WorldVeg Gene bank, and a search revealed none in any other international genebanks.

Some of the key learnings from this activity were the process required to send germplasm to other countries, and the biosecurity issues and processes that were required to be addressed.

Some of the challenges were slow communication between NAQIA in PNG and BAPHIQ in Taiwan. The germplasm was received in Taiwan at the end of 2018, after commencing the process in 2015-16. The PNG germplasm will be conserved in WorldVeg Genebank, and provides the opportunity for collection of other traditional vegetables of PNG for conservation now that the protocols, procedures and pathways have been established for sending germplasm from PNG to Taiwan. NARI staff gained skills in the techniques of morphological characterization, basic techniques and skills of molecular characterization of vegetables, and developed an understanding of the function & roles of genebanks in vegetable research, and the critical importance of germplasm conservation.

Activity 3.3 Design and conduct field trials to address constraints and issues identified by traditional vegetable growers in PNG.

The purpose of this activity was to use the results and findings from previous activities to including the characterisation work to identify locally utilised germplasm to select elite varieties for better consumer acceptance and higher nutrition value and recommend locally adopted seed saving and propagation methods.

Method

Step 1. Planning and designing of field trials using recommended varieties from World Vegetable Center and from local collections.

- Amaranth – 10 (R), 25 (L)
- Nightshade – 10 (R), 3 (L)
- Trial design – Randomized Complete Block Design (RCBD).

Step 2: Preliminary Variety trials using methods for varietal screening of amaranth and nightshade:

Preliminary Trial Selecting for the following agronomic traits:

- Pest and disease incidence
- Yield & yield attributes
- Seed production potential and seed bulking

Advanced Trial:

- Cultivar evaluation trial

Step 3: Seed multiplication (production & saving) trials with amaranth and nightshade. For amaranth the following steps were followed:

1. seeds harvested when leaves changed colour & drying
2. Put into net bags and air dried for 2 weeks
3. Threshed and winnowed
4. Seeds packed in net bags and stored in a dry place

For nightshade the following steps were followed:

1. Seeds harvested when changed colour
2. Seeds put into net bags
3. Fermented for 2 weeks
4. Crushed & washed
5. Seeds were dried
6. Seeds cleaned and stored

Results

- Selection based on good agronomic traits for high yielding, pests & disease resistance, taste, & market quality

- Different accessions were found to have differing rates of seed production
- New and improved seed saving techniques were developed from this activity and introduced to field staff.

Amaranth (aupa)

- 15 varieties of amaranth were selected for the advanced trial
- Eight promising amaranth accessions identified.
- Amaranth varieties with the highest branching index were found to be highest yielding
- 2 recommended amaranth varieties from WorldVeg failed to flower

Nightshade (karakap)

- 6 varieties were evaluated.
- 3 promising nightshade accessions identified

Photo 3: Amaranth field trials at Southern Regional Center, NARI, Laloki Port Moresby

Discussion

Methods and processes for seed bulking need to be developed for more advanced and regional trials. Currently in PNG there is a lack of appropriate and proper seed storage facilities within the country. There is a need to expand the seed multiplication plots and expand the work done on germplasm conservation and documentation for indigenous and traditional vegetables in PNG.

In addition to the above work, the World Vegetable Center team prepared and sent 1,000 home gardening seed kits to NARI in PNG. These seed kits are developed to distribute to farmer families to improve their diets and incomes through a better use of traditional vegetables.[14] Each seed kit included three seed packs of traditional vegetables for 30 m^2 cultivation and a gardening leaflet and a recipe booklet to grow and eat traditional vegetables. Seed kits with 20 different combinations of three traditional vegetables each will be distributed randomly to farmers for on farm evaluation. The Tricot[15] method developed by Bioversity International for variety selection will be applied to evaluate the preference of farmer families for different traditional vegetables.

The different combinations are to be distributed randomly to farmers for on farm evaluation following the Tricot[16] method developed by Bioversity International for variety trials with plans to test the method for comparing traditional vegetables.

Photo 4: Seed kits prepared by World Vegetable Center ready to be shipped to PNG

---

[14] Schreinemachers P, Brown S, Roothaert R, Makamto Sobgui C and Toure SH (2018) Research to impact: the World Vegetable Center's household garden model. Acta Horticulturae 36:305–314.

[15] Etten, J V, Eskender B, et a (2016) First Experiences With A Novel Farmer Citizen Science Approach: Crowdsourcing Participatory Variety Selection Through On-Farm Triadic Comparisons Of Technologies (Tricot), *Journal of Experimental Agriculture* Dec 2016 https://doi.org/10.1017/S0014479716000739

[16] Etten, J V, Eskender B, et a (2016) First Experiences With A Novel Farmer Citizen Science Approach: Crowdsourcing Participatory Variety Selection Through On-Farm Triadic Comparisons Of Technologies (Tricot), *Journal of Experimental Agriculture* Dec 2016 https://doi.org/10.1017/S0014479716000739

Activities 3.4 and 3.5: Trial growing aibika at CDU Horticulture compound in Darwin, then extend trials into community food gardens in both urban and remote areas of the Top End

Method

A call was put out over local radio for cuttings of aibika as an initial way of gathering propagation materials. We collected four varieties of aibika from backyard growers around Darwin.

We conducted trials in the horticulture compound at CDU Casuarina compound which has sandy loam soil prone to waterlogging in extended wet seasons. Plots were dug and four varieties were tested. All plots were irrigated with overhead watering and trials were conducted in both wet and dry seasons. Students undertook these trials as part of their horticultural research projects. It was expected that the aibika would not tolerate the high humidity of the wet season and the pest and disease pressure during this time would be a challenge and we suspected that perhaps it would be best as a dry season crop. Student led trials investigated the following parameters:

- Fertiliser rates and types
- Soil preparation
- Mulching depths and materials
- Pest and disease burden and observations

Once the aibika was identified as having minimal pest and disease incidence and minimal requirements for fertiliser, it was introduced more widely in urban and rural community and school gardens, accompanied with training and awareness sessions for teaching staff and students.

Results

The student led trials in the horticulture compound showed that all four varieties of aibika grew extremely well over both the wet and dry season.

Photo 5: Aibika trial plot at CDU Horticulture compound in Darwin

The aibika did not suffer any fungal, bacterial or viral diseases despite waterlogging and drying out in the dry season. The main pests were leaf eating beetles and swarming beetles common to most vegetables in the area.

All four varieties of aibika were found to produce the most leaf cover and grow most rapidly when planted in soils that had been deeply ripped prior to planting out. Of all the treatments including fertiliser rates, propagation stem length, mulching depths and materials, the only significant difference and improvement was in the deeply ripped plots.

In summary, aibika hardwood cuttings planted in prepared ripped plots in full sun with fertiliser are the most productive.

Students carried out germination tests and fertiliser trials on winged bean and rungia in the Horticulture nursery and found that both grew well in the Darwin environment regardless of treatment, though winged bean leaves appeared to be susceptible to spiralling whitefly infestations.

Aibika and other traditional vegetables have the potential to grow well in the Top End with minimal inputs and minimal pest and disease attack. Aibika is particularly well suited to remote community and school gardens as it is low maintenance, requires few inputs to produce good growth and has a high nutritional value, and appears to be widely accepted in taste tests by both children and adults.

A collection of aibika varieties was established within the Horticulture compound at Casuarina campus at Charles Darwin University to allow cuttings and germplasm to be distributed into the wider community and to conserve local varieties of aibika.

Discussion

In situations where no chemical fertilisers are available one handful of chicken manure applied at planting and one subsequent application is sufficient to grow a successful aibika crop.

Aibika was found to be growing in a few backyards in Darwin and the response to the offering of cuttings, plants and leaves at stalls and shows was overwhelmingly positive.

Activities undertaken to disseminate aibika into schools and community gardens and to socialise the vegetable to children and adults included:

- Cooking and tasting sessions at schools
- Working with teachers to plant aibika into school food gardens
- Sending cuttings with the Horticulture team teaching in remote communities to plant out food gardens in communities. There are plantings of aibika, winged bean and some rungia in many food gardens across the NT.
- Supplying aibika, rungia and winged bean to Food Ladder in Katherine who then propagated and grew larger volumes for supply to local café and restaurants.

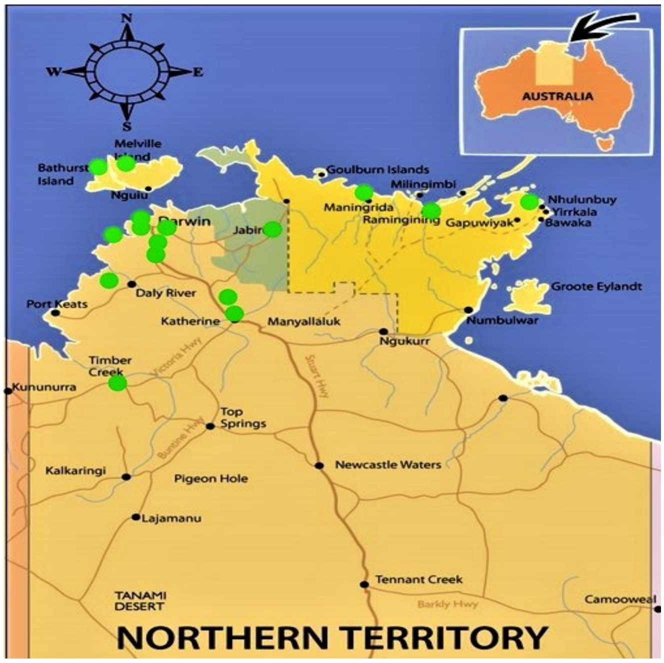


Figure 7: Current distribution of aibika through the Top End of Northern Territory

The Darwin team worked with local wholesale nursery to propagate aibika and rungia on large scale and supply to retail nurseries, including Bunnings. The local wholesalers and the project team came up with more marketable names to appeal to the local market and called aibika ‘Hibiscus Spinach’ and rungia ‘Mushroom Herb’ while maintaining their PNG name 'prominently on the label.

Photo 6: PNG Traditional Vegetables for sale in retail nurseries around Darwin

Research Question: How can we increase the awareness of the nutritional benefits of traditional vegetables amongst consumers?

Objective 4: To promote the nutritional, social and economic benefits of leafy traditional vegetables in focus areas of PNG and Northern Australia

Methods

1. Developed communication tools on production tips, recipes, picture cards for use in Papua New Guinea, Northern Australia in easy to understand formats. These were adapted and amended based on feedback from growers and users and project teams.

2. Promotion of traditional vegetables through television and radio programs e.g. “PNG Gardener”, the Saturday morning garden show on ABC Darwin NT, local kitchen/food garden and sustainability programs. Hold booths at exhibitions and shows – taste tests, cooking demonstrations, cooking competitions using traditional vegetables in both Papua New Guinea and the Northern Territory.

3. Evaluating and reviewing communication and extension materials based on findings, results and feedback from growers and the community. This was a continual process to improve the quality and relevance of the materials.

Results

Results and outcomes of this objective included:

Social media:

- Preparation and maintenance of website with all information and extension materials available, includes nutritional information, recipes and all project outputs
- Setting up and maintaining a Traditional Vegetables Facebook page with regular recipe and grower information updates. Currently 1,181 followers and 1.185 likes
- Ten YouTube videos of seed saving techniques for a range of traditional vegetables in Tok Pidgin and English

Recipe book, cooking demonstrations and taste testing:

- Recipe book with traditional and modern innovative recipes called “A Taste of PNG” in Tok Pidgin and English
- Cooking demonstrations filmed with voice overs and uploaded onto the website
- Cooking demonstrations held at schools in Lae, and around Darwin
- Taste testing and cooking demonstrations held at agricultural shows in Lae, Darwin and events in Port Moresby such as APEC, Australia Day activities, NARI open day, Botanic Gardens open day in Darwin.
- Training through the Kangaroo Foundation near for local villagers and mothers in Morobe Province on how to grow and cook traditional vegetables
- Family farm teams training in Bougainville on growing, preparing and cooking traditional vegetables with a session on the benefits for family nutrition.

Marketing tools

- Posters, flyers and handouts on growing and cooking traditional vegetables
- Colouring-in sheets of vegetables, snakes and ladders vegie game aimed at children

- Activity book of colouring in vegetables with basic nutritional information and basic children's recipes
- Illustrations and photo collection of popular and common traditional vegetables

Grower information

- Plant files on each traditional vegetable with growing information, pest and disease management, and human nutrition information and recipes

Media promotion

- TV segments on EMTV, WanTV, ABC Gardening Australia,
- Radio interviews on ABC Pacific Beat, Radio National, ABC Darwin, and local PNG radio interviews
- Magazine and newspaper articles including articles in ABC Gardening Australia magazine, Australian Farmer Magazine

These dissemination and communication activities generated a large demand for more information and recipes, and people gave useful and positive feedback on the communication tools. These tools have been adapted and updated according to project findings, feedback from growers, consumers and users of the communication tools.

8 Impacts

8.1 Scientific impacts – now and in 5 years

This project pioneered the collection, conservation and evaluation of traditional vegetables from Papua New Guinea. Work undertaken by the team revealed that there were very few to no accessions into international genebanks of varieties and cultivars of these vegetables from PNG. PNG is rich in valuable genetic resources and is one of the world's hotspots for diversification of traditional leafy vegetables, root and tuber crops, and under-utilised food crops and their wild relatives (Kambuou 2013).

One key outcome of the project has been the identification of main species of amaranthus and nightshade in PNG, and the establishment of a PNG amaranth and nightshade characterization database, which has been included in the World Vegetable Center database. This has confirmed the presence of many different amaranth and nightshade types in PNG. There were no PNG accessions of amaranth, nightshade winged bean or pumpkin in the WorldVeg Gene bank, and a search revealed none in any other international genebanks.

There is ongoing work on the morphological and genetic characterisation of amaranth species and nightshade species which will provide more data for the newly established amaranth database and the description and listing of the species present in the focus areas of PNG.

The work in this project highlighted the need for the conservation of the germplasm of traditional vegetables and other under-utilised crops and their wild relatives that have been neglected but could prove to be very useful in developing drought resilient crops and resilient food systems.

The NARI team gained valuable experience in germplasm exchange and conservation, and understanding seed distribution. There is ongoing work developed through this project of on farm trials of seed varieties of traditional vegetables from the World Vegetable Center genebank, which commenced in early 2019.

On farm seed production and conservation techniques have been disseminated by trained professionals to PNG farmer communities.

Harmonised nutritional information on the selected traditional vegetables which until now was not available in useful, reliable or uniform measurements or formats. This information can now be used by dietitians, nutritionist and others to quantify the nutritional value of these vegetables.

8.2 Capacity impacts – now and in 5 years

Over the life of the project, training and knowledge sharing was carried out on targeted specific topics such as pest and disease management, gross margin analysis to allow growers to understand the cost of inputs and production and whether they were making a profit, market quality demands and post-harvest handling of tradition vegetables, especially soft leafy crops such as aibika and pumpkin tips.

Training and capacity building was carried out on seed saving and storage to enable smallholder growers to collect and store their own seed and reduce reliance on imported seed, and reduce seed losses. Over 200 smallholder growers and 40 extension officers were trained, two NARI staff undertook internships at the World Vegetable Center in Taiwan, and based in this experience one of the NARI researchers went on to win a John Allwright

Fellowship for a Masters' degree at the University of Queensland, where she will continue the work commenced on the project working on genetic characterisation of some of the important traditional vegetables in PNG. During the internship with the World Vegetable Center, Philmah gained skills in:

- techniques & skills of morphological characterization of vegetables
- Morphological characterization protocols
- Basic techniques and skills of molecular characterization
- Collecting of leaf samples of plants for DNA extraction
- DNA extraction and isolation
- DNA Quality Testing
- DNA Quantification Testing
- Using new equipment and understand their function in the biotechnology lab.
- Seed regeneration protocols of vegetables crops in genebank
- Seed saving methods
- seed handling protocols & procedures
- Seed germination test protocols
- Understanding the importance of germplasm conservation

The time spent with WorldVeg and the investment in Philmah's postgraduate study will see her growing the capacity of the research capability and skills within NARI upon her return in late 2019.

Clementine Sesega, who at the time was a cadet entomologist with the National Agricultural Research Institute (NARI), undertook a one-month internship at the World Vegetable Center during October 2016 attached to the Entomology group to learn about pests and disease diagnostics and management. Clementine trained at the insectary in rearing insects for pest diagnosis and identification, gained in depth knowledge of planning and preparing integrated pest management strategies and spent time on common vegetable diseases.

Upon her return Clementine undertook the pest and disease identification for the project and held training and extension activities for extension staff and growers. Clementine is now a permanent staff member with NARI after the completion of her cadetship.

The NARI team learned to conduct cultivar evaluation trials, and gained skills in trial design and planning, data collection and analysis. The NARI team also presented at national seminars, gave papers at international events and prepared peer reviewed papers for publication. Philmah Seta-Waken gave a presentation at the annual Crawford Fund Parliamentary Conference in Canberra in 2018 on the nutritional aspects of the project.

Table 10: Smallholder and grower training completed

Topic	Locations	Number of participants
Record keeping	Seven villages in rural NCD	124 male growers and 181 female growers
Seed saving and storage	9 Mile kitchen garden,	20 school children, 20 local men and 20 local women growers
Seed saving, market information, economics of growing vegetables and nutrition	ATS site in Port Moresby	15 growers in total – 3 urban and 12 rural from ATS in POM; rural: Rigo, & Kuriva and Lae

Propagation and seed production, nutrition awareness	Buka Bougainville	18 local growers and their families
Pests and disease management and IPM	Laloki Port Moresby	22 extension workers and NGO staff
Nursery set up and management	Seven villages in rural NCD	124 male growers and 181 female growers
Post-harvest handling	Seven villages in rural NCD	124 male growers and 181 female growers
Packaging and bundling	Seven villages in rural NCD	124 male growers and 181 female growers
Gross margin analysis	Seven villages in rural NCD	124 male growers and 181 female growers
Marketing skills, financial literacy	Seven villages in rural NCD	124 male growers and 181 female growers

Female participation was higher overall in the grower training activities, in one village 30 women attended with only one man participating.

In summary, the major capacity building impacts of the project were:

- over 200 individual farmers were trained on a range of relevant topics to improve their production practices and income generating capacity
- 40 extension officers were trained in seed saving techniques, pest and disease diagnosis and IPM.
- 2 NARI staff undertook internships with the World Vegetable Center – one for one month and one for three months, both women.
- Inspired and motivated by her time at the Word Vegetable Centre, 1 NARI staff member was awarded a John Allwright Fellowship to undertake postgraduate studies at University of Queensland to continue with the work commenced on the project.
- The NARI, FPDA and World Vision teams gained on the job training from the international collaborators on the project in human ethics, survey and questionnaire design and analysis, and economic data collection and analysis.
- NARI and FPDA staff gained skills in preparing and presenting papers at large international conferences.
- NARI staff gained experience in writing and publishing scientific papers.
- Students within the Horticulture school at Charles Darwin University in the Northern Territory gained knowledge and skills on conducting field trials and horticultural research projects.

8.3 Community impacts – now and in 5 years

Some of the community impacts relate to the previous section on capacity impacts where training and engagement in the project has produced tangible benefits and changes to the way smallholder growers operate their business and manage their finances.

Traditional vegetables are predominantly grown and sold by women in the informal sector, and in rural areas adult literacy rates for women sit at around 50%[17] which indicates that the generation of surplus for sale in traditional vegetables is an important source of income and employment for a large percentage of the female population. Increased market access, market demand and productivity will support women's income generation with resulting proven positive impacts on household health, education and intergenerational benefits. [18]

8.3.1 Economic impacts

The supply chain and potential market returns from traditional crops were poorly understood because they are usually grown largely for subsistence and barter. This project provided a clearer understanding of the potential for growing the traditional vegetable market share, unmet demand, the limitations and obstacles, potential for demand creation, as well as methods for investigating other traditional crops with potential for improving nutrition and livelihoods in both PNG and Northern Australia.

The project revealed the large volumes of traditional vegetables being sold in open markets and the demand for them from institutional buyers, where growers did not understand the requirements of the larger institutional buyers and were unable to meet the volumes needed and the regular reliable supply needed.

A new understanding of the economic importance of traditional vegetables has come out of this work. In just one large urban market in Port Moresby, the value of traditional vegetables sold at Gordons market was over K13 million per annum from supplies of 10,103 tons of assorted traditional vegetables. Traditional vegetables sold to institutional buyers was valued over K304,416.00 per annum from the supplies of 87,840 kg.

Aibika topped the list in volume and income generated, followed by pumpkin tips and bush fern. Aibika, Aupa, kangkong and pumpkin tips are available in abundance all year round which contributes to their earning potential for growers and popularity with consumers.

A successful outcome of the project was to link growers in rural areas with an institutional buyer, resulting in a consistent reliable buyer for the group, a consistent and reliable income for the group.

One case study is that of a farmer from Saroa Keina village in Rigo district in Central Province who grows aibika, eating banana and pumpkin. Before becoming involved in the project, she had no formal agreements with buyers and sold in different roadside markets and in Gordon's market in Port Moresby. Since becoming involved in the project, she now has a formal agreement with NCS with a regular weekly income, supplies Boroko market, has reduced her post-harvest losses through better packing and handling of her vegetables and standardising the volumes sold. She now makes K1200 per week from market sales plus a regular weekly income from the NCS sales. She has now built a three-bedroom home in the village – pictured below:

---

[17] ASPBAEPNG Education Experience Survey and Literacy Assessment *available at:* *http://www.ausaid.gov.au/aidissues/education/Documents/education-aspbae-png-education-experience-survey-literacy-assessment.pdf*

[18] *UNFPA 2007* Women's Economic Empowerment: Meeting the Needs of Impoverished Women, *available at* *http://www.unfpa.org/public/global/pid/382*

Photo 7: Smallholder grower in front of her newly built home funded through her traditional vegetable enterprise

Another beneficiary of the project is a female farmer from outside of Lae who participated in one of the seed saving workshops, and used what she learned to set up her own small business selling seeds to local farmers. She also took on the nutrition message from the project and has been a great advocate and promotor of traditional vegetables holding cooking classes and sharing the project recipes among her contacts.

Another grower involved in the project became an aggregator where he collected produce from growers and onsold it to institutional buyers and retailers in open markets. He had undertaken a range of training provided through the project and used these skills to develop from a small scale and subsistence grower to the next level of being an aggregator for his local area.

8.3.2 Social impacts

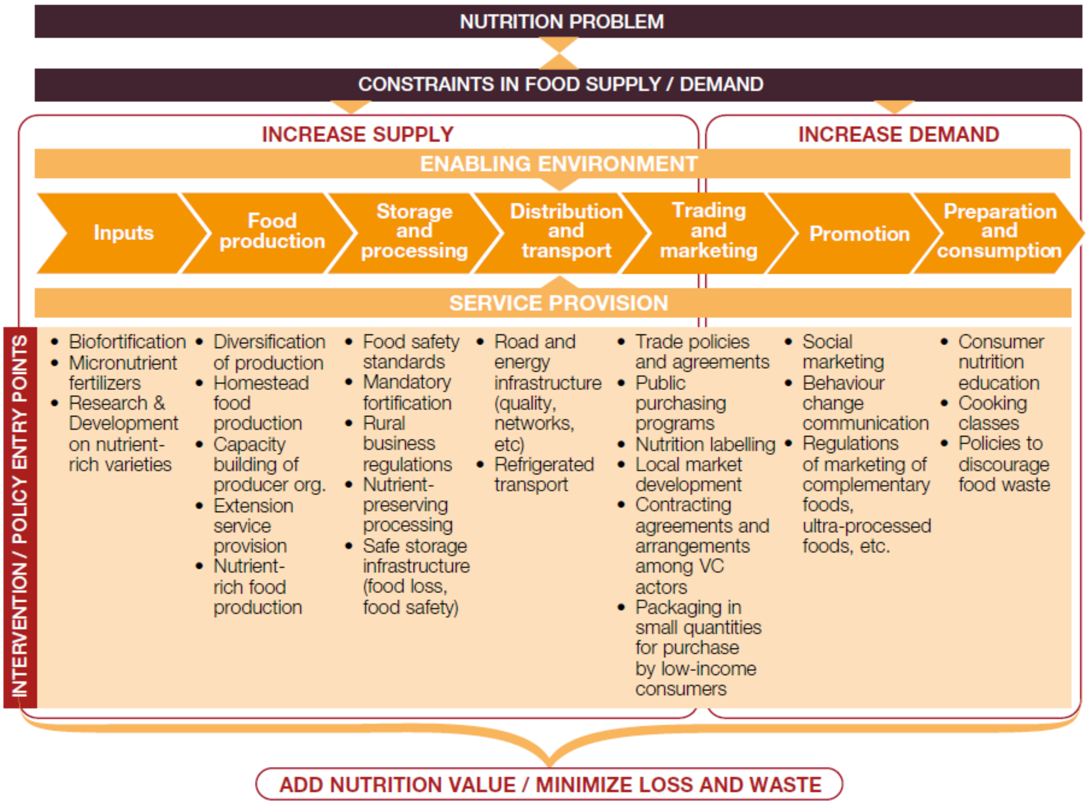
Poorer households (those in the bottom 2 income quintiles) have the worst nutritional outcomes. Some key characteristic of poorer households are that they reside on less arable land, they tend to farm on steeper-sloped land; they are much more likely to be in more remote areas, with very limited access to farm inputs and extension services; and they are more likely to be subsistence-only farmers with small cash incomes. These households are often reliant on traditional vegetables for subsistence and some small surplus for sale in informal markets.

The project impacts targeted the nutritionally vulnerable groups and poorer households involved in, and affected by, agricultural incomes and food prices, particularly smallholder famers, the urban and rural poor, and women of child bearing age and young children within those groups. There are potentially big socio-economic gains for these groups from better understanding and improving production and consumption of traditional vegetables over the longer term.

Using the framework developed by IFAD on nutritional sensitive value chains and where to generate impact, this project focused where it was possible to make some gains:

- food production component,
- promotion,
- preparation and consumption

Figure 8: Framework for nutritionally sensitive value chains and points for intervention and potential impact



One of the findings was that women farmers often sell their nutritious traditional vegetables and use the income to purchase imported vegetables in the belief that these are a healthier choice for their families. The project provided training and information to growers, families and the community on the higher nutritional benefit of these traditional vegetables and the advantages of eating them over imported vegetables.

Poor awareness of the nutritional advantages of traditional vegetables was identified as a key factor in declining consumption. The project produced educational resources, recipe books, grower’s guides and posters in easy to understand and attractive media to promote the consumption of these vegetables. There were several target audiences for these messages; the public, schools and teaching staff and maternal and child health clinics, and women farmers and traders.

The project aimed to effect behavioural changes, such as women feeding their children traditional vegetables because of a better understanding of their nutritional values. Other expected impacts are a wider appreciation of the health benefits of traditional vegetables by consumers, more diverse diets, and an increase in consumption of traditional vegetables and consequent increase in market demand.

Photo 8: Training workshop on the nutritional advantages of traditional vegetables

The expected social impacts of increased income and nutrition from traditional vegetables includes improved health and well-being for the households involved. The project created networks of farmers trained in better agronomic practices and better understanding of market needs and demands, and networks of women received information about the nutritional benefits of traditional vegetables. This shared learning increases social capital within and among communities and contributes to improved maternal and child nutrition. In the long term, improved and increased production of traditional vegetables can greatly contribute to child nutrition within the 1,000-day window between conception and age two by ensuring consistent access to diverse, micronutrient rich vegetables and reducing the impact of seasonal shortages.

