Australian Government

Australian Centre for International Agricultural Research

Final report

Re-commercialisation of the pyrethrum industry in PNG and improving harvested yields in Australia

project number	ASEM/2006/023
date published	May 2013
prepared by	Mr Brian Chung
co-authors/ contributors/ collaborators	Mr Wakasa Mecksaene Dr Sergie Bang Dr Al Gracie Mr Bill Casey
approved by	Dr Caroline Lemerle, Research Program Manager for Agricultural Systems Management, ACIAR
final report number	FR2013-04
ISBN	978 1 922137 36 4
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

The support of ACIAR in the planning and funding of this project was very important and is very much appreciated.

The input of the PNG based members of this project team has been very substantial and highly values. Janet Yando, Manday Yaso, Enopa Lindsay, Peter Corbett and Kud Sitango have been the key PNG members of this project team and their valuable contributions are very much appreciated. Much of this Final Report is based on their various reports of the activities undertaken during this project. We are also very grateful for all of the support provided by various other members of the project team in PNG, ranging from Ken our NARI driver/technical officer to the factory operators and collection depot staff and most importantly, the local pyrethrum growers in PNG.

We are also grateful to the support provided by BRA management and staff during the conduct of this project, especially the support and guidance provided by Maurice Kerr and his staff at the BRA laboratory and Helen Faber and her refinery team for their tolerance in developing procedures to refine the PNG oleoresin product.

2 Executive summary

This project has been successfully completed and very useful outcomes have been achieved. Crop management aspects in PNG such as plant density and the need for slashing can now be demonstrated to local growers by NARI working in conjunction with the local extension staff of the Enga Pyrethrum Company. The identification by NARI of high assay clones is a great achievement and these clones can now be used as the basis for commercial seed production as well as the basis for a plant improvement program. The Kagamuga extraction factory has been improved and can now produce acceptable quality oleoresin product. The success of the NIR laboratory equipment enables the factory to monitor all of the extraction operations and is also used by NARI staff to measure the pyrethrins content of the clones. The extension activities of the Enga Pyrethrum Company in raising the awareness and interest of local growers has been very successful and during the period of this project, some 200,000 kg of pyrethrum flowers have been produced and Kina 500,000 in flower payments have been injected into the local economy.

This project has had major impact on developing the capacity of the PNG partners. NARI researchers are benefiting from interaction with BRA and UTas/TIAR researchers on aspects of experimental design and conduct, data analysis and reporting. The Kagamuga extraction factory operators are gaining experience in the use of laboratory equipment and in particular, the NIR as well as the safe and effective operation of the extraction plant. The extension staff are benefiting from the study tour to BRA in Tasmania as well as exposure to BRA senior staff during their regular visits to PNG. One project team member has successfully completed an M Agr Science degree at UTas as a part of his John Allwright Fellowship. There are three other young project team members who would very much benefit from a period of formal study at an Australian tertiary institution as a capacity building investment.

The project is having very good economic and social/health impact in generating interest by smallholders to grow pyrethrum as a useful source of cash income and the funds already injected into the local community to date has been significant. The availability of an easy to grow cash crop has become a focus for local communities and had the potential to focus attention to pyrethrum growing instead of anti-social activities.

There is a good opportunity to develop the PNG pyrethrum industry to the production levels of the 1970-1980's within the next five years. Very strong momentum has been achieved by this project and on-going support from ACIAR is recommended to enable these achievements to be consolidated.

3 Background

Pyrethrum was introduced into PNG in the late 1950's and it became a good attractive cash crop for the highlands (~ 2,000 metres) where the climate is too cold to successfully grow major cash crops such as coffee. From the 1960's to the late 1980's, the pyrethrum industry played a major role in sustaining the livelihood of some 65-85,000 people in the highland areas. Local women, children and old people are the key workers in this industry and these important social groupings are the key beneficiaries from this industry. In 1995, the pyrethrum extraction factory that purchases the crop from the growers closed down and this resulted in a lot of primarily subsistence farmers losing their major source of cash income. In 2000-2001, the Enga Provincial Government invested some $A1.2 million to re-commission this factory.

Pre 1995, all of the pyrethrum crude extract, called oleoresin, produced in PNG was sold to an USA company. This marketing arrangement ceased when the factory closed in 1995 and the PNG industry has not been able to re-establish a market for their pyrethrum extract product since that time.

There are two main reasons for this failure to gain a marketing position. Pyrethrum is an insecticide and producers are required to have access to the full toxicology, ecotoxicology and use pattern Data Package before their products can obtain access into the vast majority of world markets. Unfortunately, the PNG industry does not have access to this data and the costs of obtaining this Data Package is in the order of $A3-4 million. The pyrethrum oleoresin produced by the PNG industry requires an additional refining process before it can be used by the product formulators and there are only three major pyrethrum refineries in the world.

Botanical Resources Australia –Agricultural Services Pty Ltd (BRA) was contacted by the PNG pyrethrum industry during November 2003 and there has been on-going communications since that time. BRA is one of the largest pyrethrum producers in the world and in recent years, BRA has supplied in excess of50% of the world usage of pyrethrum products. BRA is a share owner of a comprehensive registration Data Package on pyrethrum and is able to market pyrethrum products into the major world markets. BRA has a modern and technologically advanced production and manufacturing facility in Tasmania and a strong production base in Tasmania.

Following an approach from the PNG National Government during August 2005, BRA decided to develop a business arrangement with the Enga Provincial Government. BRA hosted a visit to Tasmania by the Governor, Administrator and their delegation during late October 2005. During this visit, BRA and the Enga Government signed a business agreement where the Enga Government agreed to supply and BRA agreed to purchase a specified quantity of pyrethrum oleoresin at a set price for each of the next three years. There is an opportunity to renew this Agreement after the end of this initial three years.

The PNG industry was still recovering from the joint shock of the factory closure and the subsequent withdrawal of the key US pyrethrum buyer at the start of this project. Support provided by this ACIAR project was essential to ensure that good local science and technology was available, extended and adopted by the local growers and by the extraction factory. This project is alignment with the ACIAR PNG strategy to "support applied technical and economic research aimed at the enhancement of incomes for smallholders particularly with respect to the involvement of woman farmers".

There has been no previous ACIAR investment into the PNG pyrethrum industry. The BRA approach was to ensure that available knowledge and experience in pyrethrum growing, harvesting, logistics and extraction at the factory is fully extended to the relevant targeted audience and be fully adopted. The PNG growers/Enga Government as the contracted party are keen to deliver on their part of the Agreement with BRA with regards to the timely supply of the specified quantity and quality of oleoresin. BRA is interested in increasing the quantity

of oleoresin product from PNG in the longer term to ensure that this industry has a sustainable long term future.

4 Objectives

This project had four major objectives, all of which would contribute to the re-commercialisation of the pyrethrum industry in PNG.

To develop improved pyrethrum planting material and improved agronomic practices for PNG.

The pyrethrins content of pyrethrum crops in PNG was about 1.7%, but following the downturn of the industry during the mid 1990's, most of the planting material was destroyed/lost and just individual plants in isolated farmer gardens had remained. At the start of this project, NARI had already started to collect what plants were available and had planted promising individual plants in a block at Taluma Station. The selection and commercial use of high pyrethrins content planting material will increase the yield in the field, reduce unit production costs and improve processing efficiency, all of which will impact on the price paid to the grower. Hence, there is a need to evaluate the quality of the planting material available in PNG and to implement a selection/breeding program to provide higher quality planting material for local growers.

The existing reports and other documentation on pyrethrum in PNG are scattered in various local libraries and government offices and are not readily available for use by the current pyrethrum industry. Hence, there is a need to find, catalogue and collate all available reports and other information on pyrethrum and store at a venue that is readily accessible by interested parties. This information will assist the current industry to gain a better understanding of the achievements and impediments faced by the industry in the past and thus provide some guidance to the re-commercialisation of this industry.

There are some basic agronomic management practices that would optimal production and thus require research under local conditions. These include the effects of plant density and crop slashing on yield and the efficacy and crop tolerance of locally available fungicides and an evaluation of the importance of nematode.

To assist in the adoption of improved pyrethrum production practices by the PNG pyrethrum industry

To re-commercialise the pyrethrum industry in PNG, there is a need to generate renewed grower/community awareness and interest in this crop and then follow-up with guidance and relevant production information as well as planting material for immediate uptake into crop production. The pyrethrum industry in PNG had reached a maximum of some 300 tons of dry flowers per year in the past and hence, the first target for production is to achieve a production level of 300 tons per year as soon as possible. This will be a very challenging task as the interest, expectation and knowledge of this opportunity was very low prior to the commencement of this project. Hence, a very active extension and outreach program is required to be planned, resourced and implemented in a way that is appropriate to the local community.

To assess the plant physiological factors contributing to pyrethrum yield in PNG and Australia

There is a need to gain more understanding of the plant physiological factors affecting pyrethrum yield in Tasmania. This greater understand will allow more accurate and reliable yield forecast early in the season to facilitate market planning as well to identify appropriate weaknesses/opportunities for further research input. The identification of these parameters in Tasmania will also provide some guidance as to opportunities to improve the production and yield of pyrethrum crops in PNG.

To maximise the efficiency of extraction in PNG and improve the compatibility of PNG Pyrethrum extract and BRA refining processes.

To monitor the operation and efficiency of the extraction plant will require some instrumentation to measure the pyrethrins content of products throughout the processing process, from the input flowers to the oleoresin and the marc by-product. At this time, the Kagamuga factory does not have any laboratory or other measuring/testing equipment or operating manuals and procedures. Hence, there is a need to install at least basic equipment to measure the pyrethrins content of flowers and the oleoresin as well as monitoring the moisture content of flowers and the flash-point of the oleoresin as a measure of the amount of hexane residue.