8.3.3 Environmental impacts

There were no negative environmental impacts from this project. Cropping practices developed in this project are designed to increase productivity as well as conserve soil health. Traditional vegetables are generally grown on marginal land in mixed cropping systems under organic conditions, and so cultivation of traditional vegetables stabilises and improves degraded areas.

8.4 Communication and dissemination activities

The project team undertook a wide range of communication and dissemination activities including traditional methods of presenting at conferences and publishing papers, to developing social media sites for promoting the project work, to radio interviews and capturing segments on popular TV shows in both PNG and Australia. The communication and dissemination of information on growing, using and cooking traditional vegetables was an important component of the project.

Presentations at seminars and events by team members including:

- TropAg Annual Conference in Brisbane 2017 and 2015, several presentations
- SEA Vegetable Conference Malaysia 2016 – several presentations
- State of the World's Plants symposium 2016 Royal Botanic Garden, Kew UK

- International Horticultural Conference Brisbane 2014 – several presentations

Social media:

- Preparation and maintenance of website with all information and extension materials available, includes nutritional information, recipes, video of cooking demonstrations, and all project outputs to make them widely available. http://traditionalvegetables.cdu.edu.au/

- Setting up and maintaining a Traditional Vegetables Facebook page with regular recipe and grower information updates. Currently 1,181 followers and 1.185 likes. Available at https://www.facebook.com/Promoting-PNG-Traditional-Vegetables-897906590297596/?ref=bookmarks

- Ten YouTube videos of seed saving techniques for a range of traditional vegetables in Tok Pidgin and English for PNG and Northern Australian audiences:

  Wei bilong kamapim Karakap Sid na lukautim bilong bihain taim (How to save nightshade seeds)

  Wei bilong kamapim Tomato Sid na lukautim bilong bihain tain (How to save tomato seeds)

  Wei bilong kamapim pamkin sid na lukautim bilong bihain taim (How to save pumpkin seeds)

  Wei bilong kamapim Aupa Sid na lukautim bilong bihain taim (How to save amaranth seeds)

  Wei bilong kamapin Ekplen Sid na lukuatim bilong bihain taim (How to save eggplant seeds

Recipe book, cooking demonstrations and taste testing:

- Recipe book with traditional and modern innovative recipes called “A Taste of PNG” in Tok Pidgin and English
- Cooking demonstrations filmed with voice overs and uploaded onto the website
- Cooking demonstrations held at schools in Lae, and around Darwin
- Taste testing and cooking demonstrations held at agricultural shows in Lae, Darwin and events in Port Moresby such as APEC, Australia Day activities at the Australian Embassy, NARI open day, Botanic Gardens open day in Darwin.
- Training through the Kangaroo Foundation near for local villagers and mothers in Morobe Province on how to grow and cook traditional vegetables
- Family farm teams training in Bougainville on growing, preparing and cooking traditional vegetables with a session on the benefits for family nutrition.

Marketing tools

- Posters, flyers and handouts on growing and cooking traditional vegetables
- Colouring-in sheets of vegetables, snakes and ladders vegie game aimed at children
- Activity book of colouring in vegetables with basic nutritional information and basic children’s recipes
- Illustrations and photo collection of popular and common traditional vegetables

Grower information

- Plant files on each traditional vegetable with growing information, pest and disease management, and human nutrition information and recipes

Media promotion

- TV segments on EMTV, WanTV, ABC Gardening Australia
- Radio interviews on local PNG radio stations about the benefit of traditional vegetables, especially for small scale growers and backyard gardeners in time of drought and uncertain rainfall.
- ABC Pacific Beat, Radio National, ABC Darwin, Magazine and newspaper articles including articles in ABC Gardening Australia magazine, Australian Farmer Magazine. Covering topics from food security through to how to propagate and grow traditional vegetables, http://www.abc.net.au/radio/programs/nt-country-hour/nt-country-hour/9411846

These dissemination and communication activities generated a large demand for more information and recipes, and people gave useful and positive feedback on the communication tools, and generated a wide interest in the traditional vegetables and successfully raised the level of knowledge around the benefit of these vegetables and their nutritional values, increased people's knowledge of cooking and preparing these vegetables both in PNG and Northern Australia and generated a wider acceptance of these vegetables into peoples' diets.

These tools were adapted and updated according to project findings, with feedback from growers, consumers and users of the communication tools used to refine and improve them.

9 Conclusions and recommendations

9.1 Conclusions

The project achieved its overall aims and goals, and delivered all the outputs and milestones set in the project plan. It highlighted the significant contribution to local economies of traditional vegetables, and the importance of these vegetables to smallholder and subsistence growers for generating incomes. The project shifted some growers into regular supply chains to institutional buyers and saw some growers expand into small businesses such as aggregating from local growers and providing a regular reliable supply to institutional buyers, to some farmers establishing small seed saving and selling businesses.

The project began the process of documenting species and varieties of key traditional vegetables and exchanging germplasm into international genebanks. It highlighted the lack of knowledge and documentation of these traditional vegetables in PNG and commenced making accessions into genebanks.

The project introduced a highly nutritious, low input and easy to grow leafy green vegetables into many urban, rural and remote community and school gardens throughout the Northern Territory and supplemented this through cooking and taste testing trials in schools and community events. There was strong uptake of these vegetables in schools and community gardens with a wide spread demand for planting material from schools and the general community.

A recipe book was developed using traditional recipes sourced from locals and some new recipes using traditional vegetables in new ways to bring variation and interest to cooking and preparing these vegetables. The recipe book is oriented towards urban educated consumers and consumers in Northern Australia. Factsheets for growers included recipes that were more traditional with easily sourced ingredients.

The project increased the skills and knowledge of the local team and built the knowledge and skills of growers engaged in the project. The capacity building of the project reached beyond the team and the growers to extension officers, NGO’s and other agencies engaged in agricultural research and extension and family farm teams linked with other ACIAR projects.

9.2 Recommendations

Further work needs to be done on commercialising and product marketing for traditional vegetables. There is scope for trials to test the altitudinal limits of both lowland and highland vegetables to extend the growing range and seasonal availability, and potentially improve market access of traditional vegetables.

Further work also needs to be done on the potential for value adding for a wide range of vegetables and a wide range of potential processes from drying to improved packing to looking at ways of reducing preparation times.

The major recommendation from this project is for investment to be directed towards conserving and protecting local germplasm for traditional vegetables, including the establishment of systems and processes at community, district, provincial, national and international scales for certified, disease free, true to type seeds of locally important vegetables. Seed saving and seed systems will become increasingly important into the future, and will be critical to PNG in developing resilience to adverse climatic events and protecting food and nutritional security. Specifically, further work on traditional vegetables needs to be done on:

- Improving and coordinating seed supply

- Developing community seed banks, and contributing to national seed system development
- Documenting and conserving genetic resources of traditional vegetables in PNG

These recommendations on seeds systems and germplasm could also apply to other economically important vegetable crops in PNG such as tomato, pumpkin and onion where seed supplies and viability are unreliable and access to seeds can be expensive for smallholder growers.

10 References

10.1 References cited in report

Antonsson-Ogle, A., Malambo, L., Mingochi, D.S., Nkomesha, A., and Malascha, I., Traditional vegetables in Zambia. A study of procurement, marketing and consumption of traditional vegetables in selected urban and rural areas in Zambia. *Rural Development Studies*, 1990. **28** (February).

Aphane, J., Chadha, M.L., and Oluoch, M.O., *Increasing the consumption of micronutrient-rich foods through production and promotion of indigenous foods*. in *International Workshop Proceedings*. 2002. FAO.

ASPBAE PNG Education Experience Survey and Literacy Assessment available at: http://www.ausaid.gov.au/aidissues/education/Documents/education-aspbae-png-education-experience-survey-literacy-assessment.pdf

Bautista, O.K., Kosiyachinda, S., and Abd Shukor, A. R., Traditional vegetables of ASEAN.*ASEAN Food Journal*, 1988. **4**(2): p. 47-58

Bere, E.K., K-I., Changes in accessibility and preferences predict children's future fruit and vegetable intake. International Journal of Behavioural Nutrition and Physical Activity, 2005. 2: p. 15-23.

Birch,C (ed) 2009 *Sustainable vegetable production in Central Province, Papua New Guniea*, T.I.o.A.R., University of Tasmania, Australian Centre for International Agricultural Research.

Bourke, R.M., et al., *Production Patterns of 180 Economic Crops in Papua New Guinea,* 2004. Canberra: Coombs Academic Publishing. xiv, p. 213.

Bourke, R.M., Traditional vegetables of Papua New Guinea. *Vegetables for the Hot Humid Tropics,* 1977. **2**: p. 33-6.

Bourke, R.M., *Subsistence food production systems in Papua New Guinea: old changes and new changes*, in *Pacific Production Systems: Approaches to Economic Prehistory: Papers from a Symposium at the 15th Pacific Science Congress, Dunedin, New Zealand, 1983*, Yen, D.E., and. Mummery, J.M.J., Editors. 1990, Australian National University Press: Dunedin, New Zealand. p. 148-160.

Bourke, R.M., Improving food production and people's nutrition. *Harvest,* 1983. **9**(1): p. 11-23.

Bourke, R.M., Self-sufficiency in horticultural crops in South Pacific countries. *South Pacific Journal of Natural Science*, 1982. **3**: p. 31-43.

Bourke, R.M., *Bananas, corn, sweet potato, taro, Chinese taro, giant taro, swamp taro, wild taro, traditional vegetables, pineapples, food crop farming systems*, in *Liklik buk: a rural development handbook catalogue for Papua New Guinea*, Hale, P.R., and Williams, B.D., Editors. 1977, Melanesian Council of Churches: Lae.

Brimblecombe, J.K., and O'Dea, K., The role of energy cost in food choices for Aboriginal populations in northern Australia, *MJA*, 2009. **190**: p. 549-551.

Chadha, M.L., and Oluoch, M.O., *Home-based vegetable gardens and other strategies to overcome micronutrient malnutrition in developing countries*, in *Food, Nutrition and Agriculture Series* 2003, FAO: Rome, Italy.

Department of Health (2015) NT Health Nutrition and Physical Activity Strategy 2015–2020, Darwin, Northern Territory. Available at https://digitallibrary.health.nt.gov.au/prodjspui/bitstream/10137/672/1/NT%20Health%20Nutrition%20and%20Physical%20Activity%20Strategy%202015%20-%202020.pdf

Department of Health and Community Services, Nutrition and Physical Activity Program: Action Plan 2007-2012, 2006, Department of Health and Community Services Northern Territory. Available at: http://digitallibrary.health.nt.gov.au/dspace/bitstream/10137/51/1/actionplan.pdf

Etten, J V, Eskender B, et al (2016) First Experiences With A Novel Farmer Citizen Science Approach: Crowdsourcing Participatory Variety Selection Through On-Farm Triadic Comparisons Of

Technologies (Tricot), *Journal of Experimental Agriculture* Dec 2016 https://doi.org/10.1017/S0014479716000739

FAO 2012. "Final Draft: Synthesis of Guiding Principles on Agriculture Programming for Nutrition." Rome. http://www.fao.org/fileadmin/user_upload/wa_workshop/docs/Synthesis_of_AgNutr_Guidance_FAO_IssuePaper_Draft.pdf.

FAO 1988 *Traditional Food Plants*, in *Food and Nutrition Paper*, Food And Agriculture Organisation: Rome, Italy.

Hamilton, L., Indigenous versus introduced vegetables in the village diet,*Papua New Guinea Agricultural Journal,* 1955. **10**(2): p. 54-57.

Hunt, J.M., The potential impact of reducing global malnutrition on poverty reduction and economic development. *Asia Pacific Journal of Clinical Nutrition*, 2005. **14**: p. 10-38.

IFAD 2018 Developing Nutrition-Sensitive Value Chains in Indonesia: Findings from IFAD research for development; Rome, Italy. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/93444/Developing_Chakrabarti_2018.pdf?sequence=1&isAllowed=y

Kambuou, R, 2013. Plant genetic resources of Papua New Guinea: some thoughts on intellectual property rights, in *Protection of intellectual, biological and cultural property in Papua New Guinea,* Australian National University Press, Canberra.

Kimiywe, J., et al., Utilization and Medicinal Value of Indigenous Leafy Vegetables Consumed in Urban and Peri-Urban Nairobi. *African Journal of Food, Agriculture, Nutrition, and Development*: , 2007. **7**(4).

Langellotto, G.A., and Gupta, A., Gardening Increases Vegetable Consumption in School-aged Children: A Meta-analytical Synthesis.*Hort Technology*, 2012. **22**: p. 430-445.

Lolo, M., *A survey of traditional vegetables in the Gazelle Peninsula, East New Britain*, in *Proceedings of the Second Papua New Guinea Food Crops Conference: Part One*, Bourke, R.M. and Kesavan, V. Editors. 1982, Department of Primary Industry: Port Moresby. p. 148-159.

Morgan, P.J., et al., The impact of nutrition education with and without a school garden on knowledge, vegetable intake and preferences and quality of school life among primary-school students. *Public Health Nutrition,* 2010. **13**(11): p. 1931-1940.

Morris, J.L., Neustadter, A., and Zidenberg-Cherr, S., *First-grade gardeners more likely to taste vegetables.* California Agriculture, 2001. **55**(1): p. 43–46.

Morris, J.L., and Zidenberg-Cherr, S., Garden-enhanced nutrition curriculum improves fourth-grade school children's knowledge of nutrition and preferences for some vegetables. *Journal of the American Dietetic Association*, 2002. **102**(1): p. 91-93.

Myers et al (in press) Post-project evaluation of sustainability of project outcomes: case study in eastern Indonesia, *Development in Practice,* 2014.

Ratcliffe, M.M., et al., The Effects of School Garden Experiences on Middle School-Aged Students' Knowledge, Attitudes, and Behaviors Associated With Vegetable Consumption. Health Promotion Practice, 2011. 12(1): p. 36-43.

Risimeri, J., *Status of traditional vegetables: conservation and use in Papua New Guinea: a country report* in *NARI conference paper series* 2002, National Agricultural Research Institute: Morobe Province, Papua New Guinea.

Roges, C., Bleakley, R., and Ola, W., *Rural Poverty in Remote Papua New Guniea- Case study of Obura-Wonenara District*, Development Policy Centre in the Crawford School of Economics and Government, and CARE Australia.

Rolle, R. S. (2006) *Post-harvest management of fruit and vegetables in the Asia-Pacific region.* Report on the APO seminar on Reduction of Post-harvest losses of Fruits and Vegetables, APO/FAO publication

Special Issue: Papua New Guinea Nutrition Survey, 2005. Pacific Journal of Medical Sciences, 2011. **8**(2).

Somerset, S., and Markwell, K., *Impact of a school-based food garden on attitudes and identification skills regarding vegetables and fruit: a 12-month intervention trial.* Public Health Nutrition, 2009. **12**(2): p. 214-21.

Sun Movement Secretariat (2016) *Scaling up Nutrition (Sun) Movement Strategy and Roadmap 2016-2020.* Available at https://scalingupnutrition.org/wp-content/uploads/2016/09/SR_20160901_ENG_web_pages.pdf

Traditional African Vegetables, in *PGRI International Workshop on Genetic Resources of Traditional Vegetables in Africa: Conservation and Use,* 1995, Nairobi, Kenya.

Taylor, M., Kete, T., and Tuia, V., *Underutilized species in the Pacific: An untapped source of nutritional and economic wealth.* Acta Hort., 2009.(806).

UNFPA (2007) *Women's Economic Empowerment: Meeting the Needs of Impoverished Women,* available at http://www.unfpa.org/public/global/pid/382

UNDP Papua *New Guinea*. 2012 [cited 2013 February]; Available from: http://www.undp.org.pg/.

van Rensburg Willem, J.V., Ineke H.J., Van Zijl, J.J.B., and Venter Sonja, L., Conservation of African Leafy Vegetables in South Africa. *African Journal of Food Agriculture Nutrition and Development*, 2007. **7**(4): p. 2007.

Westwood, V., and Kesavan V., *Traditional leafy vegetables of Papua New Guinea: aibika (Hibiscus manihot (L))*, in *Proceedings of the Second Papua New Guinea Food Crops Conference: Part Two*, Bourke R.M., and Kesavan V., Editors. 1982, Department of Primary Industry: Port Moresby. p. 391-395.

World Health Organisation Western Pacific Region Pacific Food Summit: Meeting Report,April 2010 Port Vila Vanuatu; Manila Philippines Dec 2010; Report Series Number: RS/2010/GE/22(VAN)

10.2 List of publications produced by project

Kawale, G. Benny,D. Seta-Waken,P. Dabae, G. Gendua, P (in prep) Promoting traditional vegetable production and consumption for improved livelihoods in Papua New Guinea: Agronomic evaluation study of Amaranth (*Amaranthus* species) in Papua New Guinea conditions, National Agricultural Research Institute, Lae PNG.

Solberg, S. Seta-Waken, P. Paul, T. (2018) *Patterns in the conservation and use of traditional vegetables from the New Guinean biodiversity hotspot;* Agroecology and Sustainable Food Systems, UK DOI: 10.1080/21683565.2018.1489932

Seta-Waken, P. Gendua, P. Solberg, S. (2018) *Eggplants and Indigenous Leafy Vegetables for Food Diversity: Improving Farmers' Livelihoods in Coastal Villages of Papua New Guinea,* Vegetables for Improved Nutrition and Livelihoods: SEA Vegetable Conference 2016, Malaysia.

Seta Waken, P. Solberg, S. Curaba, J. Luther, G. Krishnan, B. Paul, T. (2018) *Videos to Enhance Local Vegetable Seed Production Knowledge and Improve Livelihoods for Small-Scale Farmers in Papua New Guinea,* Vegetables for Improved Nutrition and Livelihoods: SEA Vegetable Conference 2016, Malaysia.

Seta-Waken P, Solberg S and Paul, T. (2016). *Indigenous Vegetables: a case study from Papua New Guinea,* State of the Worlds' Plants Symposium, May 11-12, Royal Botanical Garden Kew, United Kingdom.

Seta-Waken, P. Solberg, S., Curaba, J., Luther, G., Krishnan, B. and Paul, T. (2016) *Smartphones to enhance local vegetable seed production knowledge and improve livelihoods for small-scale farmers in Papua New Guinea,* Vegetables for Improved Nutrition and Livelihoods: SEA Vegetable Conference 2016, Malaysia.

Paul, T. Gwabu, C. Seta-Waken, P. (2016) *The challenges of increasing the consumption and* *demand for nutritionally beneficial vegetables in PNG: a case study*, International Tropical Agriculture Conference 2015: Meeting the Challenge in the Tropics, CSIRO, DAF and UQ.

Paul. T. Omot, N. Palaniappan, G. and Linibi, M. (2014) *Urbanisation and the decline in consumption of traditional vegetables in PNG, Acta Horticulturae, ISHS*, International Horticultural Conference Brisbane 2014.

Omot, N. Paul, T. Palaniappan, G. Kambou, R. and Linibi, M. (2014) *Consumer Perceptions of Traditional Vegetables in Urban Markets in Papua New Guinea*, *Acta Horticulturae,* International Horticultural Conference Brisbane 2014.

11 Appendices

11.1 Appendix 1: Agronomic evaluation trials of Amaranth in PNG

Agronomic Evaluation study of Amaranth (*Amaranthus species*) in PNG conditions.

Gena Kawale*, Dickson Benny, Philma Seta-Waken, Gibson Dabae, Peter Gendua

National Agricultural Research Institute Southern Regional Centre, Laloki P.O Box 1828, Port Moresby, National Capital District, Papua New Guinea.

ABSTRACT

Amaranth is one of the oldest food crops in the world with the genus *Amaranthus* has received considerable attention because of the high nutritional value present in some of the edible species. The importance of this crop complements increasing awareness on the diversity of locally available traditional leafy vegetables. Improving knowledge in the cultivation of traditional vegetables are ideal solutions to farm profitability as well as food and nutrition security of local farmers and communities are concerned. Making available of amaranth genotypes with good agronomic quality traits is considered an appropriate option for small holder farmers both in Papua New Guinea and Northern Australia. Thus, this study was aimed at screening and evaluating 15 pre-selected amaranth genotypes under NARI Laloki field condition.

The trial was conducted at NARI Laloki experimental station located at longitude 09º24 S and latitude 147º16 E, 40 meters above sea level. The mean annual rainfall experienced in Laloki during the period of experiment is 51.9 4 mm with maximum and minimum temperatures of 23.5°C and 32°C, respectively with soil profile comprises of dark silty clay loam with moderately well-developed structure and moderate drainage. The experimental design was a randomized complete block design (RCBD) with three replications. The following agronomic traits were assessed, earliness for maturity, high leave at harvest, high marketable branches high shoots, high marketable yield, good appearances, market quality and good taste. Significant variations were observed among the tested genotypes for all traits assessed. The 15 genotypes evaluated and 8 were selected viz; AM 7, AM 6, AM 5, AM 32, AM 3, AM 23, AM 10 and AM 11 showed potential or ability to mature early, capacity to produce high marketable yield and ability to resist/tolerate pest and disease. Because of these good characteristics and potentials these 8 genotypes can be recommended for further demonstration and distribution for general cultivation by farmers.

Key words: *traditional vegetables*, *Amaranthus, drip irrigation, agronomic traits, high yielding, market qualities, sensory evaluation nutrition*

INTRODUCTION

Amaranth is the common name for the domesticated species of the genus *Amaranthus* (family *Amaranthaceae*). It is one of the oldest food crops in the world (Gigliola Gamaggio, 2012). *Amaranthus* is one of the most promising plant genus and it consists of approximately 70 species and 40 of which are native to the Americas, 17 are mainly vegetable species, three are grain while others are weedy (Andreas et al., 2011). Amaranth is a multipurpose crop whose leaves and grains are tasty and of high nutritional value and can be cultivated as an ornamental plant (Venskutonis & Kraujalis, 2013). The genus *Amaranthus* has received considerable attention in many countries because of the high nutritional value of some species that are important sources of food, either as vegetable or grain (Srivastava, 2001).

The promotion of exotic types of vegetables in the recent past resulted in the abandonment of indigenous vegetable. However, recently, due to the realization of their high nutritional and medicinal value and low input requirement, there has been intensified awareness creation resulting in increased production, consumption and marketing of these vegetables (Wambugu & Muthamia, 2009). The volumes of production of vegetable amaranth have increased over the last few years in response to the growing urban vegetable demand (Onyango & Imungi, 2007). Vegetable amaranth is found in many supermarkets and green grocers stores in the urban centers. More than 90% of the supply of the vegetables to these outlets is normally from farms that are within the environs of the urban centre (Moraa, 2008).

With the importance of this crop complemented with increasing awareness on the importance and diversity of locally available traditional leafy vegetable varieties and improved knowledge in the cultivation of traditional vegetables are ideal solutions to farm profitability as well as food and nutrition security for local farmers and communities. The agronomic evaluation trials under the project *HORT/2012/084 "Promoting traditional vegetable production and consumption for improved livelihoods in PNG and Northern Australia"* was to evaluate the agronomic potential and identify the desirable agronomic traits of different amaranth and Nightshade varieties and recommend to farmers for general cultivation thus help increasing diversity of traditional leafy vegetables.

Therefore, the agronomic trial was looking at evaluating different varieties of two traditional leafy vegetables species (Amaranth and Nightshades) which were part of objective number 3 of this project. The variety evaluation trial aimed at determining high yielding varieties, good taste, with moderate pest tolerance grown under local conditions. Amaranth and black berried nightshades are the two traditional leafy vegetables identified for these trials.

This report provided the results obtained from variety evaluation of 15 varieties of amaranth under the confirmation study.

MATERIALS AND METHODS

Experimental Site

Description of Experimental Site and Climatic Condition

The trial was planted in October 2017 and harvested in November 2017 at the National Agricultural Research Institute (NARI), Southern Regional Centre, Laloki, Central Province. The site is located on longitude 09º24 S and latitude 147º16 E, 40 masl. The mean annual rainfall experienced in Laloki during the period of experiment is 51.9 4 mm with maximum and minimum temperatures of 23.5°C and 32°C, respectively. There was high random rainfall at the initial period of trial establishment (Figure 1). NARI SRC soil profile comprises of dark silty clay loam with moderately well-developed structure and moderate drainage (Doyle *et al.*, 2012). Laloki's climate is characterized by a marked dry season with dry southeast winds.

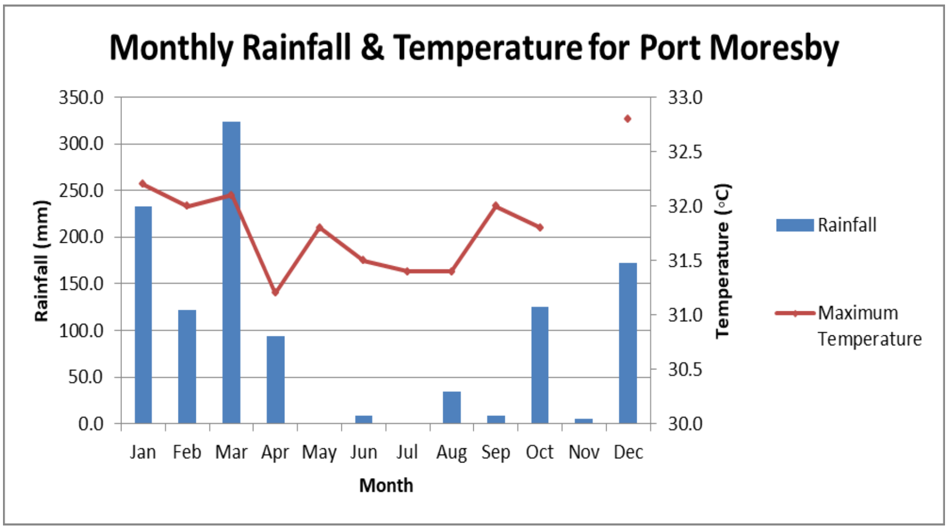


Figure 2.1 Showing the monthly rainfall and average maximum temperature for Port Moresby for the year 2017.

Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	7.5	4.4	11.2	3.5	0	0.3	0	1.1	0.3	4.1	0.2	5.6
MaxTemp	32.2	32	32.1	31.2	31.8	31.5	31.4	31.4	32	31.8		33

Table 2.1 Showing the average rainfall and maximum temperature for Port Moresby for the year 2017.

Source and selection of planting materials

There were total of 15 amaranth genotypes (collected from both local and introduced ones maintain and stores at SRC-Laloki) selected from the previous preliminary evaluation study were evaluated in this confirmation study. These accessions were chosen based their performance and seen to be promising viz, high branching number and high leaf numbers summarized from previous preliminary trial (Table 1).

The selected materials were put through germination test and shown to be more than 90% viable and were sown in the nursery and after 5 days were transplanted into individual cups for good seedlings and uniformity before transplanting in the field.

Table 1. List of the genotypes (Code names) used in the study

No.	Amaranth	Branching index	*Leaf size	Leaf shape
1	SRC-AM 1	Branches all along the stem	Big	Rhombic
2	SRC-AM 2	Branches all along the stem	Big	Rhombic
3	SRC-AM 3	Branches all along the stem	Big	Rhombic
4	SRC-AM 4	Branches all along the stem	Big	Rhombic
5	SRC-AM 5	Branches all along the stem	Big	Rhombic
6	SRC-AM 6	Branches all along the stem	Big	Rhombic
7	SRC-AM 7	Branches all along the stem	Big	Rhombic
8	SRC-AM 10	Branches all along the stem	Big	Rhombic
9	SRC-AM 11	Branches all along the stem	Big	Other
10	SRC-AM 23	Many branches (all near the base of the stem)	Big	Obovate
11	SRC-AM 24	Many branches (all near the base of the stem)	Big	Elliptical
12	SRC-AM 25	Many branches (all near the base of the stem)	Big	Elliptical
13	SRC-AM 26	Branches all along the stem	Big	Rhombic
14	SRC-AM 32	Many branches (all near the base of the stem)	Big	Rhombic
15	SRC-AM 35	Branches all along the stem	Big	Elliptical

Note: AM 2—AM 10=Amaranth genotype obtain from World Vegetable Centre -Taiwan, AM 11—35 amaranth genotypes were PNG landrace.

Experimental Design

The trial was laid out in a randomized complete block design (RCBD) with three replications. There were 15 genotypes evaluated in the field. Plant spacing of 0.60 m and 1.0 m between plants and rows respectively was used. The plot size was 7.2 m^2 (12 x 0.6 m x 1 m) with a net plot of 6 m^2 (10 x 0.6 m x 1 m) and the total experimental area was 610 m^2 (122m x 5 m).

Preparation of field and irrigation

The field was plough and rotovated into fine structure. Drip irrigation was connected into the field with drips at 30 cm interval. Plant was places at 60 cm where the drip is located. The source of the water comes from Laloki river via an overhead reservoir tank with gravity feed 25 m away from where the field is located.

Weeding and Trial Maintenance

Weeding and irrigation water management was important, particularly in the establishment and vegetative development. As the plants develop, their capacity to compete with weeds develops considerably. The trial was weeded twice in its growing season. The first weeding was done at 5 DAT at establishment phase, followed by the second at 10 DAT vegetative phases. The trial was managed using subsistence cultivation and management practices without application of chemical fertilizers, pesticides and fungicides.

Data parameters measured

Vegetative growth data such as leaf number, leaf internode length leaf area (cm^2), internode length (cm), plant height (m), stem diameter, number of branch and shoots of ten (10) plants per genotype was assessed starting at 5 days after transplanting (DAT) to fully maturity. At maturity, the days to maturity, number of shoots and branches harvested, marketable shoots, number of leaves from each branch, number of leaves from main stem, total harvestable weight/total biomass weight, marketable weight, nonmarketable weight, and market quality were assessed. After harvesting, the edible parts (leaves, shoots and stem) were stream boiled and the taste and sensory evaluation was conducted. The pest assessments were conducted on a weekly basis throughout the trial period as well as taste and sensory evaluation.

The details of how each parameter was measured are given below.

- Internode length: A 30cm ruler was used to measure the internode length between the nodes of the first and second fully opened leaves on a weekly basis.
- Internode diameter: An electronic vernier calliper was used to take measurement at the midpoint of internodes between the nodes of the third and fourth fully opened leaves on weekly basis.
- Days to maturity (DTM): Based on vegetative indices DTM was closely monitored until sign of active vegetative development sites ceased and that approximate date was recorded as maturity date for the respective genotypes.
- Plant height: The primary plant (stem) height was measured starting from the soil surface to the tip of the main stem using a 1m ruler on weekly basis.
- Aerial and total aerial biomass: Fresh aerial biomass (top stem, branches, shoots, and leaves) was harvested separately and fresh weights recorded at harvest time using electronic balance, Benchtop balance series PCE-BDM up to 10kg, readability from 0.1g
- Economic yield (t/ha) = [Total net plot marketable weight (kg) ÷ 1000 kg] x [10, 000 m^2 ÷ Net plot area (m^2)]. Total yield (t/ha) was the summation of marketable edible portion and non-marketable portion.
- Taste evaluation was a vital study in determining farmers and consumers ‘preferences. by which freshly harvested amaranths were steam boiled in the electrical deep fryer for about 4-5 minutes and served for tasting and score given for assessment.

Data Analysis

The data, on yield and yield components were analysed using Microsoft Excel and statistical software “Genstat 14th Edition” was used for the Analysis of Variance (One-Way ANOVA). Least significant difference (LSD) and Duncan’s multiple range test (DMRT) was used for selected parameters to compare differences in the test accessions at 5 % probability level.

RESULTS

Vegetative Growth

Plant height (cm)

There was significant difference (P<0.001) among the genotypes in terms of plant height in all amaranth genotypes tested when compared with the two local genotypes from Central Province, viz AM 32 and AM 35. All the genotypes show an increment in height from their establishment to 7 days after transplanting (DAT) to 22 DAT to its maturity and harvesting. High plant height was recorded in AM 32, 3, 7, 11 & 6 ranging from 0.51-0.71 m whereas genotypes AM 35, 26, 10 & 25 showed low plant height ranging from 0.41-0.49 m.

Table 1. Mean Plant height (m) for each genotype at 7, 14 22 DAT.

Genotype	7DAT (m)	14DAT (m)	22 DAT (m)
AM 2	0.1287	0.25	0.4971
AM 3	0.2212	0.4367	0.6675
AM 4	0.1717	0.3413	0.52
AM 5	0.1633	0.3917	0.6175
AM 6	0.1612	0.3254	0.6421
AM 7	0.1467	0.3038	0.6642
AM 8	0.1904	0.3692	0.6371
AM 10	0.1533	0.2571	0.4704
AM 11	0.0896	0.2808	0.6437
AM 23	0.1292	0.2333	0.5125
AM 24	0.1171	0.3188	0.5408
AM 25	0.0987	0.2613	0.4892
AM 26	0.1	0.225	0.4221
AM 32	0.1679	0.3967	0.705
AM 35	0.1292	0.2567	0.405
Grand Mean	**0.1446**	**0.3098**	**0.5623**
LSD<0.05	**1.777**	**4.111**	**7.156**
CV (%)	**21.6**	**23.4**	**22.4**
P Value (5%)	***	***	***

Note *** = *highly significant at P<0.001,*

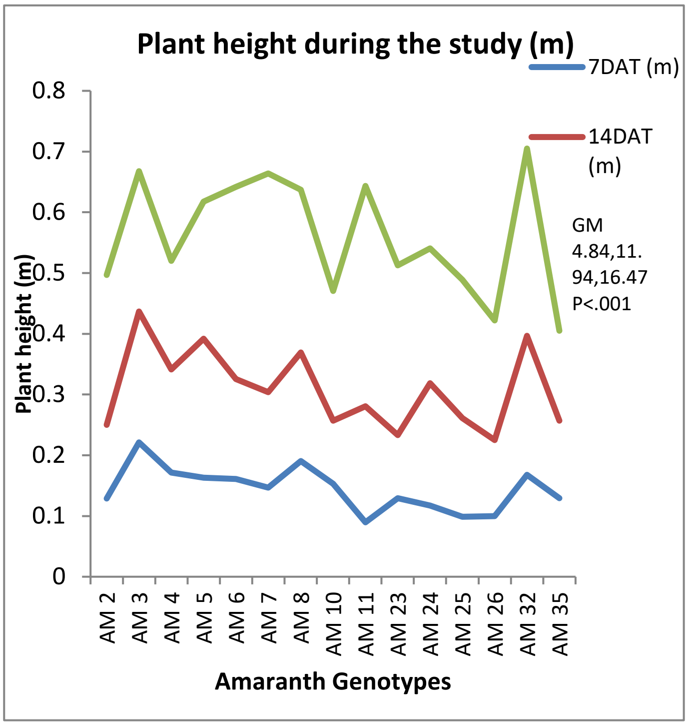


Figure 1. Graph of overall plant height (m)

The top ten genotypes having high average plant height at 7DAT were AM 3, 8, 4, 32, 5, 6, 10, 7, 35 and 23 which ranged from 0.13-0.22m respectively and 14DAT were AM 3, 32, 5, 8, 4, 6, 24, 11, 7 and 25, whereas at 25DAT which is at harvest were AM 32, 3, 7, 11, 6, 8, 5, 24, 4 and 23 respectively ranged from 0.51-0.71 m. Each genotypes response differently in terms of plant height and generally the trend to maturity of 0.5-0.6m indicated the height at which amaranth ready for harvesting.

Number of branches

The branching ability of the plant indicated the productivity and active production of succulent leaves excellent for consumption. The term yield in this research was used to include all parts of the plant that is usually harvested and used as vegetable. It included new shoots and branching with leaves or buds. From the genotypes evaluated there were significant differences (P<.001) in number of branches/shoots at 7, 14 DAT and at harvest table 3.

Table 2. Mean branch number of 15 amaranth genotypes evaluated.

Genotype	NoBr 7DAT	NoBr 14DAT	No.Br/Shts Harvt
AM 2	2.75	10.54	19.58
AM 3	6.71	14.04	13.67
AM 4	6.33	13.29	14.42
AM 5	4.42	11.96	12.54
AM 6	4.13	12.42	20.67
AM 7	4	12.54	21.75
AM 8	2.33	11.08	20.21
AM 10	4.96	10.33	16.58
AM 11	3.71	10.42	18.21
AM 23	5.42	11.33	18.08
AM 24	5.38	13.13	15.08
AM 25	5.29	13.08	15.79
AM 26	5.92	11.42	13.67
AM 32	5.92	12.96	13.92
AM 35	5.29	10.58	12.92
Mean	**4.84**	**11.94**	**16.47**
LSD<0.05	**1.081**	**1.212**	**1.534**
CV (%)	**39.4**	**17.9**	**16.4**
P Value (5%)	***	***	***

Note *** = *highly significant at P<0.001,*

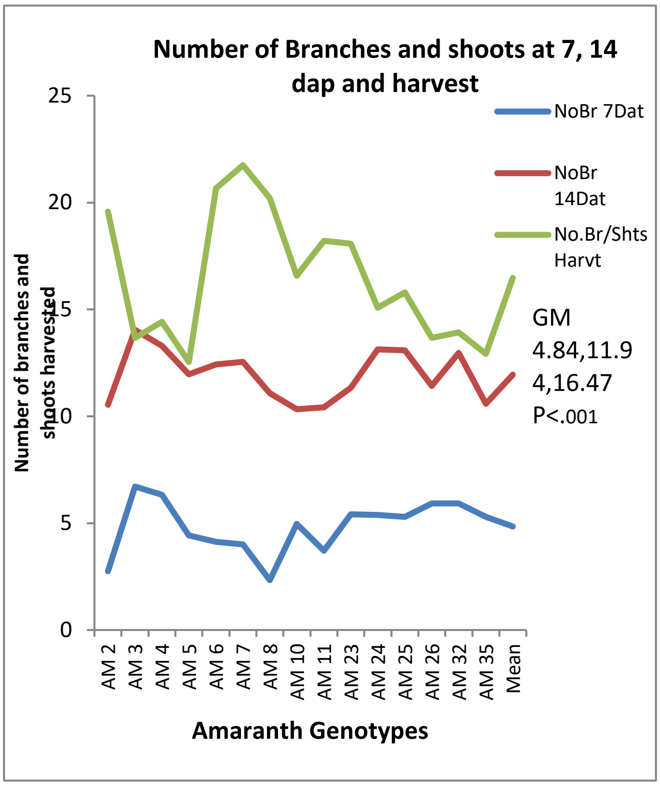


Figure 2. Graph of overall number of branches and shoots harvested

The grand mean for number of branches for the three distinct periods were 4.84, 11.94 and 16.47 showing a trend of increment in branching number during the assessment period to its maturity. Top 5 genotypes showing early branching ability found at 7DAT were AM 3, 4, 32, 26 and 23 having 5 to 6 branches above the mean number of branches. Again AM3, 4, 24, 25 and 32 were top branching at 14DAT. At harvest the number of branches and shoots were considered as economic value or harvestable portion. From the table 3shows that genotypes AM 7, 6, 8, 2 and 11 having high branching and shoots ability with 18-22 branches or shoots above the grand mean.

AM 3, 4, 32, 24 and 35 having high branching ability at 7 and 14 DAT and having low branching at harvest meaning the earlier the branching development the lower the harvestable shoots. Also the genotypes AM 32, 3, 7 and 11 can be considered as high branching and shoots harvestable during harvesting period.

Leaf number

Foliar development across genotypes under respective number of day assessed and leaf number for main stem and branches were highly significant (Table 4). The total number of leaves in all genotypes increased during its growth and development stages meaning there is an increment in the foliar development to its maximum until its maturity and harvest.

Table 3. Mean leaf number of amaranth studied for 7 and 14DAT and leaves for main stem as well as leaves for branches.

Genotype	Ln@7DAT	Ln@14DAT	LnMs	LnBr
AM 2	6.083	12.38	16.92	51.6
AM 3	4.708	10.71	15.67	68.3
AM 4	5.583	11.04	12.5	50
AM 5	5.292	11.12	11.46	55.5
AM 6	5.625	11.46	19.58	84
AM 7	5.333	10.88	21.67	82.1
AM 8	6.792	12.83	23.38	38.7
AM 10	4.542	9.33	11.04	93.6
AM 11	5.292	9.75	19	63.7
AM 23	4.042	9.58	11.96	83.8
AM 24	6.292	12.17	12.75	65.2
AM 25	5.833	11.38	14.79	83.6
AM 26	5.5	10.17	13.62	60.5
AM 32	6.708	12.54	10.08	72
AM 35	5.125	10.75	14.88	54.5
Mean	**5.517**	**11.07**	**15.29**	**67.1**
LSD<0.05	**1.0271**	**1.331**	**1.804**	**14.68**
CV (%)	**32.8**	**21.2**	**20.8**	**38.5**
P Value (5%)	***	***	***	***

Note *** *= highly significant at P<0.001, Ln =Leaf numbers, Ms=Main stem, Br=Branching*

The grand mean for, main steam at 7DAT and 14DAT were 5.52, 11.07 respectively, while the branches were 15.29 and 67.1 respectively. Eight (8) of the genotypes had values above the mean at 7DAT, while 7 genotypes in 14 DAT, followed by 6 genotypes for main stem and finally 7 genotypes for branching leaf number.

Genotypes having higher leave numbers at 7 and 14DAT tend to having lower leave numbers at harvest. From the table genotypes AM 10, 6, 23, and 25, also AM 6, 25 having both high leaf number for main stem as well as branches. On the other hand Am 8, 32, 24 and 2 had higher main stem and branches leave numbers at 7 and 14DAT were having low leave numbers at harvest. Generally, there were high correlation at 7 and 14DAT for the main stem leaves and branches leaves.

Yield and yield component

The number of amaranth genotypes screened were highly significant (p<.001) in terms of yield and its yield component (table 5). The productive of the crop is the number of shoots harvested and leaves harvested.

Table 4 . Mean yield and yield component for amaranth genotypes

Genotype	Tot.Wt. (kg)	#Brn./sht.Hvst.	Mkt.Shts	#Lvs.Brn	#Lvs. MS	Mkt. Wt.(kg)	Non.Mkt.Wt.(kg)	Mkt.Qty.
AM 2	0.41	19.58	10.13	51.63	16.92	0.2	0.08	4.31
AM 3	0.23	13.67	8.63	68.33	15.67	0.13	0.03	3.9
AM 4	0.16	14.42	8.54	50.04	12.5	0.08	0.02	2.92
AM 5	0.32	12.54	8.08	55.54	11.46	0.19	0.04	3.54
AM 6	0.49	20.67	12.88	84	19.58	0.26	0.05	4.96
AM 7	0.44	21.75	12.63	82.08	21.67	0.25	0.04	5
AM 8	0.31	20.21	8.92	38.67	23.38	0.14	0.05	4
AM 10	0.56	16.58	11.25	93.58	11.04	0.42	0.02	5
AM 11	0.49	18.21	10.33	63.71	19	0.24	0.05	3.25
AM 23	0.51	18.08	12.21	83.75	11.96	0.38	0.02	5
AM 24	0.33	15.08	9.96	65.17	12.75	0.21	0.04	3.96
AM 25	0.33	15.79	13.04	83.58	14.79	0.21	0.04	4.71
AM 26	0.24	13.67	10.33	60.46	13.63	0.14	0.03	3.29
AM 32	0.37	13.92	9.04	72.04	10.08	0.21	0.06	2.83
AM 35	0.21	12.92	9.71	54.46	14.88	0.11	0.03	2.33
Grand Mean	**0.36**	**16.47**	**10.38**	**67.1**	**15.3**	**0.21**	**0.04**	**3.93**
LSD<0.05	**0.11**	**1.53**	**1.81**	**14.7**	**1.8**	**0.07**	**0.02**	**0.31**
CV (%)	**55.1**	**16.4**	**30.7**	**38.5**	**20.8**	**61**	**85.4**	**14**
P Value (5%)	***	***	***	***	***	***	***	***

Note *** = highly significant at P<0.001

Abbreviation: Tot.Wt.(kg)=Total weight (kg), #shots hvst= number of shoots harvested, Mkt.Shots = marketable shoots, #Lvs.Brn = Number of leaves for branches, Lvs.Ms= leaf number of main stem, Mkt.Wt (kg) = marketable weight (kg), Non.Mkt.Wt (kg) = non marketable weight (kg), Mkt. Qty = market quality

Total weight (kg)

Highly significant differences (P<.001***)*** were observed for the above ground biological yield of the genotypes studied. The grand mean was 0.36 kg and 7 genotypes (AM 10, 23, 11, 6, 7, 2 and 32) had their total weights higher than the grand mean and range from 0.36 to 0.55kg above the average while 8 genotypes (AM 3, 4, 5, 8, 24, 25, 26, and 35) had their total weight below the mean. Among the top 7 genotypes, genotype AM 10 and AM 23 had the highest total biomass weight of 0.56kg and 0.51kg respectively.

Number of shoots harvested

There were highly significant difference (P<.001) among the genotypes in number of harvestable shoots and branches harvested. The grand mean of the harvested shoots was 16.47and genotypes AM 2, 6. 7, 8,10, 11 and 23 had harvestable shoots above the grand mean. However, AM 7, 6, and 8 had the highest number of harvestable shoots ranging between 20-22 harvestable shoots.

Marketable shoots

Highly significant difference (P<.001) in the Marketable shoots were observed among the genotypes studied. The marketable shoots determine the economic yield of the crop with grand mean of 0.21 kg. The seven-top yielding in terms of marketable shoots yield were AM 32, 24, 11, 7, 6, 23 and 10 ranged from 0.21 to 0.42 kg. Genotype AM 10 and 23 give the highest marketable shoots of 0.42 and 0.38 kg respectively

Marketable weight (kg)

There were highly significant differences in the amaranth economic yield with grand mean of 0.21 kg. Eight genotype yields above grand mean were AM 24, 32, 25, 11, 7, 6, 23 and 10 ranged from 0.214kg to 0. 415kg respectively. Genotypes AM 10 and 23 were the top in terms of marketable weight (kg). This trait is useful for selection of varieties with high economic value that could be of benefit to commercial growers.

Market quality

There were highly significant differences (P<.001) in market quality among the genotypes studied. The high market quality value indicated good looking and high market value genotypes. The grand mean was 3.93 and seven of the genotypes including AM 24, 8, 2, 25, 6, 7 and 23 had values above the grand mean ranging between 3.96 to 5 respectively. However, the highest marketable value of 5 was obtained by genotypes AM 10, 23, and 7 and they have the potential for promotion and dissemination for wider cultivation.

Insect Pest assessment and rating (score: 0-5)

The incidence of insect pest indicated that each genotype responded differently over two assessment periods by the visual observation and scoring.

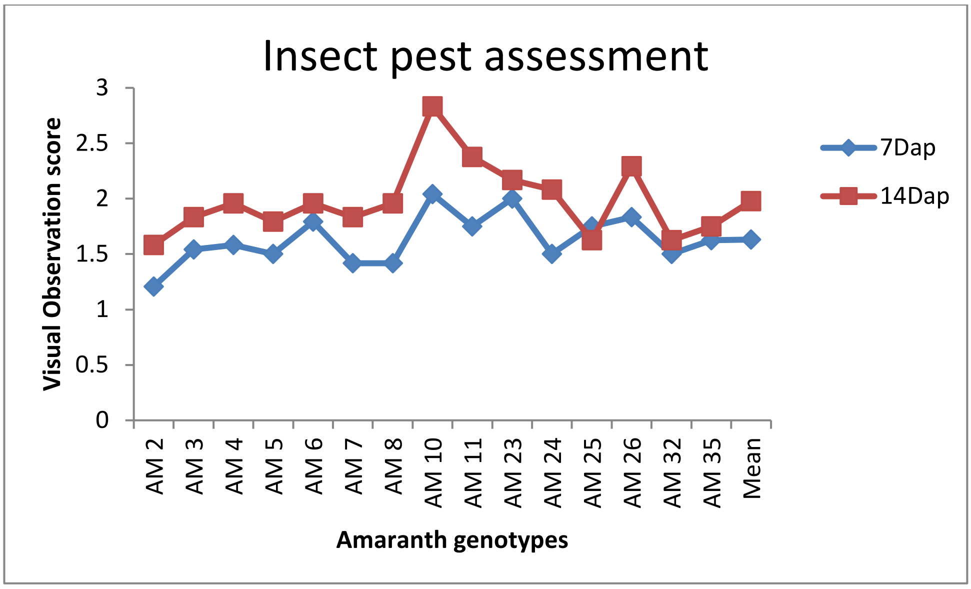


Figure 3. Graph of overall Insect pest visual observation and assessment

Insects especially leaf hoppers and leaf miners attacked was commonly observed during the early growing stage and decreases gradually as the crop develops toward its maturity. Am, 10, 11, and 26 indicated insect pest attached in the two assessment periods whereas the rest of the genotypes is at moderated attack.

Taste and sensory evaluation

Taste evaluation was a vital study in determining farmers and consumers preferences. Fourteen (14) tasters from SRC Laloki have participated including 4 females and 10 males. Freshly harvested amaranths were steam boiled in the electrical deep fryer for about 4-5 minutes and served for tasting. No other ingredients were added.

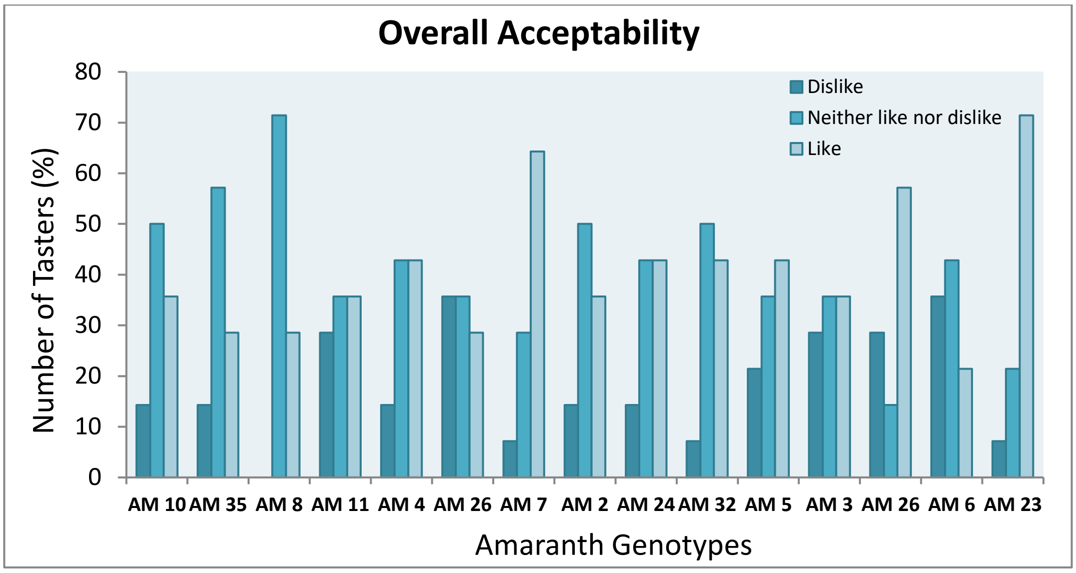


Figure 4. Graph of overall acceptability of sensory evaluation of tasters.

Leaf Color: Leaf colour was visually observed when steamed for tasting. AM10 (71%), AM35, AM 8 (64%) & 23 (57%) good indication between likes and neither like or dislike.

Aroma (smell): All genotypes tested for aroma by smelling shows that eleven genotypes have good aroma viz good indicated noted on AM8 (35%), AM 7, 23 (64%), AM5 (28%) for the participants.

Softness (palatability): Amaranth is a soft leafy vegetable by which softness can be easily judged by testing. From the testers, 85% indicated genotype AM 7 (85%), AM 5 (57%) & AM 24 (35 %).

Sweetness: Sweetness varies with individual tasters, for the 15 amaranth genotypes evaluated for taste as a very sweet genotype. AM 4 (42%), AM 11, AM 10 & AM5 (71%).

Overall acceptability was the summation of the sensory evaluation (Figure 8) Overall acceptability showing AM 23 (71 %), AM 7 (64 %), AM 26 (57%), AM 5 & AM 4 (43%) were liked by the testers.

Correlation and regression analysis of yield and yield component

The correlation analysis results of selected parameters are shown in Table 9. Results indicates that total weight had strong positive and significant correlation (r = 0.92) with marketable weight, branch number harvested, leaf numbers and market quality but a weak correlation with leaves for main stem. There was no significant correlation with marketable shoots and non-marketable weight and likewise to number of branches with leaves for main stem and non-marketable weight (r = -0.05, -0.21 and -0.28).

Table 5. Regression and correlation for parameters measured.

	Tot.Wt(kg)	*No. of Brns/shts hvst*	*Mkt.Shts*	*no.Lvs.Brns*	*No. Lvs.MS*	*Mkt.Wt (kg)*	*Non.Mkt (kg)*	*Mkt.Qty*	*PL.Hgh (m)*	*Pest*
Tot.Wt(kg)	1									
No. of Brns/shts hvst	0.6285	1								
Mkt.Shts	0.6098	0.5799	1							
no.Lvs.Brns	0.6523	0.2053	0.7556	1						
No. Lvs.MS	0.1227	0.7514	0.2454	-0.2104	1					
Mkt.Wt (kg)	0.9165	0.3977	0.6125	0.7824	-0.168	1				
Non.Mkt (kg)	0.1387	0.2875	-0.0817	-0.2825	0.2780	-0.1556	1			
Mkt.Qty	0.6807	0.6680	0.7306	0.6502	0.2596	0.7071	-0.0647	1		
PL.Hgh (m)	0.2048	0.2996	-0.1500	0.0419	0.3548	-0.0024	0.3103	0.0906	1	
Pest	0.4386	0.0724	0.1500	0.3243	-0.135	0.5438	-0.5583	0.2150	-0.2373	1

Abbreviation represent: Tot.Wt.(kg)=Total weight (kg), #shots hvst= number of shoots harvested, Mkt.Shots = marketable shoots, #Lvs.Brn = Number of leaves for branches, Lvs.Ms= leaf number of main stem, Mkt.Wt (kg) = marketable weight (kg), Non.Mkt.Wt (kg) = non marketable weight (kg), Mkt. Qty = market quality

DISCUSSION

Plant height (m)

Plant heights have strong correlation with number of leaves for main stem and non-marketable weight (kg)(Table 6). Hence, AM 3, 32 and 5 maintaining high plant height with increment of about 20% in its height development from 7 to 14 and 25DAT. Also the 6 genotypes having high plant height during the study intervals were, AM 3, 32, 8, 6, 5 and 7 stand out at 7, 14 and 25DAT respectively.