The production practices in Tasmania are very different from PNG, due to both climatic differences as well as production differences, varying from machine harvesting of mature crops in Tasmania to sequential hand harvesting of semi matured flowers in PNG. The resulting physical and chemical differences in the processing feedstock will have effects on the processing efficiencies and quality of the end product. The most important difference is that PNG oleoresin has much greater wax content compared with oleoresin produced inTasmania and thus some modification is required to facilitate the efficient refining of the PNG oleoresin by the BRA facility in Tasmania.

5 Methodology

The project activities in PNG were undertaken by NARI (National Agricultural Research Institute) and EPC (Enga Pyrethrum Company) with guidance, support and management by Botanical Resources Australia Pty Ltd (BRA).

Field trials were established by NARI at Taluma Research Station, (Taluma), Enga Provence, a former sub-station of the PNG Department of Agriculture and Livestock and at Tambul High Altitude Highlands Research Institute, (Tambul) located in the Western Highlands Provence.Taluma Research Station is located at an altitude of 2602 metres above sea level ($05^0$27' 57s South $143^0$32' 00s East). Unfortunately, very serious tribal fighting commenced within the vicinity of Taluma Station during late January 2010 and very rapidly spread into Taluma Station and the neighbouring primary school. The NARI officers located at Taluma was evacuated by a police escort and it has not been safe to return as of the end of this project. Hence, all of the trials located at Taluma have been abandoned with the last harvest result being from 27 January 2010.

Extension and Outreach activities were undertaken mainly by the EPC based in Wabag in Enga Provence. As more than 95% of pyrethrum has traditionally been grown in Enga Provence, the extension and outreach activities were concentrated in Enga Province, with just a few visits to other highland provinces such as Western Highlands, Chimbu and Southern Provinces.

Collection of pyrethrum reports and other documentation in PNG

The collection of information and literature on past research and extension work for pyrethrum in PNG involves visiting major agricultural libraries, Archives in NDAL Headquarters, PNG pyrethrum websites via internet and consultation with various experienced personnel in pyrethrum industry.

Agricultural libraries such as NARI Bubia Library in Lae, Coffee Research Institute (CRI), and NARI Library in Aiyura in the Eastern Highlands Province (EHP), NARI Tambul were visited and copies of all available information were collected and compiled. During the course of the work the NDAL Headquarter, Konedobu in Port Moresby was also visited and information collected. This work involves actual accessing of books, technical reports, analysis reports, extension bulletin, training pamphlets and others. Wherever possible a copy of each item of material was collected, including sections/chapters of books which had relevant information.

To some extent the work on collection of research and extension information and literature was limited due to inaccessibility to helpful materials in other libraries and improper recording and filling systems.

All information and literature collected were catalogued, compiled and made available in NARI Tambul office. This material will serve as a guide in the planning and implementation of research, extension and development of the pyrethrum industry in Papua New Guinea.

Pyrethrum clone collection

Prior to the commencement of this study, NARI officers had collected 18 individual pyrethrum plants from grower gardens based on criteria such as healthy plant status, larger flower size, relatively high number of flowering stems, strong plant base and good physical appearance of the plant stand. Each plant was considered to be a separate clone and was given a distinct number code. Each clone was separated into splits and planted in un-replicated collection plots at Taluma during 2006. Prior to the commencement of this project, BRA obtained a sample of flowers from each of these 18 clones for analysis by the BRA laboratory. The results showed a wide range of assay, from 0.70% to 1.54% and an average of 1.22%.

NARI intensified their collection of available plants from local farmer gardens at the start of this project and managed to collect more plants. A total of 74 clones were planted in a collection at Taluma and at Tambul, the same 74 clones plus another 10 different clones were planted in a collection. At each site, there were up to six splits of each clone.

Flowers of each clone were hand-picked at the same maturity stage (75% - 100% disc florets opened). The harvested flowers were packed in labelled paper bags and dried at 40-60^{0}C using a draught oven for 20 to 24 hours until crisp to the touch. The required quantity of dried flowers for assay is 3 – 5 grams.

During the period April 2008 to May 2009, the pyrethrins content of these harvested flower samples were determined using the NIR equipment located at the Kagamuga factory laboratory. About 3-5 grams of individual dried flower samples were milled separately using electric grinder. The grinder was cleaned after successive grinding of each flower sample to avoid contamination and 5 samples of each clone was milled each time.

Plant density study at Taluma

Three weeks before the actual planting of the trail, the ground was manually prepared. Planting was done using splits on 15th of June 2007. Splits for planting were obtained from the 18 clones selected and grown by NARI at Taluma. Details of densities and row spacing are shown in the table below.

Table 1. Plant density treatments at Taluma

Code	Density (Plants/m^2)	No of row per bed	Spacing between rows (cm)	Spacing between plants (cm)	Rectangularity (ratio)
B	2	2	70	70	1:1
C	4	3	50	50	1:1
D	8	4	35	35	1:1
E	16	5	25	25	1:1
F	24	6	20	20	1:1

Splits were all uniform in size and age. The experimental design was a randomized complete block with five treatments and four replicates**.**The trial plot was surrounded with buffer rows planted with splits at two sides.

After two month from establishment, about 25% of the plants in manyplots failed to establish and were replaced with splits obtained from the buffer rows.

First harvest commenced on 3 December 2007, some 6 months from planting. Fully opened flowers from individual plants in each replicates were harvested at approximately two weekly intervals. At each harvest, the numbers and fresh and dry weight of flowers for individual replicates were determined. The flowers were dried using electric oven at a temperature range of 40 – 60 ^{o}C. Data were analysed using Genstat software. The pyrethrins content of a sample of flowers from each plot was obtained usingthe Near Infra-RedSpectrometer (NIR) located at the Kagamuga factory.

The plants were all slashed at 10 mm above ground level on 8 February 2009, some 14 months after the first harvest. Regrowth was slow and harvesting recommenced on 14 May 2009, some three months after slashing. Harvesting continued two weekly intervals until 27 January 2010, a period of some seven months.

Plant Density study at Tambul

Three weeks before the actual planting of the trail, the ground was manually prepared. Planting was done using splits on 17th of June 2007. Splits for planting were obtained from the 18 clones selected and grown by NARI at Taluma. Details of densities and row spacing are shown in the table below.

Table 2. Plant density treatments at Tambul

Code	Density (Plants/m^2)	No of row per bed	Spacing between rows (cm)	Spacing between plants (cm)	Rectangularity (ratio)
B	2	2	70	70	1:1
C	4	3	50	50	1:1
D	8	4	35	35	1:1
E	16	5	25	25	1:1
F	24	6	20	20	1:1

Splits were all uniform in size and age. The experimental design was a randomized complete block with five treatments and four replicates**.** The trial plot was surrounded with buffer rows planted with splits at two sides.

Unfortunately, the plants at the Tambul trial were heavily infected with nematode and the trial was re-established twice, each time to a new location within Tambul. Unfortunately, each of these re-plantings was unsatisfactory with unevenness of plant establishment and was considered to be unsuitable for experimental purposes. During late 2010, it was decided to re-establish this study on a totally new site that has no previous history of pyrethrum growing. A suitable site was found some 30 km from Tambul and a nursery bed has been established on site to provide seedlings for the establishment of this study.

Slashing study at Taluma

Three weeks before the actual planting of the trail, the ground was manually prepared. Planting was done using splits on 15th of June 2007. Splits for planting were obtained from the 18 clones selected and grown by NARI at Taluma. Details of the slashing treatments are shown in the table below.

Table 3. Slashing treatments at Taluma

Code	Treatment
A	Control – No slashing off tops
B	Selective removal of flowering plant stalks following the completion of 12 months of harvest
C	Complete slash off tops at 100mm above ground level after 12 months of harvest

First harvest commenced on 3 December 2007, some 6 months from planting. Fully opened flowers from individual plants in each replicates were harvested at approximately two weekly intervals. At each harvest, the numbers and fresh and dry weight of flowers for individual replicates were determined. The flowers were dried using electric oven at a temperature range of 40 – 60 ^{o}C.

After 14 months of harvesting, Treatments B and C were imposed on 9 February 2009.Regrowth was slow and harvesting recommenced on 14 May 2009, some three months after slashing. Harvesting continued two weekly intervals until 27 January 2010, a period of some seven months.

Slashing study at Tambul

Three weeks before the actual planting of the trail, the ground was manually prepared. Planting was done using splits on 15th of June 2007. Splits for planting were obtained from the 18 clones selected and grown by NARI at Taluma. Details of the slashing treatments are shown in the table below.

Table 4. Slashing treatments at Tambul

Code	Treatment
A	Control – No slashing off tops
B	Selective removal of flowering plant stalks following the completion of 12 months of harvest
C	Complete slash off tops at 100mm above ground level after 12 months of harvest

Unfortunately, the plants at the Tambul trial were found to be heavily infected with nematode and the trial was re-established twice, each time to a new location within Tambul. Unfortunately, each of these re-plantings was unsatisfactory with unevenness of plant establishment and was considered to be unsuitable for experimental purposes. During late 2010, it was decided to re-establish this study on a totally new site that has no previous history of pyrethrum growing. A suitable site was found some 30 km from Tambul and a nursery bed has been established on site to provide seedlings for the establishment of this study.

Pest and disease studies in PNG

Fungal diseases are common in pyrethrum crops in Tasmania and the project team were advised of the likelihood of nematodes as a possible pest of pyrethrum crops in PNG. Hence, it was decided to include a recently appointed inexperience NARI plant pathologist to the project team and to include a fungicide evaluation study and to undertake some basic nematode evaluation of pyrethrum crops.

A trial to evaluate the efficacy and crop tolerance of the three commonly available fungicides in the PNG highland stores was established at Tambul during May 2008. The fungicides selected for evaluation was Mancozeb and two copper based products, all of which are used by local growers on potato crops.