The higher the plant height or tall plants turn to have less branches and leaves and it shows that they are not economical as they turn to have low marketable branches and leaves. Plant height have negative correlations on marketable shoots and marketable weight (kg) and number of branches. The lower the plant height the higher the branching ability and that contributes to more stems and shoots and prolific leave production.

Branching and shoots

The amaranth shoots and branching plays a pivotal role in the development of the aboveground plant structure. From the results, the branching mechanism was noticed at each assessment period, the earlier the development of branching have set great canopy occupying more areas utilizing more resources. The genotypes with high ability to producing branching and shoots at early growth stages (7 & 14 DAT)were AM 3, 4, 32, 23 and 26 while genotypes AM 7, 6, 8, 2 and 11 had high branching ability at harvest or maturing stage with about 18-22 branches.

Branching is a key determinant of plant shape as well as maturity. The genotypes with ability to branch early had terminated its growing ability and develop early flowering thus early maturity. Because of sensitivity to environmental factors, branching is highly plastic, when grown in a dense stand, a plant can produce a single branchless stem, whereas when grown solitarily, the same plant can produce numerous branches, resulting in a bushy habit. At any time, the number of branches formed and their size determine the total area of the plant, the spatial distribution of leaf area in the canopy and, thus, the amount of light absorbed. Therefore, plasticity in branching determines the competitive strength of the plant in relation to neighbouring plants in terms of capture of light and other resources (Evers, J.B. *et al*.2006). From the results of this study, the genotypes (AM 7, 6, 8, 2 and 11) with high branching and shoot ability although had shorter plant height, they turn to have high total weight and marketable quality.

Leaf number

As discussed previously the branching ability of the plant indicated the productivity and active production of succulent leaves excellent for consumption. The term yield in this research was used to include all parts of the plant that is usually harvested and used as vegetable. It included new shoots and branching with leaves or buds.

The leaf numbers determine its economic value of the amaranth. From this study there were high leaf numbers in genotypes AM 8, 32, 24 and 2 at7 and 14DAT with average of 7 and 13 leaves at 7 and 14DAT respectively. At harvest four genotypes giving higher main stem leaves were AM 8, 7, 6 and 11. whereas AM 10, 6, 23 and 25 having high branching leaves indicating high economic value genotypes. The genotype Am 6 was performing uniformly in terms of leaf numbers till the harvest having more leaves on the main stems as well as the branches.

There were strong correlations for number of leaves for branches with total yield and also showing positive correlation with marketable weight (table 2.) whereas the leaves for the main stem having weak correlation to total yield and other yield parameters. Hence, AM 10, 6, 23 and 25 having high branching leaves indicating high economic value genotypes.

Yield and yield parameters

Differences observed in number of leaves harvested and branch number per plant might have been due to genetic variation that existed among genotypes and or due to favourable influence of growing factors such as soil nutrients, plant canopy, water distribution, weeding and management with the interaction of environment. In general higher value of leaves harvested per plant was observed in AM 7, AM 6, AM 10, AM 3, AM 7, AM 32 and AM 11 in this season.

This might be explained due to the fact that different genotypes respond differently in this study. Some local landrace induced early flowering ability compared to other lines, and therefore extended the vegetative phase which resulted into higher number of leaves harvested. This observation is in line with findings by Okokoh and Bisong (2011) which observed a sharp decline of leaf productivity in some amaranth studied after on-set of flowering.

Total yield harvested was measured against other yield parameters by which strong positive correlations for marketable weight and market quality and positive correlations were observed for marketable shoots and branches harvested number of leaves for branches harvested, and weak correlations for non-marketable weight and plant height have very weak correlation with total yield meaning plant height have little influence on yield. It has been reported that fresh leaf yield of Amaranthus may vary from 10 to 70 t ha^{-1}, while seed yield ranges from 1 to 6 t ha^{-1} (Svirskis, 2003). Leaf yield values reported in this study were generally lower for amaranths species. Destructive harvest was carried out for the datum plant and if topping harvest than that will allows more side shoots and delayed flowering which enhances more leaf yield. These genotypic differences with regard to leaf and branching ability and there were clear differences among genotypes tested.

Sensory evaluation

The visual observation of amaranth leaves after steamed its aroma by smelling, softness, sweetness by tasting and overall judgment form the base of selection. AM10 (71%), AM35, AM 8 (64%) having good indication between likes and neither like or dislike respectively. Also for aroma by smelling shows that eleven genotypes have good aroma viz good indicated noted on AM8 (35%), AM 7, 23 (64%) and AM5 (28%). The ssoftness (palatability) for the testers, 85% indicated genotype AM 7 (85%), AM 5 (57%) & AM 24 (35 %) and finally sweetness varies with individual tasters, by which AM 4 (42%), AM 11, AM 10 & AM5 (71%). finally the overall acceptability was the summation of the sensory evaluation AM 23 (71 %), AM 7 (64 %), AM 26 (57%), AM 5 & AM 4 (43%) were liked by the testers.

Good taste and cooking appearances are potential for selection by which five genotypes indicated better taste. There are potential to evaluate and select more leafy amaranth lines with higher leaf yield as well as lines with late flowering characteristics and good taste.

CONCLUSION

From the 15 genotypes evaluated, 8 genotypes (AM 7, AM 6, AM 5, AM 32(A. hypochondriacus), AM 3, AM 23(A. Blitium) AM 10(A. hypochondriacus) and AM 11(A. dubias) showed potential or ability to mature early, capacity to produce high marketable yield and ability to resist/tolerate pest and disease. Because of these good characteristics and potentials these 8 genotypes can be recommended for further demonstration and distribution for general cultivation by farmers.

RECOMMENDATIONS

The study conducted was only for two seasons under dry Laloki (Port Moresby) environment or condition and needs to be repeated again in other environments if needed. Otherwise the selected lines can be further demonstrated in the field day for farmers assessment and selection and the general seeds storage and distribution system needs to be worked further.

ACKNOWLEDGEMENT

The financial support of the Australian Centre for International Agricultural Research is gratefully acknowledged. The authors are also thankful to the project team and NARI SRC and other research centers' staff who helped in one way or another in this study.

REFERENCES

Andreas W. Ebert, Tien-hor-Wu, & San-Tai Wang. (2011). Vegetable amaranth (Amaranthus L.). AVRDC-WorldVegetableCenter.

AVRDC, (2004). AVRDC Report 2003. AVRDC Publication Number 04-599. Shanhua, Taiwan: AVRDC-The World Vegetable Center. 194 pp.

AVRDC, (2011). New variety releases expand market options for Tanzania‟s farmers. Fresh news from AVRDC-The World vegetable center pp.1-3.

Ebert, W. A., Wu, T. and Wang, S., (2011). Vegetable amaranth (Amaranthus L.). International cooperator‟s Guide. AVRDC Publication Number 11-754. Shanhua, Taiwan

Gigliola camaggio, vera amicarelli. (2012). amaranthus : a crop to discover. forum ware international. Retrieved from http://forumware.wu-wien.ac.at/archiv/1364801634.pdf

Grubben, G. J.(2004a). Amaranthus cruentus L. PROTA.

Grubben, G. J. (2004b). Amaranthus Dubius. Retrieved from http://database.prota.org/PROTAhtml/Amaranthus%20dubius_En.htm

Kauffman, C. S., and Weber, L. E. (1990). Grain amaranth. p. 127-139. In: Janick, J. and Simon, J. E. (Eds.), Advances in new crops. Timber Press, Portland, OR.

Kaul, H. P., Aufhammer, W., Laible, B., Nalborczyk, E., Pirog, S. and Wasiak, K., (1996). The suitability of amaranth genotypes for grain and fodder use in Central Europe. Die Bodenkultur 47 (3): 173-181

Lyimo, M., Temu, R. P. C. and Mugulu, J. K. (2003). Identification and nutrient composition of indigenous vegetables of Tanzania. Plant Foods of Human Nutrition. 58: 85-92

Maundu, P., Achigan-Dako, E, and Morimoto, Y., (2009). Biodiversity of African vegetables. In: Lichtfouse, E., Hamelin, M., Nararrete, M. and Debaeke, P. (Eds.): Sustainable Agriculture volume 2. London. EDP Sciences. Ch. III.

Mlakar, S. G., Turinek, M., Jakop, M., Bavec, M. and Bavec, F., (2010). Grain Amaranth as an alternative and Perspective crop in Temperate climate. Journal for Geography, 5-1, 2010, 135-145.

Moraa, D. O. C. (2008). The physico-chemical characteristics and some nutritional values of vegetable amaranth sold in Nairobi-Kenya.

Okokoh, S. J. and Bisong, B. W., (2011). Effect of Poultry manure and Urea-N of flowering occurrence and leaf productivity of *Amaranthus cruentus*. J. Appl. Sci. Environ. Manage. Vol. 15 (1) 13 - 15

Onyango, C. M. (2010). *Preharvest and postharvest factors affecting yield and nutrient contents of vegetable amaranth (Var. Amaranthus hypochondriacus)*.

Onyango, C. M., & Imungi, J. K. (2007). Post-harvest and handling characteristics of fresh-cut traditional vegetables sold in Nairobi-Kenya. In *African Crop Science Conference Proceedings* (Vol. Vol 8, pp. 1791–1794). Egypt: 70 African Crop Science Society. Retrieved from http://www.acss.ws/Upload/XML/Research/290.pdf

Onyango, C. M., (2010). Preharvest and Postharvest Factors Affecting Yield and Nutrient Contents of Vegetable Amaranth (Var. *Amaranthus Hypochondriacus*). Thesis, Wageningen University, Wageningen, NL (2010)

Palada, M. C. and Chang, L. C., (2003). Suggested cultural practices for vegetable amaranth. International cooperator‟s guide. Kalb, T (Ed). AVRDC pub. No.3. AVRDC. Taiwan.

Srivastava, R. (2001). Nutritional quality of some cultivates and wild species of amaranthus L.Retrievedfrom http://ijpsr.com/V2I12/17%20Vol.%202,%20Issue%2012,%20RA-934,%202011,%20Paper%2017.pdf

Stallknecht, G. F and Schulz-Schaeffer, J. R., (1993). Amaranth rediscovered. Pp 211-218 In Janick, J and Simon, J. E. (Eds), New crops. Wiley, New York

Svirskis, A., (2003). Investigation of amaranth cultivation and utilization in Lithuania. Agronomy research 1(2), 253-264

United State. Department of Agricultural (USDA) (2012). National Nutrients Database for standard reference Release 24 [Online] Available from <www.ndb.nal.usda.gov/ndb/foods/show/6310>. Accessed 21/04/2012

Venskutonis, P. R., & Kraujalis, P. (2013). Nutritional Components of Amaranth Seeds and Vegetables: A Review on Composition, Properties, and Uses. *Comprehensive Reviews in Food Science and Food Safety*, *12*(4), 381–412. doi:10.1111/1541-4337.12021

Wambugu, P. ., & Muthamia, Z., K. (2009). *The state of plant genetic resourse for food and agriculture in kenya*. Kenya: Kenya Agricultural Research Institute.

Weber, L. E., (1990). Amaranth grain production guide. Rodale Press, Emmaus, PA, pp 28.

11.2 Appendix 2: Literature Review

Seed Saving Systems

Picture: Seed Saver training delivered to PNG farmers by NARI. Courtesy of Philmah Seta-Waken, NARI.

Literature Review

Prepared by Claire Webb and Tania Paul

Charles Darwin University

Contents

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
CBD	Convention on Biological Diversity
CIAT	International Centre for Tropical Agriculture
CABI	Centre for Agriculture and Biosciences International
CGIAR	Consultative Group on International Agricultural Research (formally)
FAO	Food and Agriculture Organization of the United Nations
GPA	Global Plan of Action
IPR	Intellectual Property Right
IT PGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
ISSD	Integrated Seed Sector Development in Africa
MAF	Ministry of Agriculture and Fisheries of Timor-Leste
NARI	National Agricultural Research Institute
NGO	Non-Governmental Organization
PBR	Plant Breeder's Rights
PGRFA	Plant Genetic Resources for Food and Agriculture
PNG	Papua New Guinea
PPB	Participatory Plant Breeding
QDS	Quality declared seed
SoL	Seeds of Life
UNDP	United Nations Development Program
USAID	United States Agency for International Development
WVC	World Vegetable Centre

Introduction

Agriculture is the primary source of income and support of livelihoods for 70 percent of Papua New Guinea's (PNG) population (Asian Development Bank, 2013). Seed is the crucial base genetic input required for crop production in agriculture (Louwaars, 2007; McGuire & Sperling, 2011). Adequate access to viable seed is vital for the livelihoods of agricultural communities, and for food and nutritional security. However, due to a number of challenges, seed systems in PNG are limited and largely rely on informal methods of farmer exchange (Camilla Zanzanaini, 2014; Kingwell, Godden, Kambuou, & Jackson, 2001). This system does not cater for food and seed crisis such as the 2015 El Nino driven frost and drought in the PNG Highland provinces which resulted in mass devastation of crops and loss of viable seed for the next crop production (Connors, 2015).

On a global scale, seed is a crucial genetic resource for food production, fibre, clothing, feed for animals, fuel, and shelter (FAO, 2017). According to the Food and Agriculture Organization of the United Nations (FAO), plants make up 80% of the human diet and directly or indirectly support every person on Earth (FAO, 2017). Agriculture is the main livelihood for 70% of the world's poor living in rural areas (FAO, 2016). The secure collection, conservation, and storage of seed through established systems is critical to ensuring agricultural communities have sufficient access and availability for crop production.

Developing seed systems is particularly important to protect genetic biodiversity, improve livelihoods of agricultural communities, and provide emergency response to seed and food insecurities (Louwaars, 2007). These insecurities are caused by a range of challenges such as climate change, droughts, disease, market failures, or conflicts which result in crop failure, famine and displacement of people from their productive land (Easton & Ronald, 2000; FAO, 2009b; McGuire & Sperling, 2011). The development a formal national seed system in PNG, could mitigate against the threat of climate change, and ensure farmers have adequate access to quality seed even during a crisis such as the 2015 drought (Ebert, 2015) which resulted in famine and deaths due to starvation for the first time in many decades.

This literature review was undertaken at the request of PNG collaborators during community consultation as part of the Australian Centre for International Agricultural Research (ACIAR) project "Promoting leafy traditional vegetable production and consumption for improved livelihoods in Papua New Guinea and Northern Australia." One of the key findings of the research was a serious lack of access and availability to quality local seed stock as a major constraint to sustainable crop production and food security (Ebert, 2015).

This paper is written in the context of agricultural seed systems where the word 'seed' commonly refers to planting material intended for crop production (Louwaars, Coent, & Osborn, 2011). In literature, seed can either be generative or vegetatively propagated material. According to Louwaars et al, seed in the agricultural context refers to *'any type of planting material that is intended for use in producing a new plant, i.e. either generative or vegetative, such as roots, tubers, bulbs, cuttings, rhizomes and apomictic seed"* (2007) Seed is also given the wider title of 'Plant Genetic Resources in Food and Agriculture" or PGRFA (FAO, 2017). 'Germplasm' is also used particularly in literature related to PNG to describe the base genetic materials (Kingwell et al., 2001; NARI, 2006). Therefore 'germplasm', along with 'seed', and 'PGFRA' will be used interchangeably through this paper.

The aim of this paper is to provide an overview of the global landscape related to seed saving practices within the context of PNG agricultural systems and linking to seed saving practices in PNG. The paper documents case studies with relevant systems and procedures that could be applied within the context of PNG.

What are seed systems?

The organised collection and trade of seed is understood to be a 'seed system' which can be conducted following various levels of organisation, methodologies, policies, and practices (Louwaars et al., 2011). This system involves the management, storage, conservation and use of plant genetic resources following formal or informal channels (Louwaars, 2007). According to FAO, the sustainable conservation of germplasm is important for safeguarding genetic biodiversity, crop development, adaptability of both wild plant species and cultivars, preserve traits, and developing biotechnology and commerce (2017). Germplasm is also conserved to improve access and availability of viable seed which is crucial for food and nutritional security (FAO, 2014).

Historically, germplasm was conserved primarily 'in situ', meaning in the farm or garden where plant materials are maintained in their natural surroundings or where a cultivar has developed its traits (FAO, 2018a; Wright. Brian D, 1997). In situ collections today are often referred to as 'on farm' or 'genetic reserve' conservation (FAO, 2017). Over the last three centuries, ex situ conservation has developed involving the storage of germplasm outside of their natural environments in collections and public institutions such as botanic gardens, herbariums, and genebanks (FAO, 2018a; Louwaars, 2007; Wright. Brian D, 1997). Today, the development of sustainable ex situ facilities, primarily genebanks, have been given priority under international law to combat the erosion of genetic resources (Westengen, Jeppson, & Guarino, 2013).

When examining conservation of germplasm, literature often divides seed systems into two categories: formal and informal systems (C. J. M. Almekinders, Thiele, & Danial, 2006; N. P. Louwaars, 2007; McGuire & Sperling, 2016). Formal systems are also referred to as 'commercial' and usually subject to research and regulations. Informal systems are farmer led and not subject to vigorous regulations (CABI, 2014). These two systems can use both in situ or ex situ conservation methods and have similar goals in collecting and storing seed. This section will examine seed systems under these two broad categories.

Formal systems

Formal seed systems, which are also referred to as commercial systems, are run by public and private sector institutes and agencies (CABI, 2014). It follows a standardised chain of activities involving the management and conservation of genetic resources, as well as research, storage, marketing, and distribution of seeds (FAO, 2017; N. P. Louwaars, 2007). These systems use guiding principles and regulatory frameworks to maintain variety identity, purity, and quality (FAO, 2017). They produce optimal quality seed through select breeding and research into crop varieties, hybrids, and seed multiplication. These improved seeds are then marketed through official outlets and agricultural research systems for farmer use (CIAT, 2014). The formal seed chain is demonstrated in Louwaars' (2007) flow chain (Figure 4), shows the flow of seeds that starts with inputs of genetic materials to breeding, multiplication, and then marketing.

Figure 1: Formal Seed Chain

The above figure shows that the formal chain is a closed system. Where seed input is supplied from local or wild varieties, then the improved seed leaves the chain to be distributed in to farmers (N. P. Louwaars, 2007).

Genebanks are the main formal seed saving facility invested in safekeeping food crops and long term accessibility of germplasm to plant breeders, researchers, and other users (FAO, 2014). Currently, there are over 1700 genebanks across the globe conserving millions of accessions of germplasm (FAO, 2014; Westengen et al., 2013). According to the FAO Genebank Standards for Plant Genetic Resources (2014), the main types of genebanks used in the formal system are:

Seed Genebanks: the conservation of orthodox seeds. Orthodox seeds refer to crops that can produce seed that can be conserved at low temperatures and humidity (Westengen et al., 2013)

Field Genebank: are germplasm collections involved in maintaining live plant collections. It is the most common conservation method for plants that do not produce orthodox seeds or produce very few seeds (FAO, 2014).

In vitro culture: This is system is slow growth storage. It involves plant cultures (such as shoot tips) are produced in slow growth conditions on artificial media (FAO, 2014).

Cryopreservation: Biological materials including seeds and embryos are stored at extremely low temperatures to ensure long term conservation. This method demonstrates scientific advances in germplasm conservation however it is expensive and labour intensive (FAO, 2014).

Each of the above methods are highly regulated in terms of raw material acquisition, evaluation, documentation, and security (FAO, 2014).

These formal systems are commonly used by high input agricultural enterprises that have the capacity to access and afford the improved seed varieties. Large organisations also purchase both certified seed, which is a formally released breeder seed, and standard seed for distribution in humanitarian initiatives or for emergency aid (CABI, 2014; Sperling & McGuire, 2012, p. 2). There are different terms used to classify the quality of seed produced in the formal system, according to Centre for Agriculture and Biosciences International (CABI, 2014) these classifications are:

- **Breeder Seed** – produced by plant breeders and small quantities
- **Foundation Seed** – which is bulked up breeder seed

- **Standard Seed** – is quality seed that is produced by regulatory agencies in response to demand
- **Certified Seed** – which is foundation seed bulked up to be sold to farmers. This system must have the same quality as 'standard seed' but has gone through a formal variety release
- **Quality Declared Seed (QDS**) is a system developed by FAO in 1993 and revised in 2006 to produce a 'satisfactory' quality of seed. This system does not have the same demands or standards as the 'Certified' seed but meets the demands of resource poor, financially constrained countries (Plant Production and Protection Division, 2006).

These guidelines and protocols guide the quality of seed produced which can be subject to procedures, inspections, and certification (CABI, 2014). The purpose of quality control of seed is to increase the yield, productivity of a crop, and resilience to environmental stresses.

Disadvantages of Formal Systems

Literatures in recent decades have levelled criticism of the formal system as it does not perform as well in smallholder agriculture settings due to being inaccessible, expensive, and restrictive regulations (C. J. M. Almekinders et al., 2006; Sperling & McGuire, 2012; Witcombe, Devkota, & Joshi, 2010). Current figures suggest that 80-90 percent of seed used by farmers are from informal sources depending on the region and crop (C. J. M. Almekinders et al., 2006; FAO, 2017). Formal systems prove effective when supplying to high input agriculture however is less successful to supply low input agriculture and small scale farmers.

According to Almekinders, Thiele, and Danial, supplying formal seed to small holders have encountered a number of supply and demand constraints (2006). Constraints include distributions of varieties poorly adapted to the environment and high seed prices due to production costs; (C. J. M. Almekinders et al., 2006). On the demand side: poor markets, low or variable sales.

Distance and inaccessibility of agricultural communities is another barrier. Freshly harvested seed can deteriorate while being transported long distances or arrive after the main planting season has started (N. P. Louwaars, 2007). Also, small scale suppliers of seed in remote areas tend to be untrained on how to disseminate knowledge on managing the seed of a particular crop. High yielding crops often require a higher level of maintenance including the need for fertilisers, herbicides and other inputs (Ronny Vernooy, 2003). As a result small holders do not have the expert advice required to optimise the yield of their crop include pest and disease management and nutrient deficiencies (CABI, 2014).

Seed laws, regulations, and frameworks ensure quality seed is produced, however they also create barriers. There are different regulations around the use of certified seeds. For instance, for a smallholder to grow cross pollinated crops, they are required to set up plots isolated from other crops (CABI, 2014). The farmer either comes to an agreement with their neighbours about what varieties they will grow or otherwise they just cannot grow the seed (CABI, 2014). Farmers growing certified seed also have to pay for the costs to be a registered grower, for sampling and testing, and for field inspectors (Louwaars, 2007).

Seed regulations can be so severe restrictions on smallholders that in some cases it turns farmer saved seed into illegal activities (CABI, 2014; Louwaars, 2007). For example, in 2003 Kenya introduced seed regulations so rigorous that the informal seed trade has been outlawed and farmers are not allowed to sell their own seeds (CABI, 2014). Under these regulations, farmers can only generate income from seeds as official growers of seed companies and creates obstacles such as inability to trade with neighbouring countries (CABI, 2014). Poulton and Kanyinga's working paper discusses how introducing these regulations have created sever obstacles with little headway to achieve positive goals (2013).

Informal systems

Informal systems are also referred to as local, farmer or traditional seed systems. According to FAO, around 80-90 percent of farmers use informal systems to obtain seed (2017). A recent study examined six countries across Africa and found that 90.2 percent of seed are from informal systems (McGuire & Sperling, 2016). Seed in the informal system is easily accessible and available through local farmer networks, community seed groups, and markets. Literature suggests the advantage of locally selected seed are better adapted to local growing conditions and stresses due to a process of human and natural selection (Connie JM Almekinders, Louwaars, & De Bruijn, 1994; Stone, 2002). They also support local agrobiodiversity and locally valued varieties are easily accessible (CABI, 2014).

Informal systems follow locally organised activities where farmers obtain seed through a mixture of harvesting their own seed, local networks including neighbours and community seed groups, local markets and fairs, as well as from formal seed sources (N. Louwaars et al., 2011). Farmers and community seed saver groups will do their own variety testing, selection, multiplication, and storage.

The notable differences to the formal system are they are not regulated by government policies and standards; they follow local technical knowledge, social systems; and they do not follow a linear sequence of set activities (FAO, 2017) as demonstrated in the flow chart in Figure 5. Farmers select their seed based on their needs and preferences with evidence to suggest farmers prefer a mixture of formal and informal sources (Access to Seeds Foundation, 2016).

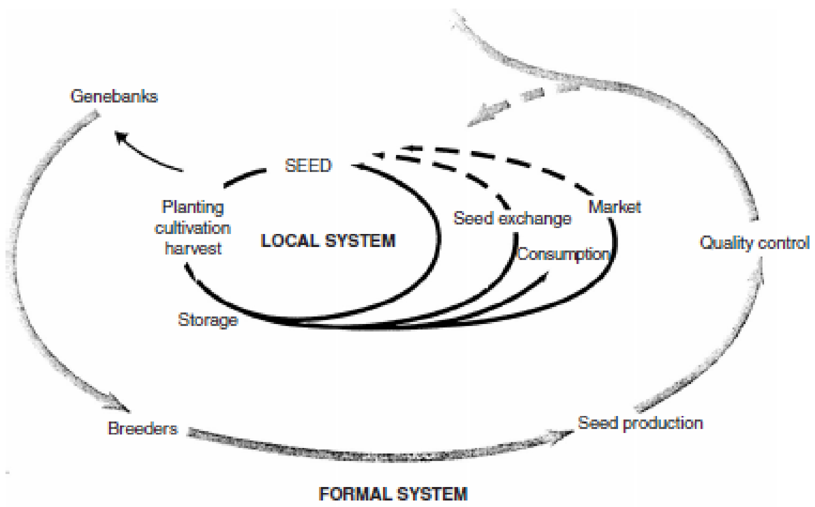


Figure 2: Farmers' sources of seed (Conny JM Almekinders & Louwaars, 2002)

Almekinders et al's flow chart (Figure 5) demonstrates the informal system which does not tend to be linear in their approach and often decentralised. This system involves a range of seed sources and actors including local seed exchange, markets, community and village seed production, local entrepreneurs, as well as sources from formal systems (McGuire & Sperling, 2016; Stone, 2002).

Disadvantages of informal systems

The disadvantage of informal seed systems is that the germplasm are often characterized as less uniform, poor cultivar adaptations, and can vary in quality compared to the formally sourced seed (C. J. M. Almekinders et al., 2006; FAO, 2017; Louwaars, 2007). Sales of seed can be low or variable which impact on farmer profits as well as high transport costs for crops with low multiplication rates which then need to be sourced from other regions (CABI, 2014).

Chronic stress situations also can impact the local supply of quality seed such as environmental pressures like drought and disease, civil strife, and poor functioning markets which can also impact on a region's food security (Louwaars, 2007; McGuire & Sperling, 2011). In these situations, informal systems can become reliant on seed aid sourced from formal systems which are supplied by various NGO's and aid programs (CABI, 2014).

Why are seed systems important?

Seed is an essential resource. It performs an important function in global food security, poverty reduction, rural development, technology development, conserving biodiversity, and as an economic trading commodity on regional and international markets (Louwaars et al., 2011;. Louwaars, 2007). According to FAO "Plant genetic resources are the biological basis of food security and, directly or indirectly, support the livelihoods of every person on Earth" (FAO, 2017). The aim of many seed systems is to collect, conserve and sustainably use germplasm (FAO, 2018a; N. P. Louwaars, 2007; Wright. Brian D, 1997).

The conservation chain starts from the in situ resources, to genebanks, research facilities and breeders, then feeds back to distributers, farming communities and consumers (FAO, 2014). Each of the players in the chain are affected by this system. This section will briefly outline the importance of seed systems in four key areas (1) Food security; (2) the farmers: Sustainable livelihoods of agricultural communities; (3) the researchers: Developing biotechnology and crop improvements; and (4) conservation facilities: Conserving genetic biodiversity.

Important for food security

Germplasm is the base biological material required for sustainable food production which is essential for the livelihoods of all humans (FAO, 2017). Food security therefore is heavily reliant on seed security. The loss of these genetic resources will threaten the world's supply of food (FAO, 2017). The world faces various challenges including the need to feed a growing population, chronic hunger, climate change, land degradation, and the loss of plant genetic resources due to environmental stresses. As awareness of these challenges have emerged, the need for conservation and sustainable use of germplasm as an essential resource has played a central role in global debates since the 1950's (FAO, 2011; Louwaars, 2007).

Local governments through to international bodies have engaged in debate to set in motion measures to support farmer rights, conservation initiatives, and regulatory frameworks to safeguard seed (Louwaars, 2007). Such international frameworks include the Global Action Plan for Plant Genetic Resources for Food and Agriculture which set out with 131 countries the priority plans to conserve genetic resources (FAO, 2011). As well as global initiatives including the 2009 'International Treaty on Plant and Genetic Resources for Food and Agriculture' (IT-PGRFA) which states in article 1.1:

"The objectives of this Treaty are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security." (FAO, 2009b)

The treaty recognises there is interdependence between seed and food security (FAO, 2009b). In 2016, the United Nations also introduced international policy under Goal 2 of the '2030 Agenda for Sustainable Development' recognising that agriculture is a key solution to eradicating hunger. In this goal it states: *"By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed… including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed".* The UN recognises that the conservation of genetic diversity from local to international levels is recognised as an important aspect of food security (UNDP 2017)**.**

Seed aid separate to food aid

The international recognition of the importance of seed has made it a key platform in development programs with the goal of promoting global food security (Sperling & McGuire, 2012). Aid agencies and development programs invest large sums around the world to improve the access, availability, and utilisation of quality seed (Access to Seeds Foundation, 2016; FAO, 2015b; Sperling & McGuire, 2012). For example, the World Bank funded 87 seed programs in the 2007-2012 period worth US $513 million and in the same period 112 grants for Africa seed programs worth $35million were dispensed by the Alliance for Green Revolution (McGuire & Sperling, 2016).

There are a number of different forces that contribute to food or seed insecurity such as environmental stresses, political or civil crisis, or disasters i.e. tsunami. There have been instances where emergency aid have provided poor quality seed or poorly adapted seed which again contribute to food issues (McGuire & Sperling, 2011). Poor quality seed can result in poor yields or lower quality of harvest which can contribute to a reduced output.

Seed security and food security are often linked when examining development programs and emergency aid responses (McGuire & Sperling, 2011; Remington, 2002; Wildfong, 1999). In discussing the links between food and seed security, it should be noted that emergency aid responses to a food crisis have in the past automatically resulted in immediate distribution of seed for agricultural production as well as food (McGuire & Sperling, 2011; Remington, 2002). According to McGuire and Sperling, the automatic assumption is that a food security crisis also means a seed security crisis or have diagnosed the problem is due to a lack of improved seed varieties (McGuire & Sperling, 2011).

The immediate diagnosis of an agricultural input has resulted in some cases of unnecessarily distributing seed or providing, poorly adapted seed, or create farmer dependency on seed aid which can make farming populations even more vulnerable (CIAT, 2012; McGuire & Sperling, 2011; Sperling. L, 2007). A farmer may have enough seed for the next production crop but does not have enough food while waiting for the harvest or vice versa, a farmer could have food but no seed for the next crop cycle (CIAT, 2014). The lack of seed policy has led to inefficiencies that impact on a community's ability to recover from a crisis.

Literature in recent years have argued that a food and seed crisis need to be assessed separately in aid programs (Sperling & McGuire, 2012). For example, in emergency aid funding proposal, citing 'drought' was enough to receive seed aid without any need for an assessment (CIAT, 2014; McGuire & Sperling, 2011). McGuire and Sperling argue that food and seed security have similar goals and definitions, assessments for seed aid took were assessed to the same diagnostic base as food aid (McGuire & Sperling, 2011). The USAID Food and Nutrition Technical Assistance (FANta), define food security as: *"When all people at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life (FANta, 1999)."*

Similarly, FAO's current definition of seed security is: '*Seed security is defined as ready access by rural households, particularly farmers and farming communities, to adequate quantities of quality seed and planting materials of crop varieties, adapted to their agro-ecological conditions and socioeconomic needs, at planting time, under normal and abnormal weather conditions*." (FAO, 2018b) Both definitions state that being food and seed secure means sufficient access and availability to both resources. The below table demonstrates the similarities:

Figure 3 – Comparison of pillars for food and seed security (FAO, 2015a)

Food security	Seed Security
Food availability	Seed availability
Food access	Seed access
Food quality	Seed quality
Food preferences	Seed preference
Stability of food security in the context of shocks and stresses - Resilience	Stability of seed security in the context of shocks and stresses - Resilience

The definition of food insecurity is easily quantifiable using international parameters such as assessing daily kilocalorie intake while by comparison it is difficult to measure sufficient seed for a household (FAO, 2015a).

In recent years, recognition that a lack of defined seed policy have led to inefficient responses to emergency aid, CIAT (International Centre for Tropical Agriculture) developed the Seed Security Assessment toolkit and FAO followed suit (FAO, 2016). The guides aid practitioners on the appropriate response (FAO, 2016; McGuire & Sperling, 2011). FAO's definition of seed security contains 5 pillars which assist in developing appropriate actions during a crisis are defined as:

- Access – how easily seed can be acquired

- Availability – *"Seed has to be available for every crop production cycle. It has to be there at the right time, in the right quantities, with the right qualities and at the right price so farmers can access the seed they need*
- Quality –germination rates, purity, and pest and disease free
- Varietal suitability – Farmers need or prefer these adapted varieties
- Stability – the resilience of the seed system to shocks and stresses

These definitions are used to guide to guide assessment tools designed for the Seed Security Assessment (SSA) toolkit which helps practitioners provide targeted emergency response to build household resilience, accelerate recovery, and reduce future vulnerably (CIAT, 2012; FAO, 2015a).

Technology development

Germplasm is the carrier of genetic diversity and a key technology in agriculture. Its makeup will determine the crop's characteristics, quality, germination rates, vigour, environmental adaptions, and yield potential and stability (N. P. Louwaars, 2007; McGuire & Sperling, 2016). The genetic makeup of a seed is a vehicle for technology transfer. Breeders manipulate the plant genes to modify its makeup to develop advanced varieties, referred to as biotechnology (FAO, 1993). Breeders select plant genes that display desirable traits and develop enhanced varieties for the purpose of profitability of crop improvements, as well as for food security, rural development, system resilience to shocks, and agricultural progress (FAO, 2015b; N. P. Louwaars, 2007; McGuire & Sperling, 2016).

Effective conservation including safe storage, germplasm characterisation, and documentation of a wide variety of seeds with different traits ensures breeders and researchers have access to a wider gene pool (Wildfong, 1999). Plant breeders and researchers select germplasm of domesticated, hybrid, or wild crop relatives to produce new varieties which result in formally released germplasm that maintain seed with optimal sanitary, physical and physiological qualities (FAO, 2017).

Breeders select raw plant genetic materials based on particular traits such as drought tolerances, improved tastes, produce high yields, pest and disease resistance, or resistance to environmental stresses (FAO, 1993; Shand, 1997). Developing improved varieties and technologies benefit crop production, build system resilience to shocks, and contribute to sustainable conservation methods which will now be discussed briefly.

Crop improvement

The focal point of breeding programs and modern biotechnology is to develop germplasm traits that contribute to more productive crops through increased or more stable yields and adaptations to growing seasons. An example of this is in Asia and Latin America, where the introduction of wheat and rice varieties with short straws allowed for larger harvests through reduced plant spacing and shorter growing seasons (Louwaars, 2007)

Other developments include improving marketable qualities such as enhanced grain colour or nutritional values (Louwaars, 2007). Breeding strategies develop new varieties to produce elevated micro-nutrient levels which increase consumer preference (McGuire & Sperling, 2016). Increasing the consumer value in a product improves market prices which also benefit stakeholders in the development, production, and marketing chain.

Pest and disease resilience

The main priority of plant breeders is to develop varieties that are resistant to pest and disease threats for major food crops (FAO, 2010). According to FAO *"Plant breeders continuously try to develop new varieties to keep one step ahead of thousands of pests and diseases"*(FAO, 1993). Crops, particularly a single uniform variety, can be most vulnerable to pest and disease attack as it can spread rapidly through the entire crop (Shand, 1997). For example, in the 1970's the southern leaf blight wiped out $1000 million worth of a genetically uniform variety of maize in the United States. A variety of maize which was resistant to the blight was located in Africa and adapted to avert further destruction (FAO, 1993; Shand, 1997). Plant breeders are continuously developing new varieties to combat this threat.

The development of genetically modified (GM) crops is where new genes are added to the plant genome. GM technology focuses on developing crops with a resistance to herbicides as well as biting insects (Louwaars et al., 2011). GM technology only targets large scale crop production due to the high costs to develop it. The technology is profitable, the trade of GM seed increased 25 fold between 1996 and 2007with a profit of reaching US$7 275 million (Louwaars et al., 2011). It should be noted that as the trend in using GM crops has grown, so have the debates about environmental and agricultural risks of this technology (Conner, Glare, & Nap, 2003). The arguments on both sides of the GM debate are too complex to expand on in this paper.

Resilience to climate change and environmental stresses

Current predictions show that average temperatures will rise by 2-4 degrees in the next 50 years and will cause changes to seasonal patterns (N. Maxted & Kell, 2009). Changes in climate conditions threaten reproductive cycles of crops including local varieties and traditional land races (FAO, 2011; N. Maxted & Kell, 2009). Crop yields, particularly in resource poor regions like East Africa, are already being affected by changing climatic conditions which threaten food security (Access to Seeds Foundation, 2016).

Environmental stresses such as droughts, land degradation, and high temperatures also threaten local and global food supplies. A prolonged drought can wipe out an entire crop and also threaten the future crop cycles (Louwaars, 2007). Breeders develop varieties to combat these stresses. For instance a variety of rice has been developed which can survive on 60 centimetres of rainfall each year while another variety has been modified to float on 7.5 metres of water (FAO, 1993).

With threats from climate change and environmental stresses, it is becoming increasingly recognised that agriculture must develop more resilient practices. Germplasm is a key technology with new adapted varieties that can be developed that can cope with the conditions (FAO, 2010, 2011, 2014).

Conservation

The use of biotechnology assists in the conservation of genetic materials through developing methods for the safe collection and storage of genetic material (FAO, 1993). Such technology can help identify desirable genes and improve long term storage and distribution techniques. A good example is tissue cultures, where cuttings from plants can be massed produced as genetic replicates from just a single cell (FAO, 1993). Genebanks store tissue cultures to conserve the genetic information.

Conserving genetic diversity

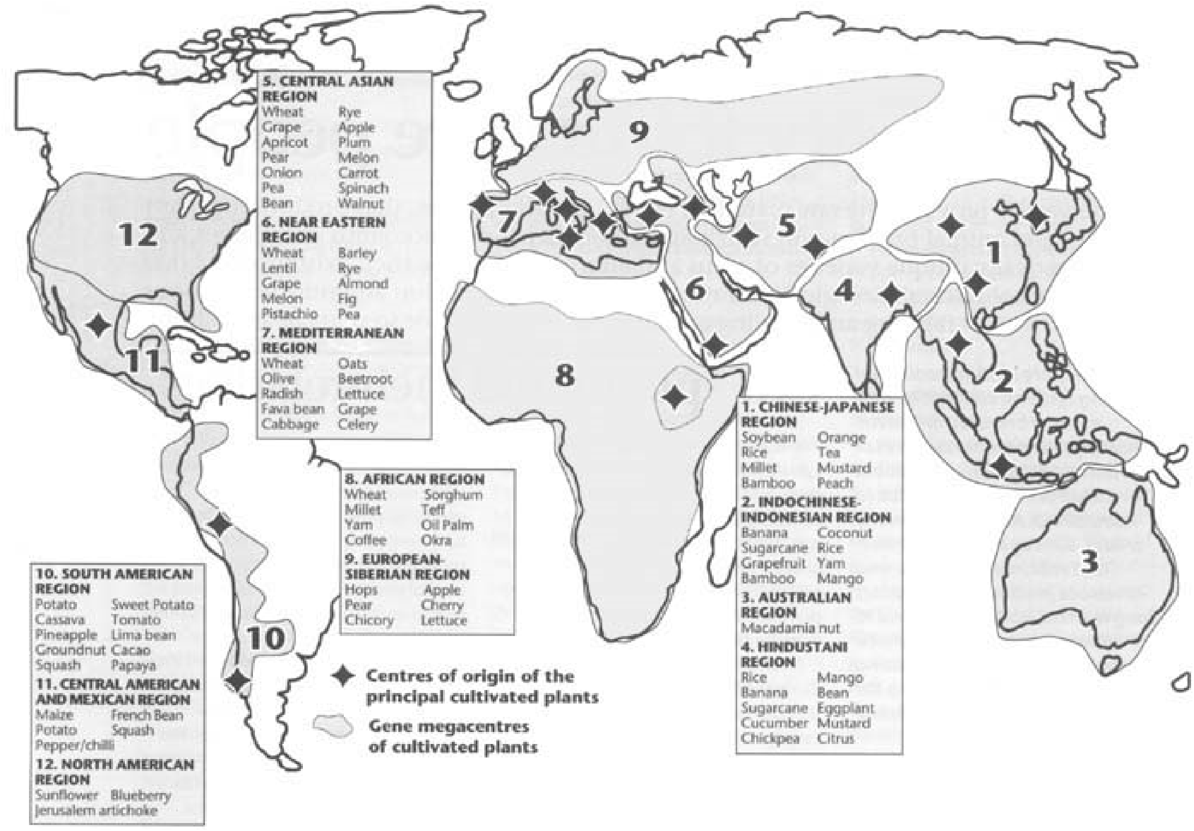
Over the last 12 000 years agricultural communities have developed thousands of varieties of seed through identifying, manipulating and domesticating plants to suit their needs, environmental conditions, and preferences (FAO, 1993; Ronny Vernooy, 2003). According FAO, genetic erosion has been occurring at a rapid rate with estimates that around 75 percent of the world's genetic crop diversity has been lost since the 1900's (Access to Seeds Foundation, 2016; FAO, 1993). Only around 150 species of plant are cultivated today while only nine of these species, including maize, wheat, potatoes and rice, supplies 75 percent the world's plant based food (FAO, 1993; Ronny Vernooy, 2003; Shand, 1997). There are a number of causes for the erosion of the world's genetic materials including land clearing, environmental degradation, overexploitation, climate stresses, and replacing local crop varieties with new ones leading to the traditional land races dying out (FAO, 2010).

A large contributor to the loss of local crop varieties occurred from the 1950's onwards with the 'Green Revolution.' Research institutes around the world bred and distributed high yielding commercial crops replacing traditional, genetically diverse plant varieties (FAO, 1993; Louwaars, 2007; Shand, 1997). In the developed world, consumer demand for cheap, predictable quality food led to the majority of food being supplied from a limited number of crop varieties produced in industrialised agriculture systems which can meet that demand (FAO, 2011).

A large proportion of food is still supplied by locally sourced germplasm in developing countries (FAO, 2011). However, new high yielding crops like rice and wheat have spread across many underdeveloped countries leading to massive decreases in genetic diversity of these crops (FAO, 1993; Shand, 1997). This agricultural practice of replacing traditional land races with single high yielding crop, referred to as monocultures, have led to a downward trend in on farm biodiversity contributing to genetic erosion (FAO, 2011, p. 14).

The loss of genetic diversity, or genetic erosion, is considered a threat to agriculture and the world's food supply (FAO, 1993; Louwaars, 2007). For breeders to maintain and develop desirable traits in major food crops such as pest and disease resistance or drought tolerance, breeders require access to fresh genetic sources including crop wild relatives (CWR) and land races of a major crop species (FAO, 1993). If breeders cannot access seed with desired traits, they cannot develop varieties that are resistant to a particular threat which leaves an entire crop vulnerable (Shand, 1997).

The tropics and subtropics are the origins of all major food crops produced in the world which is demonstrated in Figure 2 (FAO, 1993; Wright. Brian D, 1997). Many of these regions are also where underdeveloped countries are concentrated and where small holder populations still practice traditional agriculture and rely on local crop varieties (FAO, 1993). These geographic locations are known as centres of diversity (Wright. Brian D, 1997). Farmers from these regions also bring cultural diversity, their own knowledge, practices and forms of conservation (Ronny Vernooy, 2003)



.

Figure 4: Origins of major food crops (FAO, 1993)

GLOBAL BIODIVERSITY: SPECIES NUMBERS OF VASCULAR PLANTS

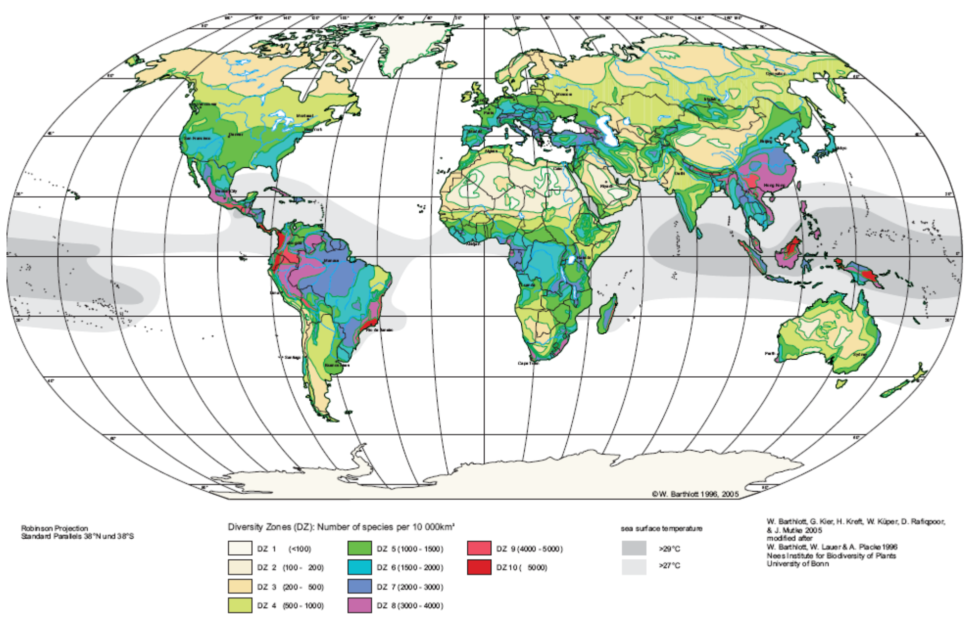


Figure 5 – Concentrations of biodiversity – red being the highest (Wilhelm Barthlott et al., 2005)

Threats to centres of diversity along with on farm seed varieties have increased in the last 20 years due to dwindling resources as well as human activities including urbanization, land-use changes, replacement of traditional land races, and climate change (FAO, 2011). National, regional and international agreements and policy plans have been developed in recognition of the need to sustainably conserve and use these resources to ensure genetic diversity exists for future generations (FAO, 2011; N. Maxted & Kell, 2009).

Sustainable livelihoods

Seed security is important for sustainable livelihoods of farming communities. It is the base genetic material required for crop production which contributes to incomes, food, and nutritional needs while improved varieties has the potential to increase productivity and incomes of agricultural communities (McGuire & Sperling, 2016). According to FAO, 70 percent of poor people around the world depend on agriculture as their main employment and source of income (2016). Agriculture is the world's largest employer sustaining the livelihoods of 40 percent of the Earth's population (United Nations, 2016b). If availability of quality seed becomes scarce due to environmental and man-made challenges, then subsistence growers and smallholder families struggle to meet their food and income needs (FAO, 2016). Seed systems play a pivotal role in ensuring seed is available thus creating resilience in agricultural communities against disasters.

Maximising the use of seed also contributes to rural development through agro-business enterprises. Small holders, farmers, and farmer groups develop seed system enterprises including collecting and selling their own seed, providing seed cleaning services or seed quality assessments (CABI, 2014; CIAT, 2014; Louwaars et al., 2011). Such enterprises improve local access to seed and also contribute to more sustainable livelihoods and agricultural community resilience (CABI, 2014). In recent decades trends are also emerging for small holder farmers to be involved in seed technology (Louwaars et al., 2011), which will be discussed further in section 2.3 "Diversified Seed Systems."

Sustainable livelihoods also contribute to larger goals of sustainable development for underdeveloped countries. According to 'Goal 2' of the United Nations' Sustainable Development Goals, hunger is a barrier which makes people less productive in contributing to development of poor communities of which are mainly from underdeveloped countries (United Nations, 2016b). Improving agricultural resilience through measures such as seed systems is important for building resilient livelihoods who can then contribute to other sustainable development goals including gender equality, health, and education (FAO, 2016; United Nations, 2016b).

Traditional knowledge and custodians

There is an increasing understanding that conserving germplasm should not just focus on the materials but also traditional knowledge of rural communities and indigenous peoples (Shand, 1997). For millennia, traditional communities and small holders have been custodians of a large diversity of plant genetic materials. The global shifts towards commercial foods has resulted in the loss of traditional knowledge of edible plants and medicines, as well as the crowding out of land races and narrowing of plant diversity (Easton & Ronald, 2000; FAO, 1993; Shand, 1997).

Debates around traditional knowledge and rights to genetic resources in international areas have led to the establishment of the **"**Intergovernmental Committee (IGC) on genetic resources, traditional knowledge and folklore" (Louwaars, 2007). The committee develops strategies weigh up protecting rights to that knowledge while still ensuring the valuable information and resources can be accessed plant breeders (Louwaars, 2007).

Women as custodians of biodiversity

The role of women should also be noted in the discussion of traditional agricultural knowledge. Across the globe, women have played a key role as custodians of plant genetic resources (Easton & Ronald, 2000). Over the millennia as agricultural practices developed, women have been central to the role of domesticating plants and cultivation seeds resulting in thousands of plant varieties (Ronny Vernooy, 2003; Shand, 1997). It is estimated that 60 percent of agricultural land across the globe are farmed by resource poor subsistence farmers or small holders, the majority of whom a women (Shand, 1997). In developing countries, women have primary responsibility to maintain the household survival including food production and the safeguarding of seed (Easton & Ronald, 2000; FAO, 1993).

Diversified seed systems

Trends have emerged in recent decades to diversify seed systems to integrate the knowledge and resources of both formal and informal systems (C. J. M. Almekinders et al., 2006; N. P. Louwaars, 2007). The two systems have worked in different zones of influence, values, practice, and philosophies with little interaction or shared benefits (McGuire & Sperling, 2016). As stated by Louwaars et al *"A lack of awareness of the genetic resources, knowledge, and capabilities available in these systems can also lead to attempts to replace informal seed systems rather than embracing their values"(N. Louwaars, Boef, & Edeme, 2013).* The lack of value in farmer knowledge and contributions to breeding strategies has led to a downward spiral of agricultural biodiversity (Ronny Vernooy, 2003).

Ideas on fresh approaches and strategies have developed that the two systems can be complementary through taking advantage of the benefits from both systems. As stated by FAO in 'The Second Global Plan of Action' "*Breeding must be needs based, with greater integration of the perspectives of farmers and other users on setting priorities and defining goals*" (FAO, 2011). A complimentary approach is to develop systems that link innovations, resources, and knowledge of agricultural communities with the formal sector's use of science and biotechnology (N. P. Louwaars, 2007; Shand, 1997).

Diversified approaches can improve the conservation and sustainable use of germplasm; improve crop production and food security; and increase efficiencies and supply to smallholders (Connie JM Almekinders et al., 1994; FAO, 2018c; N. Louwaars et al., 2013). This alternative approach where farmers and smallholders participate in private and public seed systems presents opportunities to fill in gaps in market demand, improves access to a variety of germplasm and cultivars, and increase profits (Access to Seeds Foundation, 2016). Below is a diagram (Figure 6) designed by Centre for Agriculture and Biosciences International (CABI), which demonstrates how seed companies and regulators, breeders and farmers can work together.

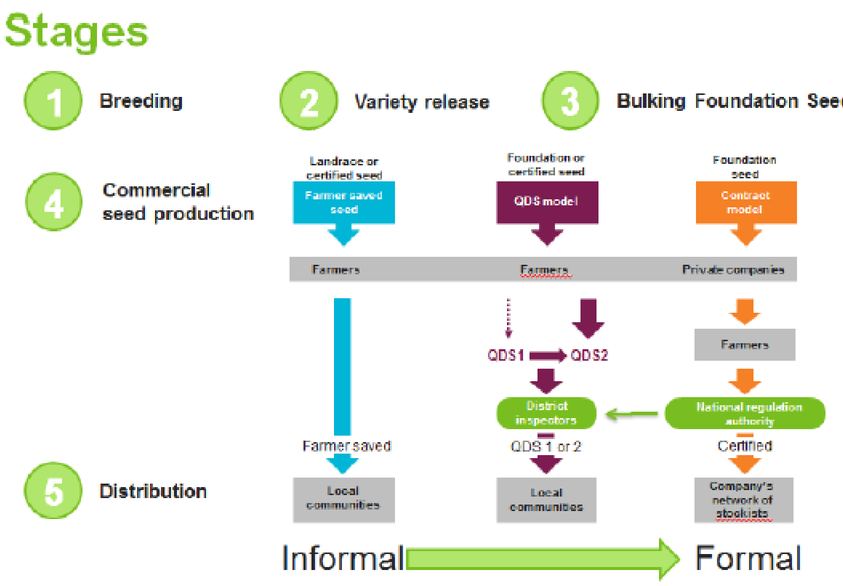


Figure 6: The links between Breeders, seed producers, farmers, and distributors (CABI, 2014)

The diagram above demonstrates how all players can work together and benefit from improved varieties and economic enterprise.

Integrated Seed Sector Development

The concept of integrating formal and farmer seed systems has taken form in recent decades in recognition that cooperation between farmers and public and private seed institutes can strengthen both systems (FAO, 2015b). Integrated approaches provide opportunities to improve production systems and distribute a diverse range of seeds including traditional landraces and less uniform varieties which benefits plant breeders and farmers (Louwaars et al., 2011).

An integration model can take place at various levels in the chain (Conny JM Almekinders & Louwaars, 2002). Informal systems supply genebanks and breeders with varieties of germplasm. The knowledge between the two can be linked to form a sound understanding of strategies for managing and conserving genetic diversity as well as collecting and characterising germplasm (N. P. Louwaars, 2007). New varieties can be developed for the farmer which has desirable traits.