Unfortunately, the plant pathologist responsible for this trial had resigned from NARI and this study was put on hold until a replacement plant pathologist is appointed by NARI. The deferment of this study was considered to be an acceptable risk because pyrethrum crops in PNG were observed to be generally free of any significant diseases.

Nematode collection and identification is a relatively new area of study for NARI and the NARI plant pathologist spent time to learn the basic techniques to collect, separate and identify nematodes. The learning process included a visit to Tasmania to spend time with the TIAR plant pathologist with expertise on nematodes. Following this period of learning, resources were provided to allow him to set up the necessary laboratory equipment and facilities at Tambul.

Unfortunately, the plant pathologist responsible for the nematode work had resigned from NARI and this study was put on hold until a replacement plant pathologist is appointed by NARI. The deferment of this study was considered to be an acceptable risk because pyrethrum crops in PNG were observed to be generally free of any significant nematode infestation.

Extension and outreach program by the EPC

Extension service provided by EPC was aimed at providing information and skills to enable rural people to apply improved cultivation methods to maximise yield. To enable immediate and rapid production of new crops, EPC also provided planting material free of charge to all interested growers. Initially, planting material were splits, but as seed became more available from 2009 onwards, seedlings became much more common than splits and by 2010, seedlings became by far the most common means of crop establishment.
The focus of the extension effort was to increase the total number of people in each household to produce pyrethrum in a land and labour mobilisation manner. This is to ensure that every household in Enga, particularly those in areas suitable for growing pyrethrum have a chance to improve their well-being through their own efforts, on their own land making the best use of whatever limited resources that are available. The methods used by EPC included daily/weekly field visits, extended visits to outlying communities, follow-up visits and monitoring, information gathering through interviews and surveys of communities, public awareness of the overall industry, ward base grower census, field days and training days, provision of handout material appropriate to growers, setting up grower cooperative societies and utilising village based service providers.

Studies to gain better understanding of factors affecting pyrethrum yield in Australia and PNG

A study of the key components of flower yield, such as ground cover and duration of ground cover was undertaken in Tasmania. Pyrethrum has very small leaves and it would be very difficult to measure the leaf area index using traditional destructive harvest methods. Digital image analysis (DIA) technology was used to measure ground cover during the season and this information was used to develop relationships between plant growth and final yield. Multivariate analysis was conducted on the large crop production datasets compiled by BRA. These datasets consists of all of the agronomic inputs and management decisions made by BRA field staff on each individual pyrethrum paddock in Tasmania over many years. This analysis will likely identify those factors that are important to crop establishment and yield and will provide guidance to the identification of the most important areas for research and extension activities by the pyrethrum industry in Tasmania and possibly in PNG.

Improvements to the operation of the Kagamuga extraction factory

Chemical analysis is a necessary component of the project and funding input to the Kagamuga processing factory has included major laboratory restoration to allow quality testing to be carried out on:

- New higher yielding clones being evaluated by NARI and EPC
- Routine analysis of extraction processes and the final product in the EPC factory to ensure optimum performance

NARI Chemistry had significant input into:

- Overseeing the EPC factory laboratory and providing technical advice
- Soils fertility testing in assessing new growing areas

At the start of the project in 2006, BRA renovated and re-equipped the old and dilapidated quality control laboratory at the EPC factory at Kagamuga, Mt Hagen. This included BRA sending their Laboratory manager to assess the laboratory requirements and organized for NARI Chemist, Peter Corbett, EPC factory manager Anthony Armban and a NARI trial scientist, Kud Sitango to undertake pyrethrum analysis training using the NIR (near infrared spectrometer) at the BRA laboratory in Tasmania during 2007.

NARI Chemistry then oversaw the laboratory set up at the factory and monitored its operation through the project life. This support continued through:

- assist in the commissioning of the project funded NIR and other laboratory equipment
- supply of further laboratory equipment, funded from the project, and recommend purchase of consumables
- monitoring, training and testing during routine visits to the laboratory, continuing for the duration of the project with three visits per year
- maintenance and calibration of the NIR including follow up with the NIR supplier on service, and maintenance of other laboratory equipment
- reviews of laboratory operations
- Liaising with BRA on factory operations and flower purchase
- Discuss and advise process operations with factory senior operator, Willy Poo

Staff training and refresher training on analysis, primarily use of the NIR instrument have been given to EPC factory staff, with senior operator and NARI pyrethrum project scientists now capable of operating the NIR.

Maintenance and calibration checking of the NIR has required NARI Chemistry input. This includes routine service, checking NIR components such as sample measuring cell assemblies, and dialog with the NIR supplier in Australia on maintenance. NIR maintenance work includes determination and checking equipment calibration factors. NIR cross checks are done by HPLC. This has been done at the BRA laboratory, however a new HPLC has now been installed at the NARI laboratory in Port Moresby and will be used for NIR checking. Earlier, BRA supplied a second hand HPLC to NARI, used for initial assessment. This HPLC was used for NIR re-calibration in 2008. Since this time the NIR has performed well, requiring no further recalibration. Other laboratory equipment requiring routine checking are the balance and oven. NARI has also supplied a new grinder for pulverizing flowers prior to NIR testing.

6 Achievements against activities and outputs/milestones

Objective 1: To develop improved pyrethrum planting material and improved agronomy practices for PNG

no.	activity	outputs/ milestones	completion date	comments
1-1	Develop improved pyrethrum planting material for local growers	Establish clones at Taluma and Tambul and evaluate for pyrethrins content, Very best clones to be given to the Enga Pyrethrum Company (EPC) for commercial seed production	Dec 2010	Taluma Clone trial A total of 74 clones established. Only 25 of these clones produced sufficient flowers for analysis and 12 of theseclones had pyrethrins content ≥1.5%. These 12 selected clones have been planted for further multiplication and assessment on yield, tolerance level to floral fungal disease and other superior yield parameters. Tambul clone trial From the 84 clones at the Tambul collection only 27 clones had sufficient flowers for analysisand 13 of theseclones had pyrethrins content ≥1.5%. These 13 selected clones have been planted for further multiplication and assessment on yield, tolerance level to floral fungal disease and other superior yield parameters.

1.2	Improve the yield potential by improved agronomy practices	To find, collate and review all old PNG DAL reports on pyrethrum production.	March 2010	A final report has been complete. This document will serve as the baseline database for PNG and the other major outcome is that a copy of all relevant reports is now located at Tambul, the key NARI research centre for the Highlands
		To prepare management information on disease and nematode pests for us by PNG farmers	To be completed	The plant pathologist undertaking this component of the work left NARI to take up a job with another PNG government organisation. As a result, the work is still pending and is on hold for an indefinitely period of time until the programme has an appropriate officer replacement on board. Project management has assessed that the PNG pyrethrum crops are generally free of plant diseases and nematodes and hence, the risks associated with this delay is within acceptable limits.
		To assess the benefits of slashing the old flower stalk and foliage as a means of increasing flower yield and possibly reducing foliage diseases	December 2010. Part to be completed	A trial was established at Taluma during June 2007 and slashed after 26 harvests have been completed. Regrowth after slashing was good and 9 months of data from harvesting after slashing has been completed up to January 2010.
		To assess the effects of plant density on the yield of flowers over time	December 2010. Part to be completed	A trial was established at Tambul during November 2007 but had to be replanted due to severe nematode infestation. The replanted trial also did not establish well, most likely due to wet conditions and some nematodes and this study is being repeated at a new site.
				A trial was established at Taluma during June 2007 and slashed after 26 harvests have been completed. Regrowth after harvest is good and harvesting after slashing has continued successfully up to January 2010.
				The results to date indicate that the current planting density appears to be adequate for the first year of production. Data on the effect of plant density on yield for the second year (after slashing) indicate similar effects of density.
				A trial was established at Tambul during November 2007 but had to be replanted due to severe nematode infestation. The replanted trial also did not establish well, most likely due to wet conditions and some nematodes and this study is being repeated at a new site.

Objective 2: To assist in the adoption of improved production practices by the PNG pyrethrum industry.

no.	activity	outputs/ milestones	completion date	comments
2.1	Provide sufficient extension staff to extend skills to growers for the production and harvest of pyrethrum	Employ one full time or 2 part time extension officers, with the role as PIDO	December 2010	Wakasa Mecksaene has continued as the key manager for the industry development activities. He has a core team of extension officers with Janet Yando, Manday Yaso and Timothy Jairus. Extension activities were severely hampered when their only vehicle was stolen by robbers in February 2009 and was not available again until November 2009. Very serious tribal fighting took place near Taluma during late January 2010 and this important production area has been tense and unsafe since that time. The focus of the extension activities is now on increasing production as well as improvements in product quality Greater focus is being placed on seeking production from larger semi-commercial farms, larger co-operatives and production on government land, The estimated number of smallholders growing pyrethrum has increased from 800 in 2006 to 7,500-10,000 by the end of 2010.
2.2	Increase the amount of pyrethrum grown by growers by the distribution of good quality seed to growers	100,000 splits/seedlings to be distributed to growers by June 2007 and seed/seedlings to be made available throughout this project.	December 2010	BRA recognised that the industry in PNG has an immediate need for good quality seed and the parties in PNG are just working towards becoming self-sufficient in quality seed production. With this knowledge, BRA decided to establish a seed production site in Tasmania using a small sample of PNG seed as the planting material. This work commenced in late 2007 and the first harvest of 12 kg of seed was provided to PNG 2009. In subsequent years, 25 kg of seed was provided in 2010 and 32 kg is available during 2011, BRA expects to continue with this seed production in Tasmania beyond 2011 until such time as the PNG industry can produce sufficient quality seed locally. Flower production by the growers has increased substantially since the start of this project and has increased from 32 tons in 2007 to 53 tons in 2008, 52 tons in 2009 and to 61 tons in 2010. EPC is aiming to have 100 tons of flowers produced by 2011.