A range of international agencies have engaged in developing policies that overcome barriers created by formal system regulations and enable linkages between formal and informal systems (CABI, 2014). In 2009, the International Treaty on Plant and Genetic Resources for Food and Agriculture (IT-PGRFA) was developed to provide an international framework for sharing benefits for conservation and use of germplasm (FAO, 2018c) *"5.1 Each Contracting Party shall, subject to national legislation… promote an integrated approach to the exploration, conservation and sustainable use of plant genetic resources for food and agriculture"* (FAO, 2009b). The argument for these policies is to put responsibility on both major systems to ensure farmers have access and availability to essential seed at the right time and price (CABI, 2014).

In 2013, Louwaars, de Boef, and Edeme introduced the 'Integrated Seed Sector Development' (ISSD) policy to provide a different approach to the current formal model (2013) with four main strategies:

“Recognising informal knowledge and genetic resources”: Develop policies to share in knowledge and genetic resources.

“Promoting interactions between formal and informal systems” – the two systems can improve the efficiency of knowledge and genetic resource exchange (N. Louwaars et al., 2013)

“Promoting a Pluralistic and entrepreneurial seed sector”: This area of policy can facilitate new pathways linking policy goals with opportunities to improve seed quality and security (N. Louwaars et al., 2013)

“Taking the evolutionary approach”: this policy takes into account evolving practices, services and incentives.

The aim of introducing ISSD program is to motivate a range of actors including farmers, community seed groups and producers, entrepreneurs, and seed companies to be involved in the seed system. Increased actors in the system contribute to an improved seed supply (CABI, 2014). Below is a diagram designed by Louwaars, De Boef and Edeme of how knowledge and resources can be linked between the formal and informal systems in an integrated system (N. Louwaars et al., 2013).

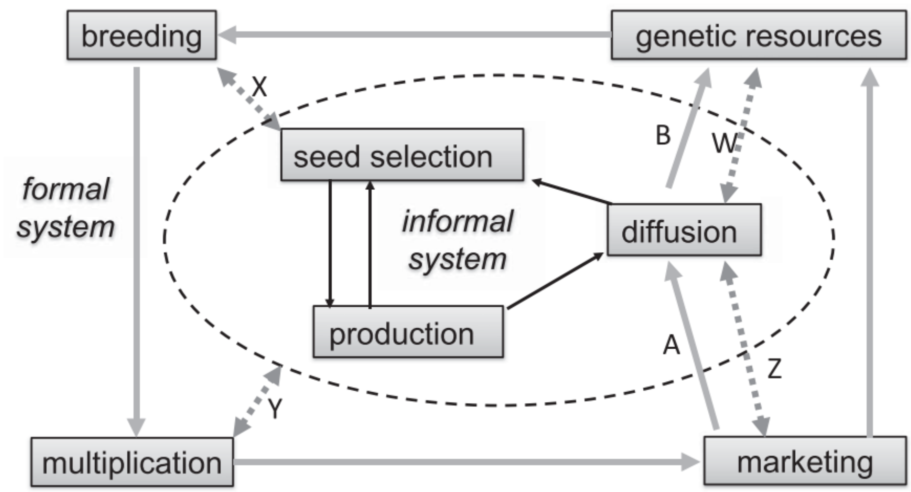


Figure 7: The links between formal and informal systems in an integrated system. (Louwaars et al., 2013)

The three focus areas of seed policy development are (1) variety release, (2) seed quality management, and (3) plant breeders’ rights. The ISSD policy model developed by Louwaars, de Boef, and Edeme (2013) compares the linear model of the formal seed system (in figure 8) to the ISSD model.

Figure 8: Comparison of policies between Formal system and ISSD models (Louwaars, 1994)

Linear model	Integrated model
Policy area 1: Seed quality	
One single system (certification)	Multiple seed quality systems, including certification, accreditation and quality declared seed
Official certification agencies control, i.e., "police" the system	Official seed quality control agencies monitor seed quality and advise on increasing seed quality
Policy area 2: Variety release	
Only seed of released varieties can be traded in the market	Seed of registered improved and local varieties is traded in the market
National variety lists may be connected to regional economic communities	Lists recommend varieties for agro-ecologies
Strict application of distinctiveness, uniformity and stability (DUS), and value for cultivation and use (VCU)	Strict distinctiveness and stability, some flexibility in uniformity, and flexibility and adaptation to local agro-ecologies in VCU testing
Policy area 3: Plant breeders' rights	
Uniform rights for breeders of all crops	Rights differentiated according to crop and seed systems
Strictly defined breeder exemption and farmers' privilege	Breeder exemption and farmers' privilege are defined within crops and seed systems
No farmers varieties	Farmers' and local varieties are addressed

The integrated seed system model can support a range of policies, as well as goals of both farmers and public and private sector systems. Louwaars et al introduced the ISSD model in the Sub-Saharan African countries of Ethiopia, Mali and Zambia (N. Louwaars et al., 2013). These three counties have different needs, characteristics, and realities which guide how the systems and policies are developed (N. Louwaars et al., 2013).

Participatory Plant Breeding

The idea that farmers are just the end recipients of the seed development and research chain rather than active participants has contributed to a decrease in plant varieties and an increased dependence on a handful of crops (Ronny Vernooy, 2003). In his paper, "Seeds that Give: Participatory Plant Breeding", Ronny Vernooy argues that the current formal plant breeding systems often neglect farmers needs and do not recognise their knowledge or roles in maintaining agricultural diversity (2003). Vernooy states that rethinking of current breeding strategies and research should work directly with farmers to ensure their needs and roles are included (2003). This type of approach is called "Participatory Plant Breeding" (PPB) where farmers are treated as active partners in research.

The concept of participatory plant breeding develops cultivars while building on current farmer seed systems, promote development, and contribute to conservation of biodiversity (C. J. M. Almekinders et al., 2006; Ronny Vernooy, 2003). PPB systems

Stakeholders and Frameworks

There are a number of stakeholders involved in both the formal and informal seed systems. The informal system does not follow a linear model of sourcing seeds as farmers will have the tendency to choose from a range of sources to meet their needs (CIAT, 2014). This system can involve a number of actors including the farmers, markets, community seed groups, farmer networks including neighbours and relatives, commercial donors, government and non-government agencies and aid response agencies as can be noted in Figure 9.

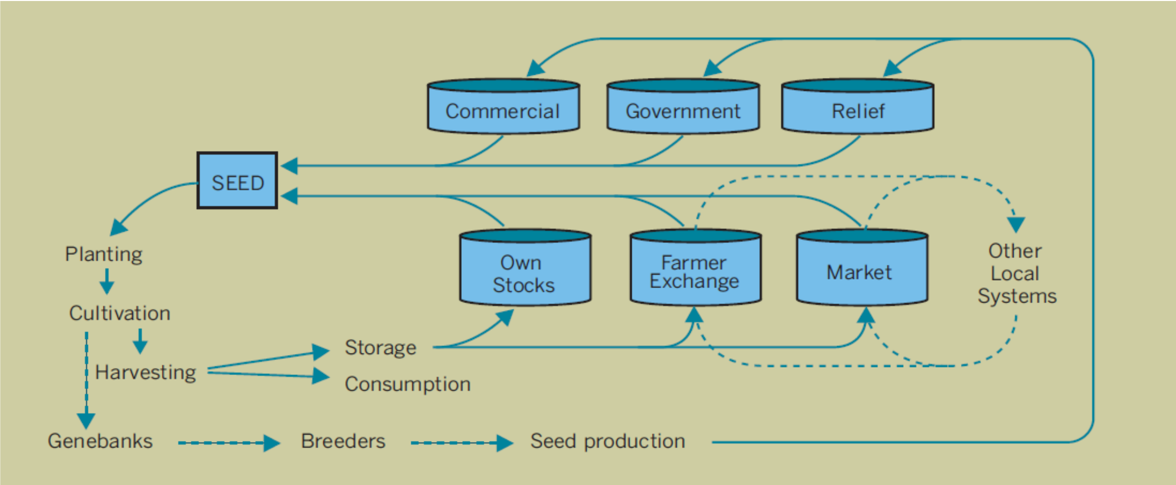


Figure 9: Farmers' sources of seed **(from CIAT, 2014)**

The formal system includes research institutes, farmers, seed producers and plant breeders, marketers and distributers, policy makers, and government agencies (N. P. Louwaars, 2007; Phillips, 2005). Figure 8 shows in the outer circle, the actors involved in seed production and distribution.

Due to the many stakeholders involved in seed systems with different needs and agendas, this system can become a complex process. There are many organisations involved in developing seed systems including the policies and regulations to help guide all the actors towards an end goal of delivering seeds to farmers (FAO, 2015b; N. P. Louwaars, 2007). Some of the key players involved in guiding policy, frameworks, programs, and research programmes include:

- African Union-African Seed Biotechnology Programme – a strategic approach to developing the seed sector and biotechnology (CABI, 2014)
- Africa Seed Trade Association – who function as a regional representative body to serve private enterprise development (CABI, 2014)
- Centre for Agriculture and Biosciences International CABI – an international and intergovernmental organisation
- FAO Food and Agriculture Organisation of the United Nations
- Departments working under FAO are the Seeds and Plant Genetic Resources; Plant Production and Protection Division
- The World Vegetable Centre (formally AVRDC) – involved in research and development to increase production of nutritious vegetables to help alleviate malnutrition (CABI, 2014)
- Association for Strengthening agricultural Research in Eastern and Central Africa (ASARECA) (CABI, 2014)
- International Seed Federation – represents the professional seed industry (CABI, 2014)
- The Centre for Development Innovation (CDI) – involved in developing a seed sector in Africa
- CGIAR Research Programs – The Consultative Group of International Agricultural Research. CGIAR is involved in interdisciplinary research into seed systems.
- Bioversity International (formally the International Plant Genetic Resources Institute) is an autonomous organisation working under CGIAR (CABI, 2014)
- Global Crop Diversity Trust – focused on seed conservation and availability (CABI, 2014)

- International Center for Tropical Agriculture (CIAT) - (CIAT, 2014)
- International Seed Federation – representing the professional seed industry (CABI, 2014)
- Svalbard Global Seed Vault – A seed vault conserving hundreds of thousands of accessions of crop germplasm (Westengen et al., 2013)

Rights to genetic resources, intellectual and cultural property, breeder rights, environmental issues, biosecurity, conservation, and quality control are contentious issues (Louwaars, 2007). Debate over agriculture and genetic resources have been included in wider political agendas around climate change, alleviating poverty, development, and food security, which has resulted in numerous organisations and governments from regional to international levels setting out regulatory frameworks, guidelines, strategies, and legislation in relation to seed management. Some of the main internationally recognised regulatory frameworks include:

Convention on Biological Diversity (CBD)

Concerns over the loss of biological diversity and international debates over the conservation and use of genetic resources led to the formation of the United Nations Convention of Biological Diversity (CBD) (N. P. Louwaars, 2007). The CBD is a legally binding multilateral treaty signed by 150 government bodies in 1993. It formulated the tools and policies to help conserve biodiversity, regulate the use of genetic resources for sustainable development, and equitable sharing of resources (United Nations, 1992).

The International Treaty on Plant Genetic Resources for Food and Agriculture (IT PGRFA)

This policy provides a framework to implement strategies for the conservation and use of plant genetic resources. The main provisions of the treat include improving access and benefit sharing; recognising farmers' rights; and sustainable use and breeding of crops (FAO, 2009b).

Voluntary Guide for National Seed Policy Formation

FAO's Commission on Genetic Resources for Food and Agriculture developed this guide in 2015 to help guide government action and policy as well as define stakeholder roles in seed systems (FAO, 2015b).

Genebank Standards for Plant Genetic Resources for Food and Agriculture

The voluntary standards cover seed and vegetatively propagated materials. According to FAO:

"They set the benchmark for current scientific and technical best practices, and reflect the key international policy instruments for the conservation and use of plant genetic resources." (FAO, 2014)

Intellectual property Rights

Intellectual Property Rights (IPRs) are a recent phenomenon in the seed sectors of developing countries. There are five different areas where IPR's protect genetic resources including patents, trademarks, plant breeder rights, trade secrets and copyright (Kambuou, 2013). Like seed laws, these new regulatory systems impact on various seed system.

In his paper "Seeds of Confusion", Louwaars argues that IPRs support ongoing trends towards the commercialisation of the breeding and seed sectors which disregards or even threatens the interests of resource-poor farmers (2007). This is especially in cases where public research institutions are encouraged to create their own revenue through the use of IPRs (Louwaars, 2007).

Seed Systems in PNG

Papua New Guinea (PNG) is rich in biodiversity with farmers growing more than 200 agricultural crop species (Camilla Zanzanaini, 2014). It is estimated around 60-70% of PNG's population works in an agriculture-related industry. Women produce 80% of the food, the majority of which are for subsistence crops while surplus produce is sold at local markets (Camilla Zanzanaini, 2014; Japan International Cooperation Agency, 2010). Despite the importance of agriculture to the incomes and livelihoods of PNG's population, there are limited seed systems and national policies in place to safeguard the base genetic resources required in the crop production (Kambuou, 2013). There is a large potential to improve PNG's development, food security, and livelihoods through improving agricultural practices and productivity (Omot, 2012).

This paper is written at the request of researchers in PNG who are involved in an ACIAR project "Promoting leafy traditional vegetable production and consumption for improved livelihoods in PNG and Northern Australia." In order to understand what potential systems would work in PNG, this section will provide an overview of the country's biodiversity along with the current systems in place to protect it.

Papua New Guinea and Biodiversity

PNG is a developing country that faces challenges related to limited skilled labour, government instability, and poor infrastructure with unmaintained roads and limited transport between regions (Kingwell et al., 2001). The 2016 United Nations Human Development Report ranked PNG with a low human development index rating of 154th out of 188 assessed countries with a low gross annual income, low gender equality, and high rates of child malnutrition (UNDP 2017).

PNG is economically poor but biodiversity rich with estimates revealing that although the country has less than 1 percent of the world's total land area, it is home to 5 percent of the World's biodiversity (Kambuou, 2013). In Kier et al's map of plant 'species per ecoregion' (Figure 10) demonstrates PNG high levels of biodiversity compared to other regions of the world. PNG is rich in valuable genetic resources, and according to Kambuou (2013) is: *"one of the world centres of diversification of traditional root and tuber crops, leafy vegetables, fruits and nuts, cooking bananas, underutilised food crops, sugarcane, medicinal plants, ornamental trees and timber trees"*. PNG is rich in a diversity of food crops and their wild relatives with varieties of sweet potato, banana, yam, taro and cassava, being the major staple across the country (FAO, 2009a).

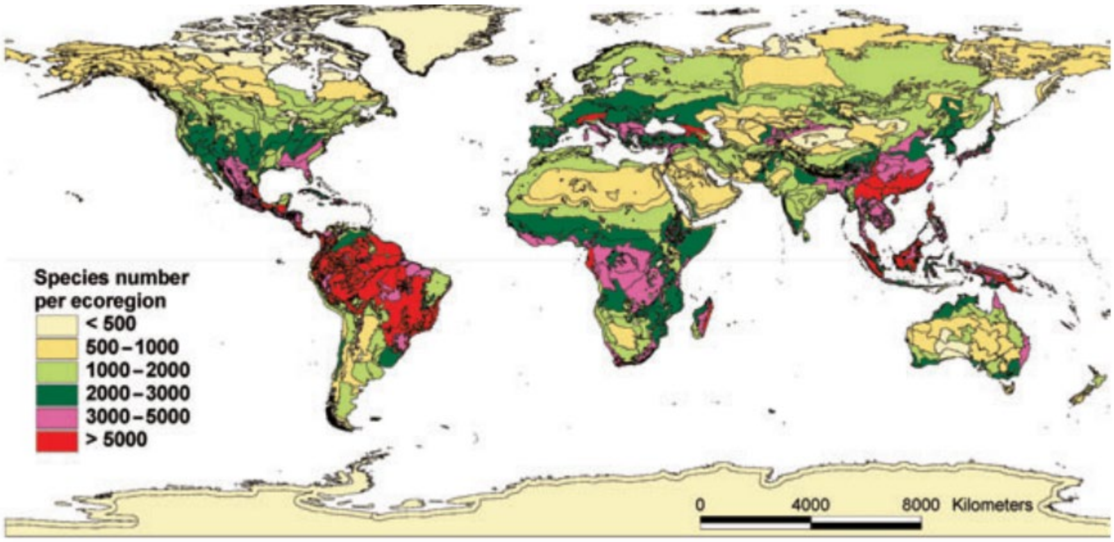


Figure 10: Kier et al's map of plants species by numbers. PNG is in red, indicating the highest level of plant species in an ecoregion (Gerold Kier et al., 2005).

The population of Papua New Guineas is around 8 million, with 40 percent living in the Highlands (Omot, 2012). Over 85 percent of the population live in rural areas where a majority rely on subsistence based agriculture and wild harvest of vegetables and fruit (Camilla Zanzanaini, 2014; Deloitte & UNDP 2017). Wild varieties and the varieties grown in smallholder farms across the country ensure a wide range of landraces are conserved and maintained. Increasingly however farmers are producing particular crops based on consumer preferences to increase profit (FAO, 2009a).

However, crop and plant biodiversity is eroding at a rapid rate because of the trend in selecting varieties based on production values and consumer preferences (FAO, 2009a).

Other threatening processes include land degradation from increasing urbanisation, mining, logging, and high input agriculture. As younger generations migrate into urban centres, the older generations die off along with their knowledge and the germplasm of underutilised crops (Kambuou, 2013). Climate change is another driver, with scientists forecasting increased frequency of climate extremes such as prolonged droughts, bush fires, and floods (Camilla Zanzanaini, 2014; FAO, 2009a).

Although agriculture is the main livelihood of much of the population and economically important, there are limited national policies and systems in place to safeguard the plant genetic resources from these threats (FAO, 2009a). The following section will briefly examine the efforts conserve PNG's genetic resources.

Formal seed systems in PNG

Papua New Guinea has a lack of formally implemented strategies, legislation, and national policies for the conservation, management and use of seed systems and germplasm (FAO, 2009a). PNG signed the 1992 Convention of Biological Diversity (CBD), however reviews show their efforts to implement obligations under the CBD to date have lagged (Kwa, 2004). The Department of Environment and Conservation (DEC) are currently responsible for funding and developing a program to conserve biodiversity. The National Agricultural Research Institute (NARI) runs the main programme for the conservation, management, and use of plant genetic resources in line with its mandate (FAO, 2009a).

NARI are the primary custodians of conserving germplasm in *ex situ* and field genebank collections which are limited to the main staple crops. These collections of crop species form the National Germplasm Collections which include sweet potato, banana, yam, cassava, taro, aibika, fruits, nuts and some traditional vegetables (FAO, 2009a). Currently NARI works with Bioversity International on the “Seeds for Needs” program that has conserved 1300 accessions of sweet potato and 850 taro accessions (Zanzanaini. C, 2014). The purpose of this initiative is to improve capacity and build system resilience through saving planting material with adaptable traits.

The large scale commodities each have their own commodity associations and groups (coffee, cocoa, palm oil, and coconut) and each maintains collections of germplasm and most have their own specialised seed systems. (FAO, 2009a). The oil palm industry, for example, has a well-established seed system in PNG in which the sale of certified oil palm seeds is a major source of revenue for the New Britain Palm Oil company.

Ornamental plants are held at the National Botanic Gardens (Kambuou, 2013). While a large diversity of non-major crops and wild species are still conserved *in situ* in gardens and by farmers across the country, a lack of national inventory means there is a lack of knowledge about what is available (FAO, 2009a).

Current Conservation Challenges

Currently, there are no formal agreements in place to collect, record, and conserve underutilised and wild varieties of crops, although NARI maintains a small *ex situ* collection of traditional vegetables nuts and fruits (FAO, 2009a). Efforts in conservation of germplasm have encountered many problems including poor policy, lack of infrastructure, poor knowledge on materials, poor access and resource sharing, lack of funding, and a range of environmental and civil issues such as landowner disputes (FAO, 2009a; Kingwell et al., 2001).

A broad range of landraces and accessions of food crops are maintained in farmer gardens and in wild habitats across PNG. This broad genetic base provides a backup to ensure crops with desirable traits such as tolerance to pests and diseases can be used or developed into new cultivars (FAO, 2009a). For example, following an outbreak of leaf blight, resistant varieties were identified from East New Britain from which new hybrid varieties were developed that are now widely used (FAO, 2009a; Kingwell et al., 2001). Germplasm collections can assist communities in recovering from disasters like the leaf blight through appropriate plant breeding as well as take advantage of future development opportunities (Kingwell et al., 2001).

Eric L Kwa’s paper on ‘Biodiversity Law and Policy in Papua New Guinea’, attributes the lack of directed policy as contributing to ineffective conservation, development, and research efforts (Kwa, 2004). The policies lack a clear understanding of the linkage between national development with conservation of biodiversity and sustainable use which results in lost opportunities for development and research initiatives (Kwa, 2004). Kwa also notes that there is no national database to indicate the numbers of plant species across the country and what plant genetic resources are available, and therefore no means to indicate the social and economic value on PNG’s resources (Kwa, 2004).

The development of a national program to improve access and benefit sharing of genetic resources and consequently the development of a national policy and legal framework, and a national inventory of all plant species in PNG is essential to protect the plant genetic resources of PNG and establish intellectual property rights over germplasm

The current issues with drafting such a policy involves negotiating aspects of Intellectual Property Rights, traditional knowledge, and traditional processes related to germplasm (FAO, 2009a). IPR laws at present do not protect PNG's biological resources, traditional knowledge, and patents that have already been available in the public domain. This lack of law to protect these resources has caused confusion and causes issues in meeting the CBD obligations (FAO, 2009a).

Lack of funding and technical expertise are other barriers to successful germplasm conservation. Setting up, operating, and maintaining germplasm collections are expensive. Setting up a functioning germplasm collection requires funding across a number of areas;

"*To optimize the future provision of genebank services, research is needed on the costs of genebanks, the market for their services, the use of genetic resources by breeders, and the implications of recognition of farmers' rights, evolving intellectual property rights, continued funding problems and developments in biotechnology"* (Wright. Brian D, 1997).

Germplasm collection incurs costs for resources and staff to provide optimal conditions such as climate controls, pest and disease protection, and maintaining large samples of in field collections (Kingwell et al., 2001). The below table (Figure 11), demonstrates the accumulated costs to maintain a sweet potato collection at NARI in Keravat in 1999.

Figure 11: Annual costs to maintain a sweet potato collection in 1999 (Kingwell et al., 2001).

	Kina[a]
Variable costs	
Land preparation	121
Planting	1123
Weeding and maintenance	2781
Harvesting	500
Field sanitation	250
Stationery and equipment operation	3026
Fixed costs	
Capital	11986
Management	17090
Total annual cost	36877

Applying the exchange rate of K1 = AUD 0.40, in 1999 it would have cost approx. AUD $14,777. Using the Reserve Bank of Australia's inflation calculator, the 2017 the cost would be approximately $24,009 AUD.

PNG has witnessed large scale loss of germplasm collections due to lack of funding to maintain the optimal storage, conservation and/or growing conditions (Kingwell. R, 2001). For example, national *ex situ* collections which included major food crops and some underutilised species is a good example of poor policy leading to failed initiatives. There were over 7000 accessions of 42 crop species maintained in the ex situ collections however a 1995 field report on the collections found that due to funding constraints, only 1474 accessions remained (Kambuou, 2013). The loss of these accessions is a loss of potentially beneficial genes and economic opportunities.

The current system is also limited in responding to environmental challenges and climate change events, droughts, volcanic activity, floods, pest, and weed disease infestations (Kingwell et al., 2001).

For instance, in 2015 frost and drought in the Highland provinces resulted in mass devastation of crops and loss of viable seed for the next crop production (Connors, 2015). Over 300,000 villagers did not have access to clean water or sufficient food sources. They lost both their crops and their seed sources for the next crop. A key problem identified in this disaster was the lack of a seed system which could provide access and availability to good quality seed to help villagers recover from the disaster (Ebert, 2015).

Informal seed systems

The majority of Papua New Guinea's rural population, particularly in remote areas, relies on *in situ* conservation where farmers save and exchange their own seed. The current seed system largely relies on family and network exchange, markets, and provision of planting materials through extension officers (Zanzanaini, 2014). Kinship and cultural traditions are a crucial feature incorporated into agricultural practices, including the supply through traditional exchanges, for ceremony, and for social status (Nordhagen, Pascual, & Drucker, 2017). These roles including the separation of gender roles, dictate how farmer knowledge and resources are exchanged (Zanzanaini, 2014).

With the growing importance of the cash economy, there is an increasing trend towards growing and selling planting materials (Zanzanaini, 2014). This provides opportunities to access new varieties not available through local networks or family connections and a chance to diversify incomes. However, selling at markets comes with its own challenges. These include a poorly maintained roads and infrastructure makes transporting goods from remote areas into market centres costly with air freight the most feasible option (Omot, 2012).

At present there is no documentation or data on seed systems for traditional vegetables, however some common practices include storage of corn cobs above fireplaces to protect them from insects and rats, storage of yam and maintenance of taro, aibika and other plants near river banks during extreme climatic events such as drought. A common seed storage method for farmers is to keep it in bamboo tubes with the ends tied up to prevent rats eating the seeds.

Diversified Approach

In recent years there has been a collaborative effort between government-led formal programs and farmers. The collaboration between NARI and Bioversity International on the Seeds for Needs program is a model involving the active participation of farmers in breeding programs. Farmers are provided with accessions of taro and sweet potato which are multiplied and tested on farm by farmers. Farmers then feed information back to NARI on what varieties are preferred. Preliminary outcomes from the Seeds for Needs program indicates that farmers are continuing to use the introduced varieties and sharing them within their networks. This diversified approach increases the reach of improved varieties as well as technical information to farmers (Zanzanaini, 2014).

Case Study: An Alternative Approach

In order to understand what diversified seed systems may work in PNG, this section provides a case study of the Seeds of Life (SoL) program delivered in Timor-Leste between. This program was selected as it has a similar geographic location to PNG, as well as being a developing country with limited funds, infrastructure, and resources. Timor-Leste has a population of over 1 million people with 70.4 percent living in rural areas where subsistence agriculture is the main source of income and livelihoods (Lopes & Nesbitt, 2012). Ranked at 133 out of 188 in the United Nations Human Development Indicator, Timor Leste suffers from food insecurity and poor living conditions including low levels of education and health (United Nations, 2016a).

Timor-Leste Seeds of Life and National Seed System

The Seeds of Life (SoL) program was introduced by the Ministry of Agriculture and Fisheries (MAF) and jointly funded by ACIAR, AusAid, FAO, and other governments and NGO's to develop the role of agriculture as part of sustainable development (Lopes & Nesbitt, 2012; Piggin et al., 2003). The Seeds of Life program was a 15 year project with an aim to improve crop production and address issues with food insecurity. The project goals were to

1. improve food security through the introduction, testing, and distribution of improved germplasm for major crops,
2. improve capacity to independently develop crop improvements

Timor-Leste has a tropical climate with a prolonged dry season which means the rural population practice food rationing for up to 6 months of the year. Food insecurity is due to very low production levels caused by crop losses, low technologies, poor land, and insufficient seed saving systems where up to 40 percent of maize was lost annually due to pests (2009; Manson, 2015). Ensuring farmers have access to agricultural inputs including seed, access to technology, and increasing capacity through government interventions can improve crop production and food security (Borges et al., 2009).