Objective 3: To assess the plant physiological factors contributing to pyrethrum yield in Tasmania and PNG

no.	activity	outputs/ milestones	completion date	comments
3.1	To identify the key physiological components affecting pyrethrum flower yield.	Define relationship between various plant characteristics and yield	December 2010	Variability in yield between and within fields and between seasons has been observed in pyrethrum production in Tasmania. Results showed that variability in pyrethrins yield could not be explained by differences in radiation intercepted by the canopy during the growing season, but there was a relatively good relationship between stem density and final yield. Multivariate analysis have been conducted on two BRA datasets to quantify the effect of agronomic variables on field establishment and pyrethrins yield components in Tasmanian crops grown in 2009 and 2010. The results from these multivariate analyses are being used to identify new areas of R&D by the pyrethrum industry in Tasmania. Seed priming is one new area that may be worthy of research, especially in years where wet weather and wet seed beds are likely to cause uneven and prolonged emergence. The need for on-going research in disease and weed management is also strongly confirmed by this analysis.
3.2	To assess the effects of environmental and management factors that has an impact on the physiological factors affecting yield	Measure the effects of environmental factors on key physiological components in Tasmania and PNG	December 2010	A new pot study has confirmed the effects of water stress on the photosynthetic process, biomass accumulation and dry matter partitioning in pyrethrum plants. The importance of plant density on yield has also been confirmed, especially under the crop production system in Tasmania. These studies were a part of the masters study program undertaken by Kud Sitango during his period as a John Allwright Fellow.

Objective 4: To maximise the efficiency of extraction in PNG and to improve the compatibility of the PNG extract with the BRA refining process.

no.	activity	outputs/ milestones	completion date	comments
4.1	Maximise the efficiency of the PNG extraction plant.	Identified the key operations of the PNG extraction plant BRA purchased, and commissioned the NIR unit at Kagamuga Identified the recovery of critical steps and make improvements as needed	March 2007 June 2008 December 2009	The NIR has been a real successful tool for the factory Samples of flowers delivered to the factory has been measured for the pyrethrins content and these factory NIR readings are well correlated with the assay results as measured by the BRA laboratory. Hence, the NIR measures of the flower assay can now be accepted with confidence by the local industry. Similarly, the assay of the oleoresin produced by the factory can now be confidently measured by the factory operators with the NIR and hence, the efficiency of the extraction factory can be continuous monitored by the factory operators to ensure that any serious malfunctions of the factory can be identified on site. This is a significant step forward for the factory/PNG industry and has occurred because of the support from this ACIAR project. The oleoresin product produced by the Kagamuga, PNG factory still has significant quality problems, especially the high wax content as well as a low flashpoint from too much hexane left in the end product. BRA consulted the UK based engineer who built and commissioned this extraction plant and improvements have been achieved. The pyrethrins content in the oleoresin has increased from some 28% to 32 % and the hexane levels in the oleoresin has been reduced.
4.2	To evaluate improved mechanisms for refining the PNG oleoresin at the BRA CO2 refinery	Identified improved means of refining the more waxy oleoresin from PNG	December 2008	Good progress has been made and a practical procedure has been developed by BRA to effectively refine the PNG oleoresin product. This part of the project is now completed. The balance of the funds allocated to this part of the project has been directed to the production of pyrethrum seed in Tasmania for use in PNG

7 Key results and discussion

7.1 Develop improved pyrethrum planting material for local growers

Twelve out of 74 clones collected from grower gardens and planted at Taluma was identified to be high in total pyrethrins content ,ranges from 1.5 to 1.8% (Table 1.1). At Tambul 13 out of these 74 +10 clones had pyrethrins content ranged from 1.5 to 1.8% (Table 1.2).

The clones high in pyrethrins content across two sites were 126 (1.6%), 163 (1.6%), 164 (1.7%) and 166 (1.7 & 1.5%). The site specific clones selected for Taluma in Enga Province were 138 (1.8%), 164 (1.7%) and 1.6% for clones, 163, 105, 107and 159 while for Tambul in Western Highlands Province were 117 (1.8%) followed by 108(1.7%) and 1.6% for clones 110, 137, 156, 164, 166 and 181.

These results were obtained from un-replicated plots and there is a need to evaluate these clones in a replicated trial and to assess the other visual agronomic characteristics such as flower density, plant vigour and the level of disease. Planting material of the clones high in pyrethrins content were given to Enga Pyrethrum Company to further multiply and distribute to farmers as an interim step whilst the selection and improvement process continue.

Table 1.1. Pyrethrum clones with assay ≥1.5% at Taluma

No.	Clone	% Total pyrethrins
1	138	1.8
2	164	1.7
3	163	1.6
4	105	1.6
5	107	1.6
6	159	1.6
7	101	1.5
8	103	1.5
9	106	1.5
10	126	1.5
11	129	1.5
12	166	1.5

Table 1.2 Pyrethrum clones with assay ≥1.5% at Tambul

No.	Clone	% Total pyrethrins
1	117	1.8
2	108	1.7
3	110	1.7
4	137	1.7
5	156	1.7
6	164	1.7
7	166	1.7
8	181	1.7
9	126	1.6
10	152	1.6

11	163	1.6
12	176	1.6
13	182	1.6

Table 1.3 The clones high in pyrethrins content across two sites Taluma and Tambul.

No.	Clone	% Total pyrethrins
1	137	1.7
2	164	1.7
3	163	1.6
4	126	1.6

Clones with different physical growth characteristics

NARI assisted with the re-commercialisation of the pyrethrum industry by releasing the best available planting material to the industry as shown in Table 1.4 below and participating in various Outreach and grower/community liaison activities.

Table 1.4. The distribution of planting materials to EPC and growers

Clone selection	Stakeholders	Type of planting material	Number of planting materials	Place/Province distributed
First 18 clones	Enga Pyrethrum company	Splits	First nursery Taluma Second nursery Sirinki	Materials distributed throughout pyrethrum growing areas in Enga
	Betty Igins, Farmer in	Seeds and splits	Seeds of clones and made nursery for distribution	Gembogl in Chimbu Province
	40 farmers around Tambul	20 to 30 splits per farmers		
	7 farmers around Tomba Area	40 to 50 splits per farmer		Tambul/Nibliyer District, WHP
Second 13 clones	47 farmers around Tambul area	80 Splits to 47 farmers in Tambul area	Splits from multiplication and germplasm collection plot at Tambul	Tambul and Tomba area, WHP
	Seeds given to two farmers in Tambul area	600 grams of seeds given to farmers	Seeds from germplasm and multiplication plot	Tambul area, WHP
	Enga Pyrethrum Company (EPC)	3600 grams of seeds given to EPC	Seeds for nursery establishment at Sirinki	Materials for distribution to pyrethrum growing areas in Enga province
	Total of 4200 grams of seeds distributed	2 farmers and EPC extension team	Distributed for nursery establishment	WHP and Enga

7.2 Search and collection of past literatures and extension information on reports and results from the DASF annual reports

A total of 24 research reports, extension information and reference materials were collected during the information search in libraries across PNG (Table 2.1). A total of 29% of the items were on liaison and extension component of the crop or industry, 12% relates to botany and agronomy while 2% of the information were on other aspect of the crop(Table 2.2)

Table 2.1The list of research reports, references,extension articles and reports on pyrethrum collected in libraries across PNG.

No	Title of literature	Type	Author & Date of publication	Remarks
1	Chemical assay of pyrethrum grown in Enga gardens and in clonal trials at Sirinki	Technical Report 87/10	Day, S.R & McLaren, A.(1987)	Dep't of Agriculture and Livestock
2	Pyrethrum in the highlands of New Guinea	Technical Report	Schindler, A.J. (1959)	Physical attributes and management of the crop
3	Notes on pyrethrum	Information	Nagle, W.G (1969)	Introduction, History, and Crop Botany, Properties Pyrethrum,
4	Growing pyrethrum in the highlands	Information Pamphlet	Mengge Nang, A (1969)	Introduction and Crop Botany, Cultivation Method
5	Farming notes on pyrethrum	DPIPublicationPort Moresby	Dep't of Information & Extension Services (1969)	Farming notes
6	Increasing pyrethrum production in Enga	Individual Clone	Anon (1995)	Internal report for Enga provincial government
7	Kagamuga pyrethrum factory refurbishment project	Report	Dalgety, A. T (2001)	Progress report No. 4
8	Agriculture in the economy; A series of review papers on pyrethrum	Review papers	Anderson, D (1975)	Pyrethrum production in the highlands, Location and structure of the industry, processing, marketing and future of the industry
9	Pyrethrum and the highlander	Extension Bulleting No. 3	Scoullar, B (1973)	Fact finding mission in relation to adoption of pyrethrum
10	Plant pathology notes: no. 5: Root knot nematode	Report	Clarkson, D	
11	Agricultural land use potential and soils in the selected portions of EngaProvince	Report	Dr Geoffrey Scott, A.J (1979)	Prepared for Enga Rural Development Study
12	Grow good pyrethrum: Book 1	Information Pamphlet	Dep't of Information & Extension Services (1969)	Preparing the Land (Written in both English and Pidgin)
13	Grow good pyrethrum: Book 2	Information Pamphlet	Dep't of Information & Extension Services (1969)	Planting of Splits (Written in both English and Pidgin)
14	Grow good pyrethrum: Book 3	Information Pamphlet	Dep't of Information & Extension Services (1969)	Harvesting (Written in both English and Pidgin)
15	Grow good pyrethrum: Book 4	Information Pamphlet	Dep't of Information & Extension Services (1969)	Garden Care (Written in both English and Pidgin)
16	Pyrethrum analysis report, pyrethrum flowers from Western Highlands	Analysis Report	Michael, D (2005)	A NARI cadet scientist produced the report.
17	Pyrethrum next best thing to gold	News paper article	Tomorop, J (2003)	Pyrethrum Co-ordinator and Factory Manager
18	Lagaip pyrethrum factory assessment report	Report	Sitango, K (2003)	Request from Lagaip LLG and farmers

19	Pyrethrum industry development	Report	Mandeakali, L. & Kendiga, J. (2005)	Brief Report on the Field Trip Findings and Developments
20	Pyrethrum industry in Papua New Guinea	Overview	Dep't of National Planning & Monitoring (2006)	Nucleus Agro Enterprise Project
21	Pyrethrum	Farming Note	Dep't of Primary Industry (1976)	One of the series of Farming Notes
22	Plant nematodes of PNG: their importance as crop pests	Survey Report	Dr Bridge, J. & Page, S. L. J (1982)	Report of a plant nematode survey in PNG
23	Pyrethrum factory opening	Newspaper article	Gumuno, J.A (reporter, 2003)	Address by Agriculture Minister; Moses Maladina
24	The use of pyrethrum marc in grower pig nutrition	Honours Degree Thesis paper	Benedict H M Mindiria (1981)	Admittance to the University of Papua New Guinea

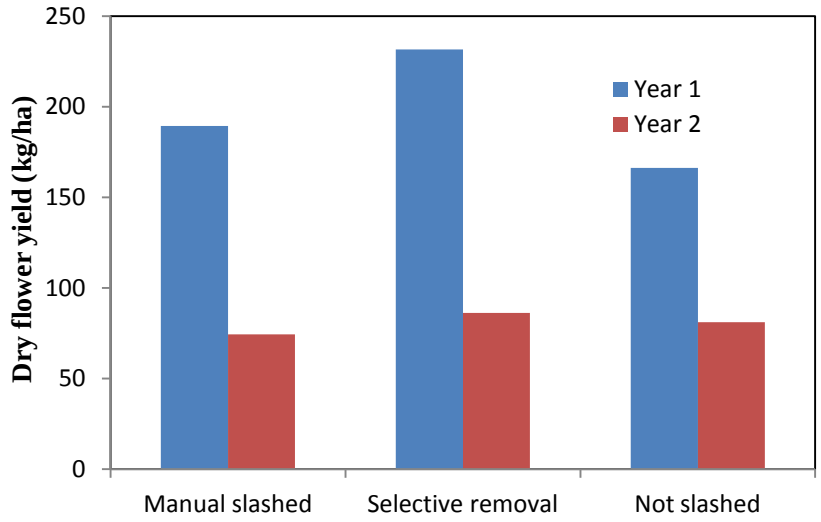
Table 2.2Category of information collected on pyrethrum in libraries across PNG

No	Category of Information	Type of Information	Total
1	Literature on chemical assay	Pyrethrins assay and technical report	2
2	Literature on agronomy and botany of pyrethrum	Technical report and Information bulletin	3
3	Liaison and Extension materials	Farming note, Information leaflet	7
4	Pyrethrum production	Production report	3
5	Economics of pyrethrum production	Review paper	2
6	Pyrethrum pest and disease management	Assessment and survey report	2
7	Plant nutrition	Assessment report	2
8	Pyrethrum factory processing plant	Refurbishment report	3

7.3 Slashing studies

Total flower yields for the three treatments for the two years are shown in Fig 1 below. The yield differences in year 1 indicated plot variability as no treatments were applied until after one year of harvest. As the flower yield of all treatments appears similar in Year 2, it appears that there were no benefits from the slashing or the selective stem removal treatments.

Figure 1.The effect of different flowering stem and crop biomass slashing techniques on annual total flower yield crop in first and second year crop



7.4 Density studies

The effects of plant density on flower yields for two years are shown in Fig 2 below. There appears to be plot variations for the 8 plants/m2 treatment and so the data from this treatment should be treated with some caution. The data appear to show that the best yield can be obtained between 4-16 plants/m2. Flower yield at 2 plants/m2 was lower and there was likely to be yield reductions from density higher than 16 plants/m2. As growers in PNG commonly grow at about 4 plants/m2, it appears that the current commercial plant density is within the acceptable range and there is no need for growers to grow at higher plant densities. Similar effect of plant density on flower yield was observed in the second year.

Plant density had a major effect on the flower yield per plant as shown in Fig 3 with higher densities significantly reducing the flower yield per plant.

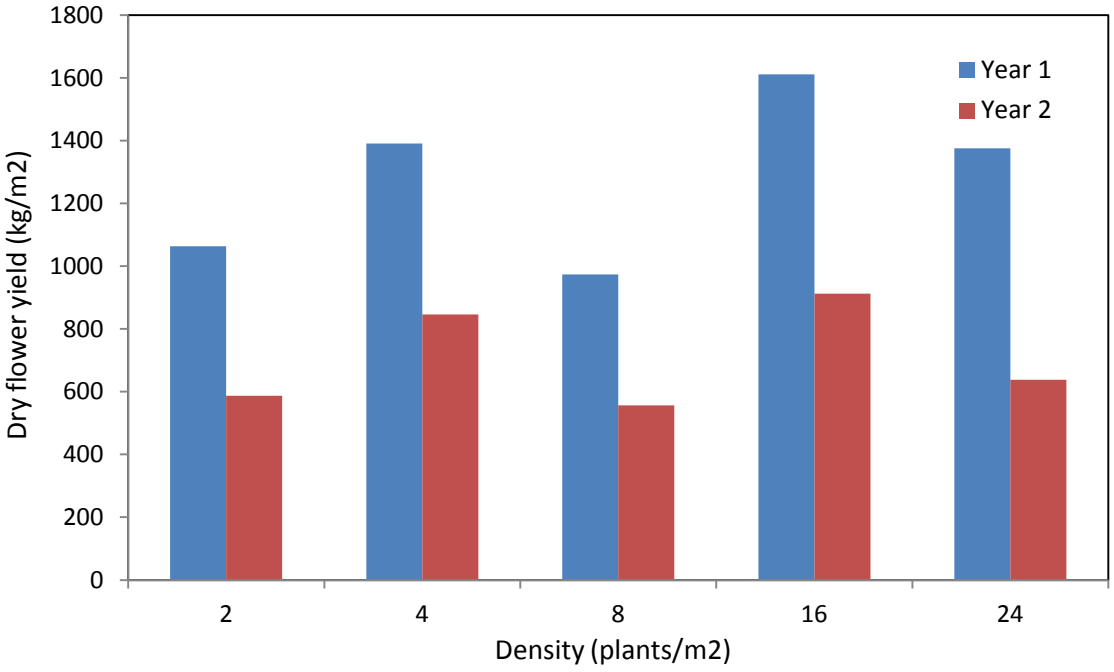


Figure 2 The effects of plant density on flower yield for two years.

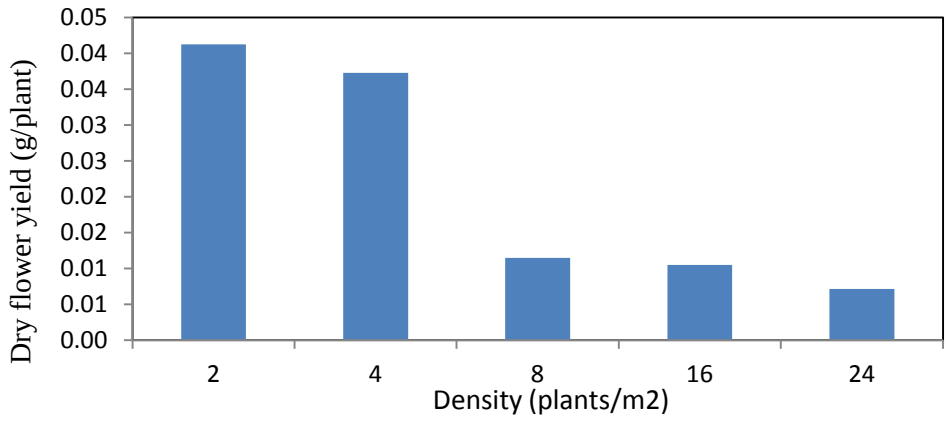


Figure 3 The effect of plant density on flower yield per plant

7.5 Extension and outreach activities

Extension services were viewed as the most important means to disseminate information, technical advice and actually demonstrating how to grow the crop because most of the growers lack literacy and numerical skills. Personal intervention in terms of providing extension to the local pyrethrum growers worth mentioning are:

Daily/Weekly Field Visits

Field visits were daily activities done almost every day or weekly to growing sites to distribute planting materials, supervise planting, nursery preparation and establishment and general awareness campaigns. This was an important approach where most smallholder growers were contacted and assisted and as well identifying problem or needs that could affect cropping activities.

LLG Ward Based Pyrethrum Growers Census

All hamlets in the province are put into distinct groups called local level government wards. These wards are then put together to form the local levels of government in each district. The total number of wards in a district varies, ranging from forty to ninety wards. Enga Pyrethrum extension program has initiated deliver of extension services down to ward and households levels. Priority is to visit every household and record necessary detail concerning their pyrethrum growing activities at the household level. This was an efficient method of extension services deliverance because every household at the ward levels were given a chance of being visited and supplied pyrethrum planting materials.