The Seeds of Life project consisted of four main components:

1. Crop identification and development: This objective involved rehabilitating two research centres and four research stations where research and field trials could take place on identifying and improving crop varieties for release. MAF now completely manages this research facility (ACIAR 2016).
2. Source Seed and Quality Control: This objective made sufficient quality seed of improved varieties available for distribution which is was achieved through:
3. Developing and operating a certified seed system
4. Seed System Management: This component developed an operational National Seed System. A National Seed Policy is implemented and overseen by the East Timor Ministry, technical materials were distributed, gender in agriculture programs were developed, and capacity building of MAF staff took place to sustainably manage the seed system

Some of the main achievements of the program included:

- established seed grading, packaging and storage systems
- establishment and operation of a quality assurance system for both commercial and certified seed

- multiplication of each improved seed variety to ensure access for the wider community
- supply of foundation seed to contract seed growers who under supervision produce certified seed
- seed development was occurring in all 13 municipalities of Timor-Leste
- 1,191 community seed groups were producing and distributing the improved seed.
- an umbrella association for the community groups was set up
- agricultural shops were selling the seed distributed by the community groups

The SoL program, achieved positive outcomes on multiple fronts. It developed a National Seed System which made improved varieties available to farmers and operated by the Timor-Leste government (MAF) (ACIAR, 2016). Increased access to improved germplasm has resulting in better yields that are adapted to local conditions and are more nutritious which has improved national food security (MAF, 2016). Capacity has been built in many areas including training MAF staff to research and manage a seed system. Community groups, farmers, and women through different programs have been given technical knowledge to improve agricultural production as well as the capacity to develop their own seed enterprises. As reported by ABC News' Sky Manson, *"Businessmen and women are learning to grow and barter seeds from crops like corn, thanks to the help of an Australian Government aid program*"(Manson, 2015). This also improves incomes and livelihoods.

Additionally, the Timor-Leste government no longer has to buy and distribute imported seed (MAF, 2016). As reported in the ABC news: "*The millions of dollars that used to go out of the country to Indonesia or Vietnam now stay in the country and those commercial seed producers are probably the first genuine entrepreneurs in agriculture"* (Manson, 2015). The establishment of a sustainable seed system ensures Timor-Leste can not only source and grow their own crops but also move beyond subsistence agriculture to pursue large income commercial ventures (MAF, 2016).

The SoL program took advantage of the resources, networks, and knowledge from both the informal and formal seed systems to achieve its goals. On the formal side, MAF managed the research on improved varieties and operates the National Seed System. On the informal side, the quality germplasm is accessed by community groups to multiply and distribute to their networks and agricultural shops (ACIAR, 2016).

Conclusion

The safe collection, storage, and conservation of a diverse variety of crop germplasm through seed saving systems is important for food security, technology development, conservation of genetic diversity, and sustainable livelihoods, however this review highlights that there is very limited documentation of these systems, and a dearth of research, information and data on seeds, seed systems and conservation of the genetic plant resources of Papua New Guinea. There is a great need for more research and documentation in this area, and much more work to be done on establishing systems and processes for the future conservation and use of these resources, and a need for a focus by the PNG National Agricultural Research Systems (NARS) on policy development in this area.

References

Access to Seeds Foundation. (2016). *Access to Seeds Index Report 2016*. Retrieved from https://www.accesstoseeds.org/app/uploads/2016/08/Access-to-Seeds-Index-2016-online.pdf

ACIAR. (2016). *Seeds of Life 3*. Retrieved from Australian Centre for International Agricltural Research:

Almekinders, C. J., & Louwaars, N. P. (2002). The importance of the farmers' seed systems in a functional national seed sector. *Journal of new Seeds, 4*(1-2), 15-33.

Almekinders, C. J., Louwaars, N. P., & De Bruijn, G. (1994). Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica, 78*(3), 207-216.

Almekinders, C. J. M., Thiele, G., & Danial, D. L. (2006). Can cultivars from participatory plant breeding improve seed provision to small-scale farmers? *Euphytica, 153*(3), 363-372. doi:10.1007/s10681-006-9201-9

Borges, L. F., do Rosario Ferreira, A., Da Silva, D., Williams, R., Andersen, R., Dalley, A,. Erskine, W. (2009). Improving food security through agricultural research and development in Timor-Leste: a country emerging from conflict. *Food Security, 1*(4), 403. doi:10.1007/s12571-009-0037-8

CABI. (2014). *Good Seed Initiative: a strategy for CABI-led work on seed systems in Sub-saharan Africa and South Asia, 2014-2019*. Retrieved from https://www.cabi.org/Uploads/seed%20(1).pdf

Camilla Zanzanaini. (2014). *Seeds for Needs – Papua New Guinea.* In. Retrieved from http://hdl.handle.net/10568/49620

CIAT. (2012). *Seed System Security Assessment (SSSA): An essential tool for improving the effectiveness of agricultural assistance*. Retrieved from East Anglia, UK:

CIAT. (2014). Understanding Seed Systems Used by Small Farmers in Africa: Focus on Market. *Seed Aid for Seed Security, 6*.

Conner, A. J., Glare, T. R., & Nap, J. P. (2003). The release of genetically modified crops into the environment. *The Plant Journal, 33*(1), 19-46. doi:doi:10.1046/j.0960-7412.2002.001607.x

Connors, A. (2015). Frost and drought wipes out subsistence crops in Papua New Guinea, Solomon Islands highlands. Retrieved from http://www.abc.net.au/news/2015-08-19/frost-drought-wipes-out-subsistence-crops-in-png-solomon-islands/6707964

Deloitte, & United Nations Development Promgramme. (2017). *Fulfilling the land of opportunity: How to grow employment in Papua New Guinea*. Retrieved from http://www.pg.undp.org/content/papua_new_guinea/en/home/library/launch_businessreport.html

Easton, P., & Ronald, M. (2000). Seeds of Life: Women and Agricultural Biodiversity in Africa. *World Bank Group, 23* Washington DC. Available at: https://openknowledge.worldbank.org/handle/10986/9413

Ebert, A. (2015). Producing and Saving Seed in PNG. *Latest News: Oceana.* Retrieved from http://avrdc.org/producing-and-saving-seed-in-papua-new-guinea/

FAO. (1993). *Harvesting Nature's Diversity*, available at: http://www.fao.org/3/V1430E/V1430E00.htm#TOC

FAO. (2009a). *Country Report on the State of Plant Genetic Resource for Food and Agriculture: Papua New Guinea*., Rome, Italy; available at: http://www.fao.org/3/i1500e/Papua%20New%20Guinea.pdf

FAO. (2009b). *International Treaty on Plant Genetic Resources for Food and Agricultur*e, Rome, Ital, available at: http://www.fao.org/plant-treaty/en/

FAO. (2010). *The second report on the State of the World's Plant Genetic Resources for Food and Agriculture*. Rome, Italy.

FAO. (2011). *Second Global Plan of Action: for Plant Genetic Resources for Food and Agriculture*. Rome, Italy:

FAO. (2014). *Genebank Standards for plant genetic resources for food and agriculture*. Retrieved from Rome, Italy: http://www.fao.org/docrep/019/i3704e/i3704e.pdf

FAO. (2015a). *Household Seed Security Concepts and indicators*. Retrieved from Rome:

FAO. (2015b). *Voluntary Guide for National Seed Policy Formation*. In: Food and Agriculture Organization of the United Nations Rome, Italy

FAO. (2016). *Seed Security Assessments (SSA): Better Assessment, Better Decisions*. Rome, Italy

FAO. (2017). AGP - What are Seed Systems. *Sustainable Crop Production Intensification,* Rome, Italy Retrieved from http://www.fao.org/agriculture/crops/thematic-sitemap/theme/compendium/tools-guidelines/what-are-seed-systems/en/

FAO. (2018a). AGP – Conservation of Plant Genetic Resources. *AGP - Conservation of Plant Genetic Resources,* Rome, Italy Retrieved from http://www.fao.org/agriculture/crops/core-themes/theme/seeds-pgr/conservation/en/

FAO. (2018b). Seed Security and Rehabilitation, Rome, Italy Retrieved from http://www.fao.org/agriculture/crops/core-themes/theme/seeds-pgr/seed_sys/security/en/

FAO. (2018c). Seeds and Plant Genetic Resources: A basis for life, Rome, Italy Retrieved from http://www.fao.org/agriculture/crops/thematic-sitemap/theme/seeds-pgr/en/

Gerold Kier, Jens Mutke, Eric Dinerstein, Taylor H. Ricketts, Wolfgang Ku¨per, Kreft, H., & Barthlott, W. (2005). Global patterns of plant diversity and floristic knowledge. *Journal of Biogeography, 32*.

Japan International Cooperation Agency. (2010). Country Gender Profile: Papua New Guinea. *IMG Inc*. Available at: https://www.jica.go.jp/english/our_work/thematic_issues/gender/background/pdf/e10png.pdf

Kambuou, R. (2013). *Plant genetic resources of Papua New Guinea some thoughts on intellectual property rights*. Canberra: ANU press.

Kingwell, R., Godden, D., Kambuou, R., & Jackson, G. (2001). Managing and funding germplasm preservation in Papua New Guinea — for improved indigenous foods. *Food Policy, 26*(3), 265-280. doi:https://doi.org/10.1016/S0306-9192(01)00003-3

Kwa, E. L. (2004). *Biodiversity law and policy in Papua New Guinea*, Papua New Guinea Institute of Biodiversity, University of Auckland, New Zealand and University of Papua New Guinea, Port Moresby.

Lopes, M., & Nesbitt, H. (2012). Improving food security in East Timor with higher yielding crop varieties, in Templeton, D ed (2012) *Food security in East Timor, Papua New Guinea and Pacific island countries and territories. Technical Report 80:* Australian Centre for International Agricultural Research, Canberra.

Louwaars, N. (1994). *Integrated Seed Supply: A Flexible Approach*, Seed Production by Smallholder Farmers: Proceedings of the ILCA/ICARDA Research Planning Workshop held in ILCA, Addis Ababa, Ethiopia pp 39-36 FAO Rome, Italy.

Louwaars, N., Boef, W. S. D., & Edeme, J. (2013). Integrated Seed Sector Development in Africa: A Basis for Seed Policy and Law. *Journal of Crop Improvement, 27*, 186–214. doi:10.1080/15427528.2012.751472

Louwaars, N., Coent, P. L., & Osborn, T. (2011). *Seed Systems and Plant Genetic Resources for Food and Agriculture*, FAO, Rome Italy. Retrieved from www.fao.org/docrep/013/i1500e/i1500e21.pdf

Louwaars, N. P. (2007). *Seeds of confusion: the impact of policies on seed systems*, Dissertation Wageningen University ISBN 9789085047933 - 151

Manson, S. (2015). Fortunes of farmers in East Timor grow as seeds start to drive the economy. Retrieved from http://www.abc.net.au/news/rural/2015-06-08/farmers-saving-the-economy-in-easttimor-through-seeds-of-life/6518046

McGuire, S., & Sperling, L. (2011). The links between food security and seed security: facts and fiction that guide response. *Development in Practice, 21*(4-5), 493-508. doi:10.1080/09614524.2011.562485

McGuire, S., & Sperling, L. (2016). Seed systems smallholder farmers use. *Food Security, 8*(1), 179-195. doi:10.1007/s12571-015-0528-8

N. Maxted, & Kell, S. (2009). *Establishment of a Global Network for the In Situ Conservation of Crop Wild Relatives: Status and Needs,* Commission on Genetic Resources for Food and Agriculture, Background Study Paper No. 39, October 2009

Kambuou R. (2006) Aibika Genetic Diversity of Papua New Guinea. In*. NARI Extention Booklet No. 9*, National Agricultural Research Institute, Laloki, Port Moresby PNG.

Nordhagen, S., Pascual, U., & Drucker, A. G. (2017). Feeding the Household, Growing the Business, or Just Showing Off? Farmers' Motivations for Crop Diversity Choices in Papua New Guinea. *Ecological Economics, 137*, 99-109. doi:https://doi.org/10.1016/j.ecolecon.2017.02.025

Omot, N. (2012). *Food Security in Papua New Guinea* in Templeton, D ed (2012) *Food security in East Timor, Papua New Guinea and Pacific island countries and territories. Technical Report 80:* Australian Centre for International Agricultural Research, Canberra.

Phillips, C. (2005) "Cultivating practices: saving seed as green citizenship?" Environments, vol. 33, no. 3, 2005, p. 37+. Academic OneFile, Accessed 11 Mar. 2019.

Piggin, C., Palmer, B., de Costa, H., Piggin, C., da Cruz, C., & Fox, J. (2003). An introduction to the ACIAR project "Seeds of Life"—East Timor. *Agriculture: New directions for a new nation. East Timor (Timor-Leste)*, 65-71, ACIAR Canberra.

Plant Production and Protection Division. (2006). *Quality Declared Seed system*, FAO Plant Production and Protection Paper 185, Rome, Italy. Available at http://www.fao.org/3/a0503e/a0503e00.pdf

Poulton, C., & Kanyinga, K. (2013). *The Politics of Revitalising Agriculture in Kenya*. Future Agricultures Working Paper, UKaid, available at: https://eprints.soas.ac.uk/20549/1/FAC_Working_Paper_059.pdf

Remington, T., J. Maroko, S. Walsh, P. Omanga, and Charles,E. (2002). Getting off the seeds-and tools treadmill with CRS seed vouchers and fairs. *Disasters, 26*(4), 316-328,Wiley online library, available at: https://doi.org/10.1111/1467-7717.00209

Riely. F, Mock. N, Cogill. B, Bailery. L, Kenefick. E (1999). *Food Security Indicators and Framework for Use in the Monitoring and Evaluation of Food Aid Programs*. Food and Nutrition Technical Assistance, FoodAid: USAID, Washington DC. Available at http://pdf.usaid.gov/pdf_docs/Pnacg170.pdf

Shand, H. (1997). Human Nature: Agricultural Biodiversity and Farm Based Food Security, in Thrupp, L. (2000) *Linking Agricultural Biodiversity and Food Security: The Valuable Role of Sustainable Agriculture;* International Affairs (Royal Institute of International Affairs 1944-), Vol. 76, No. 2, Special Biodiversity Issue (Apr., 2000), pp. 265-281 Royal Institute of International Affairs.

Sperling, L., & McGuire, S. (2012). Fatal gaps in seed security strategy. *Food Security, 4*(4), 569-579. doi:10.1007/s12571-012-0205-0

Sperling. L, D. A., Assefa. S,. (2007). *Long Term Seed Aid in Ethiopia: Past, Present, and Future Perspectives*. FARO, Rome, Italy Retrieved from http://agris.fao.org/agris-search/search.do?recordID=GB2013203366

Stone, E. (2002). Community Seed Saving. *Kastom Gaden Association*., available at http://kastomgaden.org/

UNDP (2017). *Human Development Report 2016: Human Development for Everyone*. UNDP New York available at: https://www.undp.org/content/undp/en/home/librarypage/hdr/2016-human-development-report.html

UNDP (2016b). Sustainable Development Goals: 17 goals to transform our world.UNDP New York, Retrieved from http://www.un.org/sustainabledevelopment/hunger/

Vernooy.R, (2003). Seeds that Give: Participatory Plant Breeding, in Vernooy,R (2007) *Participatory Plant Breeding to promote farmers' rights*, Bioversity International,

Westengen, O. T., Jeppson, S., & Guarino, L. (2013). Global Ex-Situ Crop Diversity Conservation and the Svalbard Global Seed Vault: Assessing the Current Status. *PLOS ONE, 8*(5), e64146. doi:10.1371/journal.pone.0064146

Wildfong, B. (1999). Saving Seeds. *Alternatives Journal, 25.1*(Winter 1999).

Wilhelm Barthlott, Alexandra Hostert, Gerold Kier, Wolfgang Küper, Holger Kreft, Jens Mutke, . . . Erdkunde, J. H. S. (2005). Geographic Patterns of Vascular Plant Diversity at Continental to Global Scales. *Erdkunde, 61*.

Witcombe, J. R., Devkota, K. P., & Joshi, K. D. (2010). Linking Community-Based Seed Producers to Markets for a Sustainable Seed Supply System. *Experimental Agriculture, 46*(04), 425-437. doi:10.1017/s001447971000061x

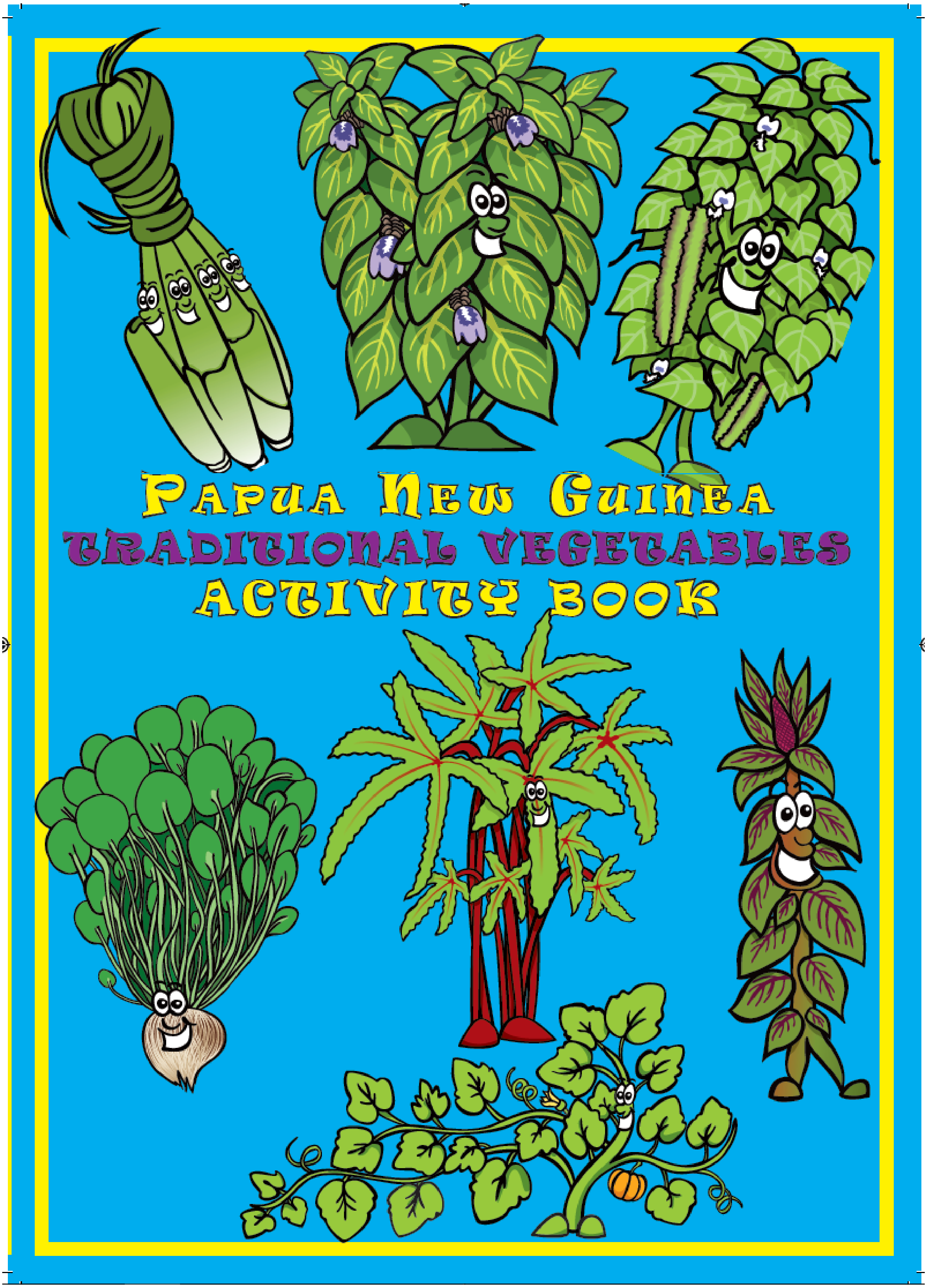
Wright. Brian D. (1997). Crop genetic resource policy: the role of ex situ genebanks. *Australian Agricultural and Resource Economics Society Inc, 41*(1), 81-115.

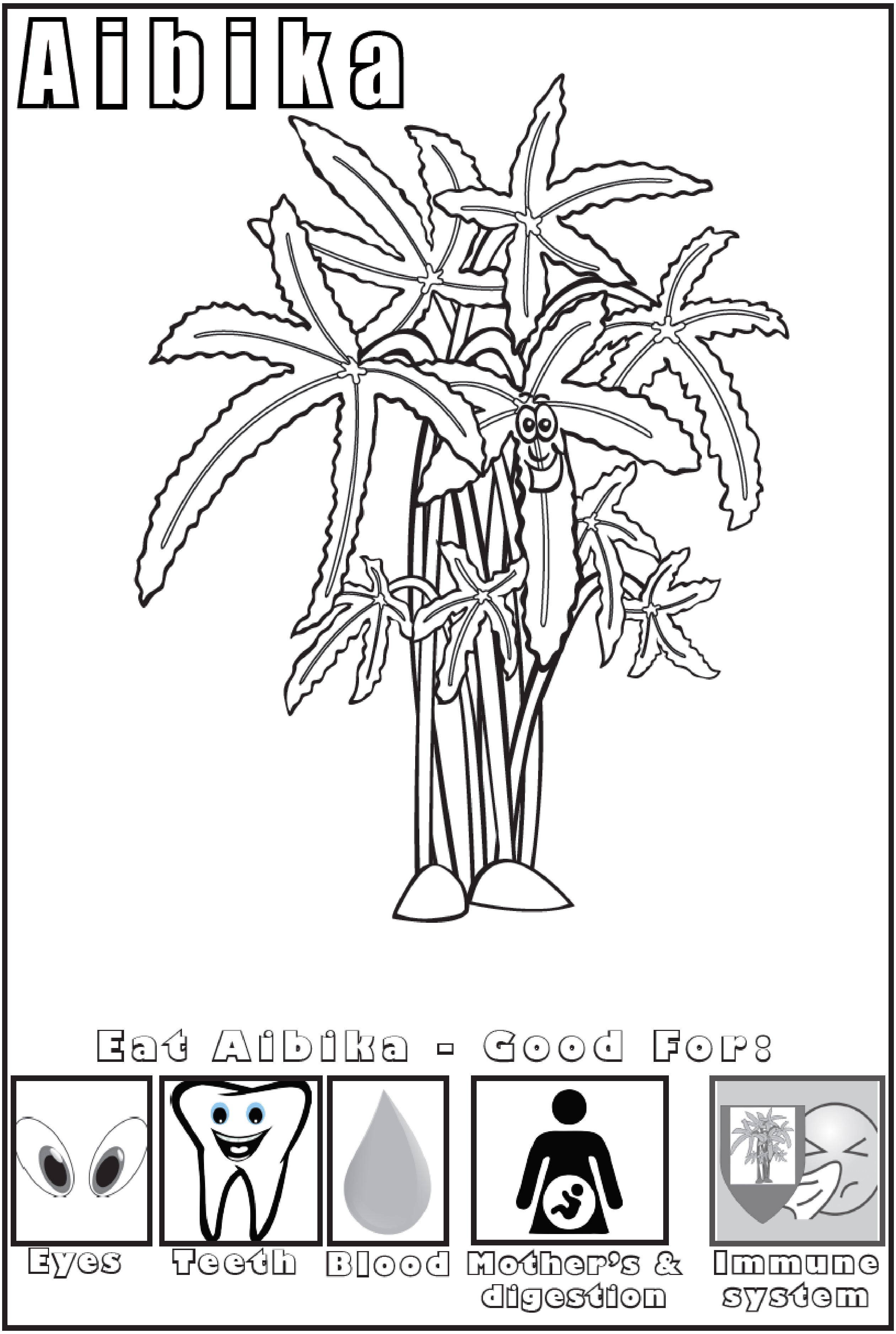
11.3 Appendix 3: Harmonised Nutritional Data on Traditional Vegetables

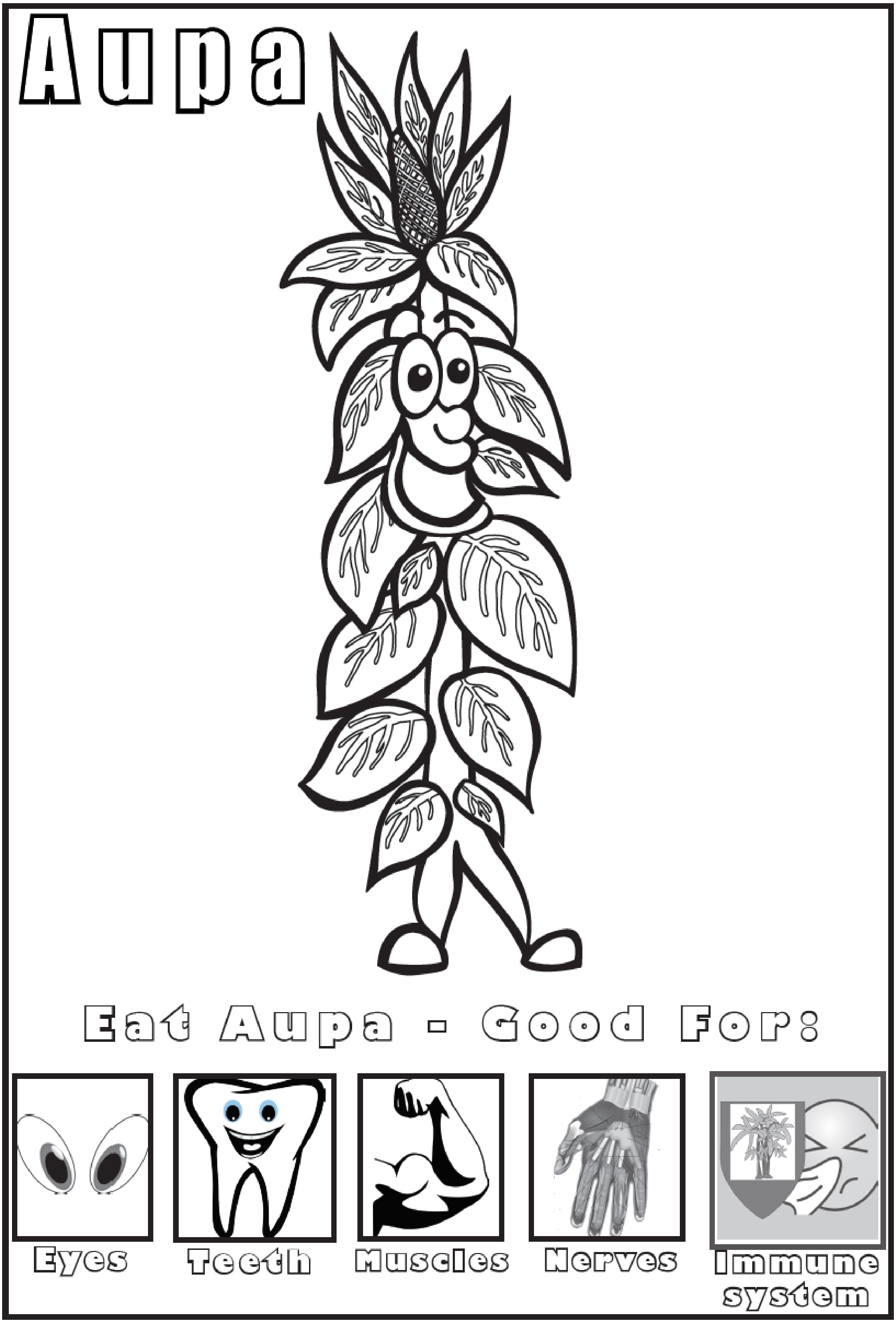
Common name	Botanic name	Energy kJ	Protein	Fats	Carbohydrate	Fibres	Sodium	Magnesium (Mg)	Potassium (K)	Calcium (Ca)	Iron (fe)	Zinc (Zn)	Copper (Cu)	Sulphur (s)	Thiamine	Riboflavin	Niacin	Folate	Vitamin C	Vitamin E	Vitamin A	Lutein	Alpha Carotene	Beta carotene
		kJ	g	g		g	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	µg	mg	mg	mg	mg		mg
Aibika /100g dry	Abelmoschus manihot						710	3200	2360	7.3	4.4		450								100.6	3.1	31.5	
Aibika100gboiled	“	120	3.4	0.8	0.3	3.5	6	108	201	216	1.5	1.2			0.1	0.3	1.3		7	1	731			8770
Aupa /100g dry	Amaranthus spp							1880	4500	1550		6.4										46.2	0.8	35
Aupa 100g boiled	“	97	2.6	0.9	0.1	2.2	24	56	240	273	2.2	0.4				0.18	1		11	0.2	634			7608
Bamboo Shoots fresh 100g	B. vulgaris		3.64	0.5	6.51	4.24	400	100	920	320									4.8	0.52				
Bamboo shoots Canned	“	57	0.8	0	1.3	2.8	10	5	51	15	0.4	0.5	0		0	0	0.3		0		0			0
Choko Tips 100g	Sechium edule							310	1010	570		9	1.7									24.9	0.5	8.4
Choko tips 100g boiled	Sechium edule	90	4.3	0.3	T	0.7	3	51	352	70	7.2	0.2			0.12	0.08	0.4		20	1	7			78
Fern Tips 100g	Diplazium esculentum	4.7	1.7		8	3	40	535	59	14.7	0.5							7		283				
fern boiled 100g	Diplazium esculentum	81	2.4	0.4	0.5	2.1	6	19	234	17	2.4	1.8				0.15	0.6		2	0.3	211			
Sandpaper fig leaf	Ficus spp							3900	28000	18800	72	31		2300								554	159	57
Fig leaves, boiled 100g	Ficus copiosa	92	2.3	0.4	1.6	1.5	18	14	184	53	1.2	0.2			0.07	0.25	1.1		82	0.2	435			5220
Kapiak Leaves	Ficus dammaropsis																							
Karakap 100g	Solanum nigrum	125	1.82	0.85	5.1	2.3	0.061	0.667	3.084	4.421	0.496	42	16											
Karakap, cooked,100g	Solanum nigrum	179	4.9	0.8		8.3	4	61	339	221	18.6	0.3			0.11	0.27	1		1.5	1				