Table 01 Geographical Baseline Data – Enga Province

District	*Statistical LLG*	*# of Wards*	*# of Households*
Laiagam/Pogera	4	90	15847
Kandep	2	53	8549
Wabag	3	46	10406
Kompiam Ambum	3	77	8569
Wapenamnda	2	50	9741
Total	***14***	***316***	***53112***

Source: 2000 National Census

Pyrethrum Farmer's Cooperative Societies (PFCS)

It was an initiative of the Enga Pyrethrum Project to mobilize pyrethrum growers to form cooperate societies. The main purpose behind this initiative was to mobilize land, labour and other important resources in the community where such important resources are scarce and distributed amongst individuals. There are five registered cooperatives currently under pyrethrum production. These cooperatives have become central contact points for the project extension team. They are involved in planting, distribution of planting material, purchase of dry flowers and supply to Enga Pyrethrum Company. These cooperatives are from the Lagaip Pogera district only where 90 percent of pyrethrum is collected.

Names of recognized pyrethrum cooperative societies in the province

1. Pealin Cooperative society
2. Kinapulam Cooperative society
3. Sirinki Cooperative society
4. Mape Cooperative society

5. Pilikambi Cooperative society

Each of these cooperatives has more than 200 members and own more than 2-3 hectares of land under pyrethrum production. They also buy pyrethrum flowers from the smallholders to supplement their production and supply at an average of 500 kilograms on a monthly basis. We plan to increase this level of production.

Village Based Service Providers (VBSP)

This was an innovative approach initiated by the extension program basically to train and engage potential service providers who are growers themselves and are able to coordinate extension at the village level. The focus in this approach was to mobilize more smallholders and provide timely visit. To locations where extension officers cannot reach due to limited access, the service providers would represent as agents of change. The project had started with the chairpersons of the five cooperatives as a trial and has proven to be a worthwhile approach.

Trainings and Field Days

Farmers are gathered together during trainings and field days. These were very important events where people came together and openly learn new things. The project conducted several trainingevents associated with field demonstrations on proper planting, management, right picking time, proper drying and storage and disseminate other related information.

Major Pyrethrum Extension Activities in Province

Initial extension programs of the pyrethrum industry revitalization program in Enga started in 2007 where all operations were based at Taluma Higher Altitude Resources Centre (HARC), a property owned by the Enga Provincial Government. Taluma became the centre for all activities, both extension and research. Public awareness campaigns, planting materials multiplication and distributions were the initial activities executed by the project team. Laiagam/Pogera and Kandep districts became priority areas because more than 90 percent of the dried pyrethrum flower is received from locations in these districts, and then spread out to other parts of the province.

Seedling Nurseries

Seedlings were the recommended planting materials to the growers after field observations have proven that seedlings would perform better in terms of high establishment rate, quick growth and has high numbers flower heads counts per plants. Seedlings also helped minimize the spread of fungal diseases with the distribution of older plant clumps. Establishment of nurseries was done at all government base camps, ward levels and as well as at government institutions such as schools where free labour is available. Average nursery size for most locations was 20mx5m and amount of seeds applied was an average of 400 – 1000 grams per sites.

Some achievements made so far,

- 22 nurseries established at the base camps (Taluma, Kandan and Pumas) and more than 100, 000 seedlings were distributed to 2,200 growers.
- 10 nurseries were done at schools and involved more than 1,000 students to actively involved in nursery procedures and assist their parent transplant in their farms/gardens. The schools involved were Sirinki High School, Taluma Primary School, Tambus Primary, Yokonda Primary and Meriamanda Primary in the Kompiam district
- 105 nurseries were done at ward levels and distributed to 4,000 growers.
- Others received older clumps for splitting.

Planting Material Improvement through Clonal selection

This activity was carried out in collaboration with NARI at the base camps. Various plants in the field were randomly selected and laboratory tests done on the percentage pyrethrins content. The plants with highest pyrethrins contents were selected and maintained in nurseries for natural crossbreeding by insects and wind.

Some achievements to date;

- 22 clones selected and recommended by the NARI were multiplied in a 20m x 10m block in Taluma. When EPC moved to Sirinki, these clones were transferred as well and have been maintained for seed collection and further plant multiplication and distribution.
- 1200 grams seeds collected were used to establish new nurseries and these seedlings have been distributed.
- 600 grams seeds are in store for sowing new nurseries later in the year.

Training of Female Rural Development Technicians

One important program that Enga Pyrethrum Company promotes is Rural Development Female Training (RDFT). Young females who had dropped out by the formal education system were selected for this training. They were trained in all aspects of growing and managing pyrethrum and as well as other important trainings required under this program. The purpose of this training was to train young females so that they could pass the traits when they become mothers. This program started with the project in 2007 where two young females were trained at Taluma base camp. When Enga Pyrethrum transferred its operations to Kandan base camp in Sirinki, another two females were engaged with the project under this program.

Estate Development for Commercial Production

Enga Pyrethrum Company has purchased a tractor in 2008 but was not used due to insufficient funds to purchase implements, particularly disc ploughs and harrows. During 2010, when funds were finally available to purchase the implements, the tractor was used to plough and develop the base camp in Sirinki between May and July 2010. The tractor will then continued on to developing pyrethrum cooperative lands, thus started with Pealin Cooperative at Yokonda in the Laiagam district. Currently, the tractor is under excessive use.

Some areas developed by the tractor;

1. Kandan Base Camp (4.0 ha)
2. Pealin Cooperative (1.2 ha)
3. Kinapulam Cooperative (0.7 ha)
4. Maliso Paul (pyrethrum private buyer – 0.6ha)
5. Porea – Menda Yaso (0.05 ha)
6. Kaipsanda (0.4 ha)

Basic Assumptions

1 ha = 50,000 plants = 1000 kg/year
$1m^2$ = 100grams dry flower/ year
Economic life span = 3 yrs

The total area developed and currently under pyrethrum production is approximately 6.95 hectares. It is expected that the first harvests will be made between August and September 2011. Thus, the total pyrethrum production outcome expected from all these areas is 7000 to 8500 kilograms by the end of year 2012.

Other locations identified and ready for development

1. Pumas – both state and customary land (30ha)
2. Kaipale – Tom Kom (8 ha)
3. Sirinki Cooperative(10 ha)
4. Meapu – Patrick Ailya (2ha)
5. Mapu – SakatiasU. (.05 ha)
6. Kaipsanda (6 ha)
7. Tambus (3 ha)
8. Others

7.6 Extension coverage by districts

Laiagam Sirinki/Pogera District

This district is the leading pyrethrum producer in the province. Almost 99 percent of the total pyrethrum production from Enga comes from areas in this district. Laiagam is located west of Wabag town, above 2200 to 2600masl and is the largest district with population well over 99, 000 people (2000 National Census). Households living as far as Mulitaka and all the way towards Pogera do not grow pyrethrum because of geographical restrictions, mountains, very thick cloud cover all through the day and unfertile land. Pyrethrum growing areas are only in the Lagaip Rural Level Government including Sirinki where more than 8,233 households live and benefit from pyrethrum production.

Table 1. Summary of pyrethrum growers in the Laiagam Sirinki/Pogera District from 2007 - 2010

Year	Total Households	Total Persons	Total Py Growers(in households)	Total p/materials distributed	Total area into prod^{n} (ha)	Households yet to cover
2007	8 233	41 195	1 580	183 280	15.60	2700
2008			2 233	259 028	19.18	
2009			1 200	139 200	13.78	
2010			500	58 000	22.16	
Total	**8 233**	**41 195**	**5, 513**	**641,250**	**70.72**	**2700**

Data Source: 2000 National Census and Extension Raw Data Sheet.

There are 41 wards that are actually pyrethrum production sites out of the total of 49 wards in the Local Level Government (LLG). About 2000 households are restricted to pyrethrum growing due to unfavourable environmental conditions and geographical location. In some locations, there are swamps where soil is water logged and in others is mountains and hills which are not conducive for pyrethrum. Enga Pyrethrum Company extension target now is on the 700 households which are identified as yet to be covered.

Kandep District

Kandep is located south of the province and is approximately 45 to 50 kilometres away from Laiagam District. This district is the second leading pyrethrum producer in the province. Altitudes vary from 2000 m to 3500 m on the mountain. People live between 2000m to 2500m. According to the 2000 National Census, total population in the Kandep district is 6,000.

Initial extension, awareness campaigns and planting material distribution in this district started in 2007. People were very keen and many started to plant pyrethrum. Currently, the total number of pyrethrum growers in households from this district is 960. Continuous extension services were delivered, planting pyrethrum; managing and other aspects were closely supervised by the technical team. Unfortunately, early 2008, due to problems relating the stolen of the extension vehicle, there was threat in visiting Kandep District again.

Table 2; Summary of pyrethrum growers in the Kandep District from 2007 - 2010

Year	Total Households	Total Persons	Total Py Growers	Total plant materials distributed	Total area into prod^{n} (ha)	Households yet to cover
2007	4 131	22 066	712	152,000	5.04	3,171
2008			250	12,200	2.24	
2009			Nil	Nil	Nil	
2010			Nil	Nil	Nil	
Total	**4 131**	**22 066**	**960**	**164,200**	**7.28**	**3,171**

Data Source: 2000 National Census and Extension Raw Data Sheet.

There are total of 53 council wards in the Kandep district. Out of this, only 22 wards are potential pyrethrum growing areas. 960 households in five wards were touched or covered in the 2007 and 2008 extension activities. About 1,250 households in the pyrethrum growing areas are yet to be covered. About1920 households are located in geographical restricted locations where smallholders cannot grow pyrethrum.

An alternative approach to extension recovery in this district is to engage some contact farmers through establishing pyrethrum cooperative societies. These contact farmers would be trained and given responsibilities similar to an extension officer's duties. They can also be given the priority to purchase pyrethrum dry flowers from small holder growers in the areas and deliver to Enga Pyrethrum Company.