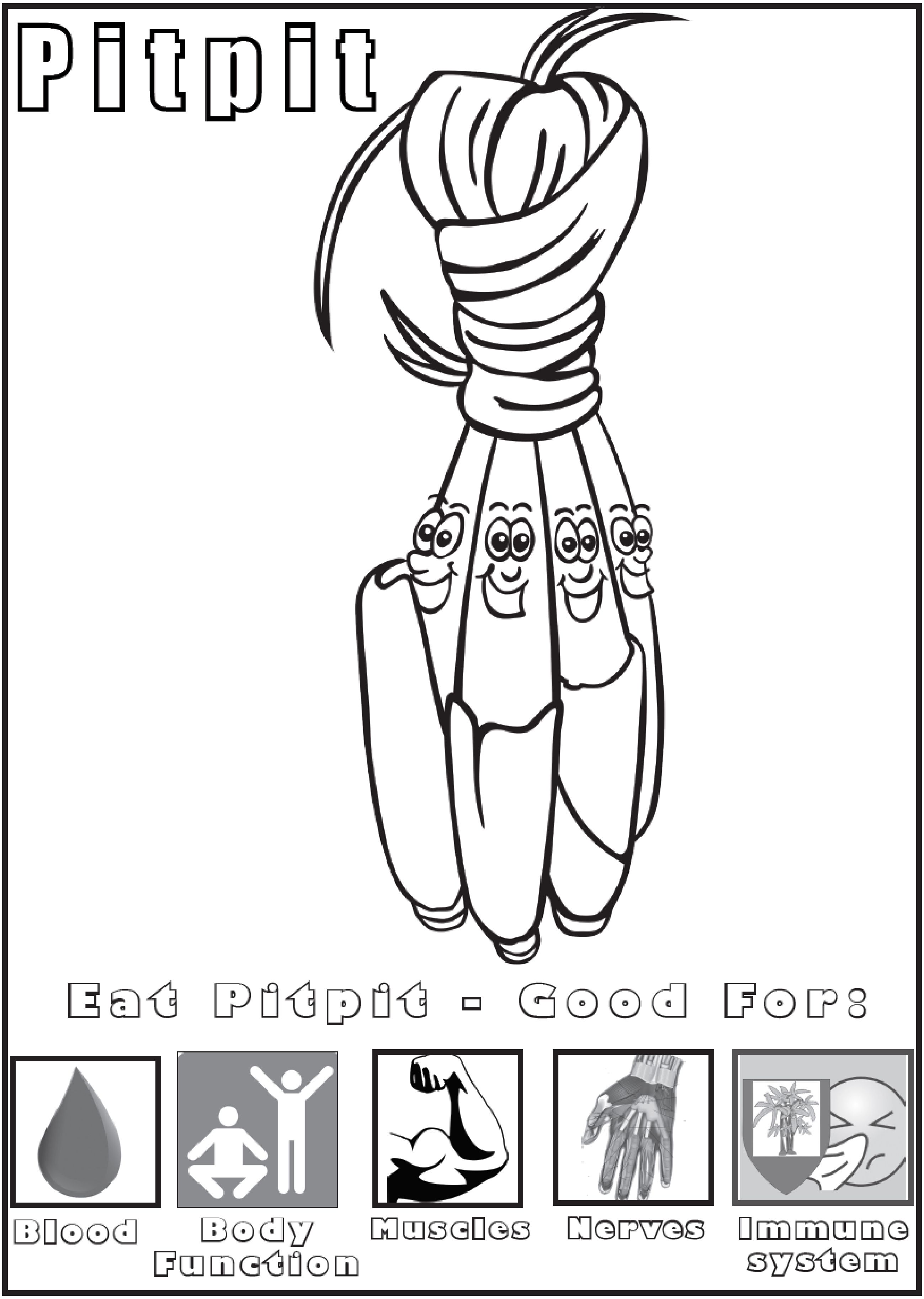
Pitpit Lowland raw 100g	Saccharum edule	165	4.2	1	1.7	3.6	18	48	636	4	1.1	1.1			0.04	0.06	1.3		14	1.8	T			
Highland Pitpit:baked 100g	Setaria palmifolia	141	1.6	0.3	5.1	2.3	3	46	601	18	0.9	1			0.16	0.17	1.3		19	1.5	3			30
Pumpkin Tips 100g	Cucurbita spp							550	4400	880		7.2	1.7								1	288		11.7
boiled 100g	Cucurbita pepo	108	2.7	0.2	1.5	3.7	5	38	114	335	1.5	0.4			0.3	1.1	0		4	1	248			2972
Rungia mg/100g	Rungia klossii		3							272														
Tulip leaf boiled 100g	Gnetum gnemon	147	1.6	2	0.6	4.5	7	67	614	75	1.6	0.2			0.1	0.14	0.9		66	1	185			2220
Valanguar 100g dry	Polyscias verticillata							1260	2600	2620	4.2	6.8	1								1.23		3	12.5
Watercress 100g	rippa Nasturtium aquaticum	46	2.3	0.1	1.29	0.5	41	21	330	120	0.2	0.11	0.077		0.09			9	43	1				
cooked	"	77	2	0.2		4.4	4	15	391	117	2.9	0			0.08	0.08	0.9		29	0.5	245			2940
raw	Nasturtium officinale	110	2.9	0.4	0.8	3.8	48	23	507	85	3	0.7			0.02	0.16	0.8	280			3.35			19.8
Waterdropwort 100g	Oenanthe javanica	109	2.4	0.1		1	1	36	156	134	0.2	1.1			0.1				60		593			
cooked	"	123	2.4	0.1	4.3	1	1	60	153	131	1.8	0.3			0.08	0.24	0.5		29	1.8	262			3140
Winged Bean raw 100g	Psophocarpus tetragonolobus	621	11.6	0.9	28.1		35	24	586	30	0.2	1.39	1.386		0.379			66	18					
Winged Bean baked 100g	Psophocarpus tetragonolobus	198	3.2	0.9	5.4	2.7	4	25	223	62	1.7	0.4			0	0	0			0.3				
Winged bean leaf raw 100g	Psophocarpus tetragonolobus	311	5.85	1.1	14.1		9	8	176	224	0.2	1.28	0.456					16	45					
Winged leaf cooked 100g	"	130	3.4	1.1		3.9	6	32	322	43	2.7				0.65	0.47	2.7		45	1	397			4760
English Cabbage								1450	29000	5700	40	20	2	5900								5		2
Cabbage european, white, boiled,100g	Brassica oleracea var. capitata	125	1.6	0.3	4.6	1.3	14	15	316	55	0.8	0.3			0.03	0.03	0.3		41	0.2	1			10

11.4 Appendix 4: Extracts from children's colouring book




Aibika
Eat Aibika - Good For:
Eyes
Teeth
Blood
Mother's & digestion
Immune system


Aupa
Eat Aupa - Good For:
Eyes
Teeth
Muscles
Nerves
Immune system


Pitpit
Eat Pitpit - Good For:
Blood
Body Function
Muscles
Nerves
Immune system

Australian Government

Australian Centre for
International Agricultural Research

CHARLES DARWIN UNIVERSITY

NARI

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Vegetable Illustrations:

World Vegetable Center

Papua New Guinea Women in Agriculture

World Vision

monkey soup

11.5 Appendix 5: Extracts from "A Taste of Papua New Guinea' Recipe Book

Aibika and Pork Satay

By Claire Webb - Serves 3-4

1. SATAY INGREDIENTS
1 bundle (4 cups) aibika - washed, stems, old leaves removed
1 carrot—cut into matchsticks
1/2 brown onion—sliced lengthways plus another 1/4 finely diced
2 chilli's—diced
1 cup peanuts—roasted, unsalted
2 cloves garlic—crushed/grated
3 tbsp. sweet soy sauce (kecap manis)
1 tsp sesame seed oil
2 tbsp. fish sauce
1/2 lime juice
1/3 cup coconut cream

2. PORK INGREDIENTS
400g pork—diced
2 cloved garlic—crushed
1 tsp ground cumin
1 tsp ground coriander
1 tsp turmeric
1/2 tsp paprika
1 chilli—diced
Zest from 1 lime
1/3 cup coconut milk
3 tbsp. fish sauce
1 tbsp. sweet soy sauce
1 tbsp. honey
1 tsp olive oil

OTHER
Bamboo skewers
2 tbsp. cooking oil

METHOD

1. Soak bamboo skewers in water
2. Mix all ingredients from the second list (excluding the pork) in a bowl to make a marinade. Add pork, coat in mix then set bowl aside in fridge for 2 hours.
3. After marinating, arrange pork on skewers then cook in grill or BBQ. Reserve some marinade for basting pork halfway through cooking.
4. In a food processor or mortar/pestle, grind peanuts into a crunchy paste.
5. Heat 1 tbsp. oil in hot frypan, add garlic, 1/4 onion and chili. Cook until lightly browned, lower to medium heat and add soy sauce, sesame oil, fish sauce, and coconut cream. Simmer gently for 5 minutes then mix in lime and peanuts. Stir until well mixed then remove from heat. Reserve 1/4 as dipping sauce for the pork. Set aside the rest.
6. Heat 1 tbsp. of oil in a frypan over moderate heat. Add 1/2 onion and carrot, stir until onion lightly browned. Add aibika, turn regularly until it begins to wilt then add the peanut sauce. Stir through until aibika completely wilted
7. Serve aibika and pork with rice

NUTRITIONAL INFORMATION	PER SERVE	
ENERGY	kJ	3341
	Cal	798
Protein	g	54
Fat - total	g	45
- saturated	g	11
Carbohydrate	g	40
- sugars	g	17
Dietary Fibre	g	10
Sodium	mg	2786
Calcium	mg	1321

10

Fried Aupa

Serves 4 - By Maria Linibi, Lae

Ingredients

2 bundles of Aupa
1 tablespoon of oil
4 cloves of garlic – crushed
1 cup water
3 tablespoon of black sauce (optional)
Pinch of salt

Method

1. Wash leaves, remove stalk, and leave to dry.
2. Heat oil in a pan - add garlic.
3. Once garlic smell is strong add Aupa leaves and water.
4. Stir fry until leaves are soft, add salt and black sauce and stir through.
5. Remove from heat and serve.

Tok Pisin

Ingredients

Tupla han Aupa
Wanpla tablespoon wel
Forpla garlik – brukim
Wanpla kup wara
Trepla tebolspun blaksos (sapos yu laik)
Lik lik sol

Method:

1. *Wasim han wantaimsop na wara.*
2. *Wasim lip, rausim bun, lusim long drai*
3. *Hotim wel insait long sospen - putim garlik.*
4. *Taim smel bilong garlik kumup strongpla kapsaitimlip na wara .*
5. *Praiminap kam up malolo, putim sol na blaksos na mixim. Rausimlong paia na kai kai.*

BBQ Amaranth and veggie Breakky

By Brenda Jarratt

Ingredients

Quarter of a pumpkin -Diced
Three carrots -diced
2 cups amaranth - chopped
Four coriander leaves - chopped
Big sprig of dill
Quarter of a lime
Olive Oil
Salt and pepper

Method

1. Turn BBQ to high heat with lid on.
2. Add olive oil, then pumpkin and carrots. Drizzle over some more olive oil
3. Cook on high for 10 minutes then turn vegetables over
4. Turn to low heat with lid on. Cook for 20 minutes or until just soft.
5. Turn heat off. Add rough chopped amaranth, dill and coriander, squeeze of fresh lime juice, salt and pepper
6. Turn vegetables over. Let sit with BBQ lid down.

Serve after sitting for 10 minutes

Nutritional Information	per serve	
ENERGY	kJ	1052
	Cal	251
Protein	g	5
Fat - total	g	18
- saturated	g	3
Carbohydrate	g	15
- sugars	g	12
Dietary Fibre	g	7
Sodium	mg	60
Calcium	mg	197

Aibika Pumpkin Rice Balls

Makes 20-25 balls

Ingredients

2 cups brown rice – cooked
2 cups pumpkin – cooked and mashed
1½ cups aibika – thick stems removed, diced
1 brown onion – diced
3 cloves garlic – crushed
1 cup red capsicum – diced
1 tbsp. ground cumin
2 tsp. ground coriander
1 tsp. turmeric
½ tsp cayenne pepper (adjust to taste)
1½ cups breadcrumbs
2 eggs - whisked
5 tbsp. olive oil

Method

1. Preheat oven to 190C. Grease baking tray.
2. Cook rice and pumpkin. Mash pumpkin then cool. Note: brown rice takes longer to cook
3. Heat 1 tbsp. oil in pan. Fry onion, garlic and capsicum until browned. Stir through spices for 1 minute then remove from heat.
4. Mix pumpkin, rice, aibika, onion mix in a bowl
5. Place eggs and 2 tbsp. oil in a seperate bowl
6. Roll small handfuls of rice mix into balls. Dip into egg mix then into a bowl of breadcrumbs
7. Line balls on tray. Place in oven. Turn every 10 minutes 3-4 times or until they are crispy brown.
8. Serve with salad and sauce.

Nutritional Information	per ball	
ENERGY	kJ	615
	Cal	147
Protein	g	4
Fat - total	g	5
- saturated	g	1
Carbohydrate	g	21
- sugars	g	2
Dietary Fibre	g	2
Sodium	mg	76
Calcium	mg	47

Aibika Alfredo

Serves 3-4 - By Claire Webb

Ingredients

2 cups aibika—washed, stems removed, chopped roughly
2 cups pasta (spiral or penne)
2 cloves garlic - crushed
1 brown onion - diced
1 cup of vegetable stock
1½ cups of Greek (or plain) yoghurt
1 cup shredded parmesan (or tasty) cheese
Oil for cooking

Method

1. Cook pasta in boiling water until soft. Drain.
2. Cook onion and garlic in pan until browned.
3. Add stock and aibika on medium heat. Simmer until aibika slightly wilted (3-4 minutes).
4. Lower heat. Whisk in yoghurt and cheese until melted. Do not allow to boil.

Serve sauce over cooked pasta. Top with cheese

Nutritional Information	per ball	
ENERGY	kJ	2284
	Cal	546
Protein	g	26
Fat - total	g	26
- saturated	g	13
Carbohydrate	g	52
- sugars	g	8
Dietary Fibre	g	4
Sodium	mg	709
Calcium	mg	809

Aupa Pesto vegetable pizza

Makes 2 pizzas - By Claire Webb

Base ingredients
2 cups flour—sifted, more for dusting
1 tsp dried yeast
3/4 cup warm water
1/2 tsp salt
1/2 tsp sugar

Toppings
1/2 medium sweet potato, halved and sliced thinly
1 cup eggplant—diced
1/2 red onion—sliced in strips
2 tbsp. olive oil1 cup aupa - washed, stems removed, roughly chopped
10-15 black olives - halved
1 cup shredded cheese
1 cup Aupa pesto (see recipe)

Part 1 - Pizza Base

1. Mix water, sugar, yeast in large bowl. Set aside 10 minutes in warm place until frothy.
2. Sift flour into yeast mixture. Knead on floured surface until smooth and elastic. Add small amounts of flour if sticky.
3. Divide into 2 balls, place in floured bowls and cover with tea towel. Leave in warm place for 1 hour.

Part 2—pizza tiopping

1. Preheat oven to 220C. Spread flour on flat trays
2. Boil sweet potato and eggplant until soft. Drain.
3. Once pizza dough balls has doubled in size. Place on floured surface and roll out into shape with floured rolling pin.
4. Spread out pesto over pizza base.
5. Distribute sweet potato, eggplant, onion, then aupa and olives over base. Top with shredded cheese.
6. When both pizzas prepared, put in oven until cheese melted and crispy.

Tastes good topped with dollops of Greek yoghurt.

Nutritional Information	per serve	
ENERGY	kJ	3172
	Cal	758
Protein	g	24
Fat - total	g	45
- saturated	g	12
Carbohydrate	g	61
- sugars	g	7
Dietary Fibre	g	10
Sodium	mg	804
Calcium	mg	514

Bamboo Shoots

Coastal Bamboo: *Nastus elatus;*
Coastal *or* Mambu: *Bambusa forbesii*;
Large Bamboo: *Bambusa vulgaris*

Tok Pisin: Gutpela blong kari na praim

Provides a crunch to curries and stirfries.

*Note: Not all bamboo shoots are edible and most edible varieties must be boiled before eating.

Pork bamboo curry

Serves 5-6

Ingredients

2 fresh bamboo shoots (or 2 cans)
400g pork – diced
500g or 2 cups cassava (or potatoes)
10 winged beans (or green beans) – diced
2 brown onions
3 cloves garlic – crushed
2cm ginger – grated
1 tbsp. ground cumin & 1 tbsp. ground coriander
1 tsp ground turmeric & 1 tsp salt
2 cups coconut milk
1 cup vegetable stock

Method

Preparation: Peel sheaths off fresh bamboo, wash, and boil for 2 hours. Drain, wash, and cut into 2cm thin slices.

1. Remove outer layer of cassava, boil until soft, drain. Remove middle string and black parts. Dice into 2cm
2. Heat oil in large fry pan, stir fry pork, onion, garlic, and ginger until meat cooked. Add spices.
3. Add bamboo shoots, coconut milk and stock. Bring to boil then simmer for 1 hour.
4. Add winged beans, simmer 30 minutes

Serve with rice and fresh coriander.

Nutritional Information	per serve	
ENERGY	kJ	1863
	Cal	445
Protein	g	25
Fat - total	g	22
- saturated	g	14
Carbohydrate	g	33
- sugars	g	5
Dietary Fibre	g	7
Sodium	mg	624
Calcium	mg	53

Bamboo Stirfry

Serves 3

Ingredients

1 ½ cups bamboo shoots – diced into strips
2 brown onions – cut into strips
1cm/1 tsp fresh ginger – shredded
2 cloves garlic – crushed
1 medium capsicum – cut into strips
1 large carrot – cut into strips
2 tbsp. Oyster sauce
3 tbsp. thin soy sauce
2 kaffir lime leaves – de-veined, sliced thinly
½ cup watercress – for garnish

Method

Preparation: Peel away layers from fresh bamboo, wash, and boil for 2 hours. Drain, wash, and cut into 2cm thin slices.

1. Heat oil in large pan. Brown onion, garlic, ginger then add soy sauce
2. Stir in carrots and capsicums. Sauté for 5 minutes then add bamboo shoots, kaffir lime leaves, and oyster sauce. Stir until bamboo shoots heated through.

Serve with steamed rice or noodles. Top with watercress.

*Note: A full nutrient table provided at back of book

Nutritional Information	per serve	
ENERGY	kJ	923
	Cal	221
Protein	g	6
Fat - total	g	13
- saturated	g	1
Carbohydrate	g	15
- sugars	g	13
Dietary Fibre	g	9
Sodium	mg	2041
Calcium	mg	79

"In my village mostly we harvest bamboo shoots about 30-50cm long. We remove 2-3 outside layers. Then we gently crush the shoots with our hands. Then it is ready for boiling. Most times we cook it in mumu. It tastes good. You can add salt and pepper to add flavour. It is perfectly sweet"

Dickson Benny, Kossena Village, Kainando

Fern Tips

Tree fern (*Cyathea spp*)
Vegetable fern (*Diplazium esculetum*)
Kumugrass (*Callipteris prolifera*)

Rausim strongpela rop. Boilim o praim long kaikai

Remove tough stems. Boil or steam like a spinach or mix into stirfries.

Nutritional Information		per serve
ENERGY	kJ	3675
	Cal	878
Protein	g	43
Fat - total	g	69
- saturated	g	49
Carbohydrate	g	22
- sugars	g	11
Dietary Fibre	g	8
Sodium	mg	1530
Calcium	mg	133

Creamed Fig Leaf with Pitpit

Serves 4 - By: Monica Jack, Lae

Ingredients

2 bundles of fig leaf
8 lowland pitpit
500g of chicken thigh (or 8 chicken legs)
4 cups (or 3 cans) coconut cream
1 tomato - diced
1 brown onion - sliced
1 tsp turmeric
5 cloves garlic - grated
1 chicken stock cube
1 tbsp full grated ginger
½ tbsp salt

Method

1. Place coconut in a large pot. Break the fig leaf up in your hands and add to coconut cream.
2. Add the onion, tomato, garlic, ginger, turmeric, stock, and salt to mix.
3. Break the pitpit into 2-3 pieces, layer on top of mix, followed by the chicken.
4. Place pot on high heat then reduce to simmer with lid on once coconut cream starts boiling.
5. Simmer for 30 minutes or until chicken is cooked through

Serve with Rice

"Kumu mosong grows in Central province. We use it as a medicine. Some people, when they are sick for a while, they steam the leaves in hot water. They put a blanket over themselves and the hot mix and breathe it in. Some people boil it then eat it - it is soothing on the throat"

Peola Utama

Lime Chicken and Watercress

Serves 4-5- Claire Webb

Ingredients

1 bunch watercress - washed
4 chicken thighs
6-8 large potatos - quartered
2 red onion - cut into eighths
1/2 red capsicum - sliced thingly
2 limes - 1 juiced, the other sliced
2 cloves garlic - crushed
2 tsp cumin - ground
2 tsp coriander - ground
2 tsp smoked paprika - ground
1 tsp salt
1 tbsp olive oil

Method

1. Preheat oven to 200C.
2. Part boil potatos for 10 minutes, drain, toss mix with oil, and place on oven tray along with onion, sliced lime, and capsicum.
3. Mix cumin, coriander, paprika, salt, oil, garlic, and juice of 1 lime. Rub mix over the chicken
4. Place chicken on top of potato mix. Cook in oven for 1 hour. Allow to cool for 10 minutes.
5. Roughly chop watercress then toss through the chicken mix in a mixing bowl. Serve

Nutritional Information

Nutritional Information	per serve	
ENERGY	kJ	2479
	Cal	592
Protein	g	38
Fat - total	g	24
- saturated	g	6
Carbohydrate	g	49
- sugars	g	6
Dietary Fibre	g	11
Sodium	mg	596
Calcium	mg	106

Watercress and Pork Stir fry

Serves 3

Ingredients

500g pork – diced
2 bundles watercress – washed, diced roughly, thick stems removed
1 brown onion
2 cloves garlic
2 tsp minced ginger
½ cup soy sauce
1/3 cup rice wine vinegar
1 Tbsp. corn starch
Vegetable oil

Method

1. Heat oil in large pan then fry garlic, onion and pork until browned then add ginger.
2. Lower heat, add soy sauce, vinegar and corn starch and allow to simmer for 15 minutes.
3. Turn off heat and stir though watercress.

Serve with steamed rice topped with fresh watercress.

Nutritional Information

Nutritional Information	per serve	
ENERGY	kJ	1656
	Cal	396
Protein	g	59
Fat - total	g	15
- saturated	g	3
Carbohydrate	g	35
- sugars	g	30
Dietary Fibre	g	9
Sodium	mg	3655
Calcium	mg	230

Sweet and Sour Pork and Winged Beans

Serves 4 - By Claire Webb

Ingredients

8-10 young winged beans - ends removed
500g pork—diced
1 500ml can pineapple— juice reserved
1 carrot—sliced into matchsticks
1 red capsicum—diced
1 brown onion—chopped into chunks
250ml rice bran or cooking oil

Pork Marinade

2 cloves garlic—grated
2 tbsp soy sauce
2 tbsp rice wine vinegar
1 tbsp. olive oil
1 egg—whisked
3 tbsp. cornstarch
2 tbsp. plain flour

Sauce

I cup water
50ml tomato sauce
50 ml sweet chili sauce
50ml rice wine vinegar
1 tbsp. cornstarch
Reserved pineapple juice from can

Method:

1. For marinade, mix egg, soy sauce, garlic, vinegar and oil in bowl. Coat pork in mix then put in fridge for 5 minutes.
2. Add flours to pork mix, coat thoroughly. Place in fridge for another 30 minutes
3. Mix water, tomato and chili sauces, vinegar, cornastarch, and reserve pineapple juice in saucepan. Bring to boil, then lower to medium heat to simmer, Stir until it turns thick and syrupy
4. Heat oil in a small frypan - enough to cover base of pan. Cook pork in batches until crispy brown. Place on paper towel to soak up oil
5. Dispose of all but 1 tbsp of remaining oil in frypan. Heat the oil and add the winged beans and carrot. Cook until winged bean bright green then add onion and capsicum. Stir for 3-4 minutes then stir through cooked pork.
6. Remove from heat then stir through sauce.

Serve with steamed rice

Nutritional Information		per serve
ENERGY	kJ	3050
	Cal	729
Protein	g	45
Fat - total	g	40
- saturated	g	6
Carbohydrate	g	59
- sugars	g	44
Dietary Fibre	g	6
Sodium	mg	1549
Calcium	mg	64