Wabag District

Wabag district covers parts of the upper Maramuni valley, Sirinki plateau and upper Lai Valley. Altitude varies from 1400m to 3000m along the central range where most people live between 2000m and 2600m.Pyrethrum is grown by smallholders from 18 different council wards in the Sirinki plateau and upper Lai Valley. The average total number of pyrethrum growers in this district to date is 480households in only seventeen sites/ wards. Some locations, about 4 council wards around the Wabag Township located on mountains and hills were newly covered in late 2008 and distributed planting materials. Growth performance and productivity were closely monitored. Generally, pyrethrum growth was 75 percent and productively in terms of flowers head counts was relatively poor.

Table3; Summary of pyrethrum growers in the Wabag District from 2007 – 2010

Year	Total Households	Total Persons	Total Py Growers	Total p/materials distributed	Total area into prod^{n} (ha)	Households yet to cover
2007	8 384	47,692	85	2500	1.05	2549
2008			154	32,200	8.62	
2009			105	16000	2.05	
2010			136	12000	1.24	
Total	**8 384**	**47 692**	**480**	**43 430**	**12.41**	**2 549**

Data Source: 2000 National Census and Extension Raw Data Sheet.

There are three statistical LLGs in the district and in two LLGs, the Wabag urban and Maramuni rural LLGs where 2,022 households live; pyrethrum is not grown due to warm climatic conditions and other unfavourable conditions. Pyrethrum is grown only in seventeen different wards by 480 households or smallholder growers out of 3,029 total households living in these LLG wards. About 2,000 households live under unfavourable environmental conditions where pyrethrum would not perform well. The remaining 549 households are the target group in the next twelve to twenty months.

Ambum Kompiam District

Ambum-Kompiam district is located northeast of the province, above 400m to 3000m and holds a total population of more than 44,332 people (*2000 National Census).*Not all parts of this district has the potential in growing pyrethrum because the climate is warm and mountainous where other cash crops like coffee can grow well. Pyrethrum can only perform well in few locations in the district. About 24 wards out of the total 77 LLG wards in the district have the potential to grow pyrethrum. These areas were newly covered in extension, awareness campaigns, planting material distribution and seedlings nurseries in 2009. The total number of pyrethrum growers found in the Ambum Kompiam district to current is 224.

In most of these areas that received planting materials, pyrethrum was not able to do well in terms of establishment, growth and flowers per plant. Pyrethrum was promising only in five sites or wards.

Table 4; Summary of pyrethrum growers in the Ambum Kompiam District from 2007 - 2010

Year	Total Households	Total Persons	Total Py Growers	Total plant materials distributed	Total area into prod[n]	Households yet to cover	Remarks
2007	This district was not reached in extension in 2007 and 2008. Initial extension with general awareness campaigns and planting material distribution started in 2009.						
2008							
2009	3001	15,023	98	1680	2.32	2777	
2010			126	6200	3.24		
Total	**3 001**	**15, 023**	**224**	**7 880**	**5.56**	**2777**	

Data Source: 2000 National Census and Extension Raw Data Sheet.

Generally, closer monitoring and observations results have shown that pyrethrum is not an ideal crop for majority of the areas in the district, even if there were other seventeen to twenty potential pyrethrum growing sites were recommended for growing pyrethrum. Soil type is quite water logged and there are a lot of mountain ranges following the massive Ambum River.

Tsak Wapenamanda District

Wapenamanda district is located north east of the province, above 1,000m and 3,800m and covers the Tsak and Lai valleys. The main cash crop for the people in this district is coffee and others like banana and taro. Pyrethrum is an alternative cash crop for some parts of Tsak valley in the Wapenamanda district, particularly; Pumakos, Yapomanda, Alumanda and Angimanda. These places are located at the borders between Kandep District of Enga Province and Southern Highlands Province.

Yapomanda has become a centre for distribution where a nursery size of 2,500m^2 was established and more than 6,000 seedlings were distributed to 86 smallholders from the area. Alumanda is another location in the Tsak that received more than 10,000 seedlings from Taluma High Altitude Resources Centre. After two months later, this place was visited and results have shown that pyrethrum was not promising because there were no satisfactory outcomes gained in terms of volumes of flowers over the last two years. Therefore, no more follow up visits and planting materials were distributed.

Table 5; Summary of pyrethrum growers in the Tsak Wapenamnda District from 2008 – 2010

Year	Total Households	Total Persons	Total Py Growers	Total plant materials distributed	Total area into production (ha)	Households yet to cover
2008	1040	5167	86	6500	0.13	814
2009			158	15 000	1.03	
2010			Nil	Nil	Nil	
Total	**1040**	**5167**	**226**	**21, 500**	**1.43**	**814**

Awareness campaigns at Pumakos -2008

Nursery at Pumakos Village in 2008

7.7 Current production status in Enga Provence

Total Pyrethrum Growers Population in Enga; 2007-2010

The entire pyrethrum production in the province is done by smallholders. The total number of grower currently growing pyrethrum is 7,423. These are registered growers actually contacted during visits and seedling distributions as well as during sale of pyrethrum flowers. There could be other growers in locations limited to access due to geographical constraints. Hence, the anticipated total number of pyrethrum growers is between 8,000-10,000 growers.

Table 6. Summary of the number of pyrethrum growers in EngaProvince: 2007-2010

Year	Total Growers	Total Planting Materials Distributed (clumps/seedlings)	Total area under production (ha)	Smallholders yet to cover
2007	2,377	337,780	21.69	3,673
2008	2,723	309,928	30.17	
2009	1,561	171,880	19.18	
2010	762	76,200	26.64	
Total	**7,423**	**895,788**	**97.68**	**3,673**

Brief Notes;

- Total number of planting materials in the form of clumps and seedlings distributed to smallholder growers is 895 788.
- Total area currently under pyrethrum production is 97. 68 ha.
- Smallholder grower population in target area yet to be covered is approximately 3,673.
- Most households were covered between 2007 and 2008. In 2009, majority was also covered.
- In 2010, not many distribution of planting materials were done because of a prolonged dry season (February to October 2010).

Current Pyrethrum Production Trend (2005-2010)

The annual production from 2005 to 2010 ranges between 29 tons to 61 tons respectively. The 2005 and 2006 productions are included to show the trend over these years, indicating the slow pick up of the industry.

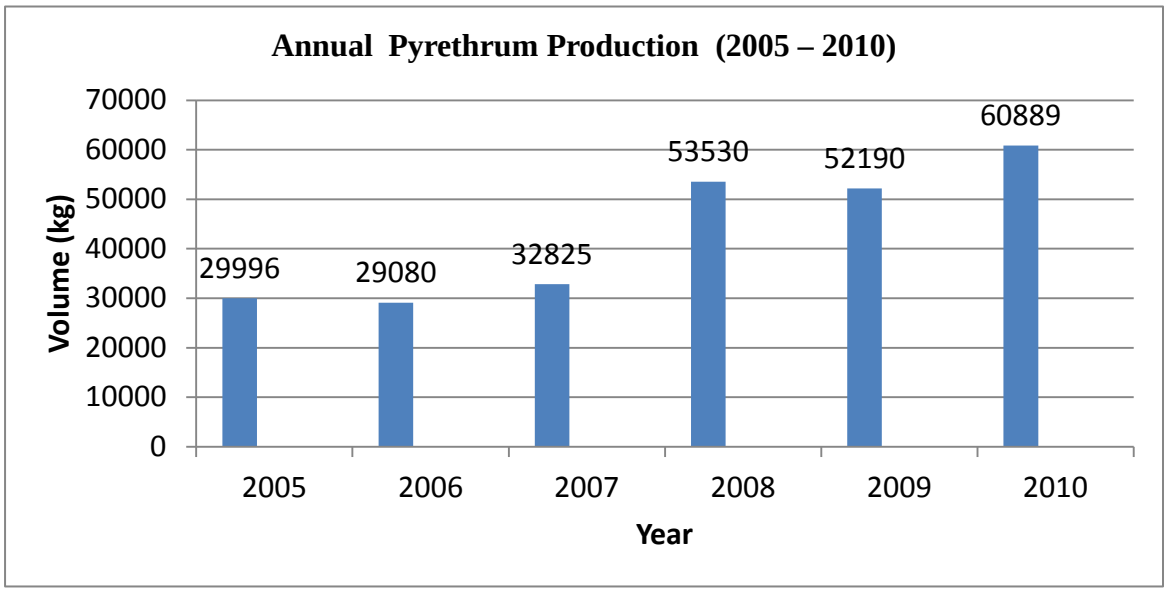


Figure 1. Annual pyrethrum productiondata from 2005-2010.

- The target set by EPC for 2010 was 100 000 kilograms of pyrterhum at the end of the year. However, only 60.89 percent of the target was reached.
- Standard price paid to the growers is at K2.50 per kg. However, an K0.20 per kg incentive is paid to farmers who bring 200 kg or more at their own transport cost.
- The total money that went into the pockets of the rural people through the sales of pyrethrum flowers over the four years period (2007 – 2010) is K5000,000.

Some Problems that affect pyrethrum production in Enga- PNG

Unpredicted Weather Patterns

All regions throughout PNG experience wet seasons between October 2009 and February 2010 and dry seasons with some rains in between March and September every year. Farmers are encouraged to do every planting during the wet seasons and probably harvest during the dry seasons. However, with the recent changes in the weather patterns due to global climate change, PNG is experiencing adverse weather effects which affects majority of farmer's farming programs. In the year 2010, Enga as well as other provinces in the highlands region of PNG experienced a long dry season from February to October 2010. As a result, most smallholders' pyrethrum production and supply was reduced.

Geographical Land Forms and Land Pressure

Enga Province is located in the higher altitude regions of PNG, meaning that most of its land form is mountainous and climate is colder, prone to frost. Enga covers 118,000 square kilometres of the total highlands land in Papua New Guinea peaks. However, 50 percent of the total land is mountain and another 20 percent is swamp, meaning that 70 percent of the total land mass is unproductive land. Therefore, people find place to live only in the valleys and plains where they could farm and earn their livings. Population densities are very high, 24 -360 persons per square kilometre. This means that there is pleasure in land owned by individual households because a majority of the total population in the province is self employed through agricultural farming activities. As a result, it is impossible for individual households to expand production because there is limitation to land boundaries.

Traditional Method of Cultivation

Enga Pyrethrum Company has been relying on smallholder pyrethrum growers who plant pyrethrum as a side crop on kaukau mounds, which in fact is delaying the quick recover and commercialization of the industry. Because of rapid increase in population sizes per square kilometre of land, there is pressure on land usage. Every household prioritise sweet potato *(Ipomea batatas)*, the staple food to feed the increasing heads in their households and therefore, often the only land available for planting pyrethrum is as a side or mixed crop on sweet potato mounds. As a result, a household or individual can only supply pyrethrum at an average of 16 to 20 kg of every 3 to 4 weeks *(according to records from the weekly collection at Wabag).*

Migration - People moving out in search of better living and employment

There are a number of people moving out from the remote rural settings every year to town, cities and mining areas looking for better access to services, more productive environment and wage employment. Youths and middle aged persons in the 20s and early 40s seem to migrate into towns and cities looking for better living and employment opportunities. Therefore, pyrethrum continues to be a crop for old women and men and children in the villages/ communities.

Difficulty in transport to market.

Most pyrethrum growing locations in Enga is in the remote settings of the province where access to transport services is limited and constraint. Inadequate transport and poor access to roads has been major hindrance in marketing of pyrethrum for the rural people especially

farmers in the upper Lagaip headwaters, Yapai Kindarep, kandep and Londol in the Ambum Kompiam district. There are feeder roads that link these places from the main Wabag town but these are not adequate for easy access for transport vehicles. In walking it takes them more than 4-6 hours to reach Wabag town. Most farmers walk long hours to reach the main highway to catch PMVs to travel to Wabag to sell their bags of pyrethrum flowers.
Worse of all, farmers are charged extra for the bags of pyrethrum. Each bag is charged K4.00 on top of the normal charge which varies depending on the distance of travel, K7.00 from Laiagam, Kandep K20.00 and Kompiam Ambum is K10.00.

7.8 Management strategies to increase production

Resources mobilization through Pyrethrum Co-operative Societies

The two most important attributes for successful pyrethrum production in the province are land and labour. Since the majority of the land is customarily owned by the local people, Enga Pyrethrum Company has taken the initiative to form pyrethrum co-operative societies as a way forward to boost the pyrethrum industry. A total of five registered co-operative groups have been formed in 2008 in different pyrethrum growing sites purposely to mobilize growers support through utilizing of free land, labour and other household resources. With the availability of the EPC tractor, priority is given to the co-operatives groups to plough unused lands for pyrethrum development. Three of the cooperatives have already benefited with the tractor developing more than 7,000 m^2 to 10,000$m^2$of lands each.

Promote large scale growers by way of incentives.

It is an initiative of the Enga Pyrethrum Company to assist semi commercial pyrethrum growers with incentives in the form of items like fertiliser, spades and grass killer as required by the grower to promote production. This is basically to encourage more growers to mobilize more land into pyrethrum production and supply on a consistent weekly or monthly basis.

Mobilize and develop existing state lands.

Current pyrethrum production and supply situation in the province is too low to meet the capacity required for processing and to meet the current market demand. The export demand for pyrethrum is 8,000 kilogram extracted pyrethrum oleoresin for export requirement is about the total dry flower production target of 300 tons. This target is five times more than the current production and supply trend in Enga Province. In order to reach this export target, the local pyrethrum industry needs to promote mass mobilization of existing state land into pyrethrum cultivation. A total area of about 450–500 hectares would be required for commercial production.

Currently, the small scale growers are cultivating pyrethrum only in 50 – 120 ha land. Therefore, the priority now is to promote mobilization of state land for pyrethrum production. Identified state lands in the province are Taluma, Sirinki, Kepela, Kepesanda, Pumas, Kandep, Mapumanda and others. EPC is currently developing a 4 hectare block of land at the Sirinki base camp for pyrethrum alone and anticipates 2,000 to 3,500 kilogram flowers per year beginning 2012.

7.9 Social and economic issues

Community benefits

The wider grower population as well as the general communities have received direct benefits from the income derived from sources like the sales of pyrethrum, contractual work on nursery constructions, causal engagement for work at the base camps and dividend payments from proceeds by cooperative societies.

Income to the growers through the sales of pyrethrum over the four years (2007-2010) was approximately K500,000.This amount of money is now circulating in the rural communities. Growers have used these earnings to have access to decent meals, improved means of transport, decent clothes, capacity to meet medical expenses, school fees for children and others. Business houses have also benefited from increased spending by growers for purchase of goods and services. These targeted services providers included trade store owners, PMV operators, schools etc. The Enga Pyrethrum Company has also benefited from increased income from sales which maintained financial capacity to sustain its operations.

Women and youth groups have also benefited and can now have access to the same level of benefits as their male companions. As pyrethrum farming is a traditional job for women, more women are encouraged to actively participate in the industry. They can make their own decisions on areas where they could spend their earnings from pyrethrum.

HIV/AIDS and Gender Mainstreaming

Pyrethrum production and management is a traditional job for women and young children. This is because pyrethrum plants are planted as a side crop along the edges of sweet potato mounds, where women are involved. Therefore a lot of women are encouraged by way of involving them in trainings, awareness and similar other activities. This approach is deems as a positive step in the commercialisation of a growing big industry. The women folk are also trained to make wise decisions on how well they could use their income from the sales of pyrethrum. This is because the extra cash available to the women will allow the family to purchase better and a variety of food for an improved nutritional health status, therefore they could have the ability to protect and recover from diseases and illnesses such as HIV/AIDS.

Enga Pyrethrum Company's inputs in greater contact with women in terms of awareness and trainings improves their level of knowledge and understanding of HIV/AIDS, thus reduce its spread and better able to seek treatment for it. Safety gear such as condoms was also distributed by EPC to reduce the risk of spreading the disease. So far, the project had distributed 2,000 male and female condoms to areas in the Laiagam/Sirinki and Kandep areas as a part of their extension activities.

Law and Order

Tribal fight and other law and order issues is a great concern in the province. There is demand for containing lawless around the pyrethrum growing areas. Escalating law and order problem is a major constraint towards the growth of industry as it affects not only the free movement of extension officers but also the movement of the growers as it instil fear and anxiety and often forces farmers to migrate to other areas for safety, thus abandoning their gardening areas. The tribal fights often cause mass destruction of properties including commercial cash crops. The pyrethrum project has played a major role not only in generating income for rural people but also in reducing the level of law and order problems in the pyrethrum growing areas and wider communities. There has been generally free movement for the EPC extension officers throughout the remote settings in the province delivering extension services since the establishment of this project.

7.10 Pyrethrum delivery and purchasing operations in PNG

Pyrethrum Collection

Enga Provincial Government supports the overall operations of EPC as well as the purchasing of pyrethrum flowers for the extraction factory. First purchase of dry pyrethrum flowers began in July 2007 when funds were released to EPC. By 2009 pyrethrum purchase has almost exceeded K135,000 for the year and a similar amount was purchased in 2010.

Collections of pyrethrums are done every week. From 2007 to 2008, most of the road side collections were done by the EPC company vehicle. When this vehicle was stolen by criminals in 2009, most of the flowers have been purchased at the Wabag buying centre. Other pyrethrum suppliers include:

Co-operative Buyers

Five co-operative groups have been established and registered under the PNG Co-operative Society rules in 2008. These co-operatives collect pyrethrum from the small growers and deliver the flowers to the Wabag buying centre on a weekly basis. Current volumes (kg) collected are shown in Table 1. The cooperatives supply from the major production sites especially in the Laigaip headwaters of the Laiagam District.

In 2009, 12,610 kg of pyrethrum have been supplied by the cooperatives, which is about 21% of the total collection for that year. With an average collection of 1,100kg a month, the cooperatives have the potential to maximize production but they lack capital, manpower, skills, and transport as well as other socio- economic problems such as lawless, inaccessibility to roads , price etc.

Table 1. Pyrethrum (kg) supplied by the five cooperatives from January to October 2009

Cooperative groups	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Total
1.Yokonda	812				22	104	148	210		508	1804
2.Kinapelam	856			560	500		430	296	456	296	3394
3.Philikambi						516	1170	582	369	522	3186
4.Sirinki				210	310	344					864
5.Pylian	762			511	710	550		460	369		3362
Total	**2430**			**1281**	**1542**	**1514**	**1748**	**1548**	**1194**		**12,610**

Private Buyers (middleman)

Private buyers or middleman also supply pyrethrum to the buying centre on a weekly basis. They mainly supply from locations where cooperatives do not exist at present. Table 2 shows the total pyrethrum collected from the nine (9) private buyers in 2009. A total of 10 289 kg of pyrethrum were supplied by private buyers in 2009, a monthly average of 800 kg.

EPC subsidizes transport logistics for delivery of pyrethrum flowers by the co-operatives and private buyers. A freight bonus of 20 Toya per kilo is paid if the volume supplied for a shipment is above 200 kg. This incentive has encouraged more private buyers to collect from the small growers and deliver on a regular base.

The numbers of private buyers are continuing to grow. However, law and order problems, lack of transport, lack of funds and inaccessibility to other production sites due to tribal enemies are all factors which have hindered private buyers from increasing their weekly deliveries.

Table 2. Private pyrethrum buyers and quantities (kg) supplied in 2009.

	Private Buyers	Locations	Kg
1	Yapane Kalo	Pangu	1970
2	Negro Man	Kinderep, kandep, Ipai	1643
3	Chris Pyia	Kanak-Wanepop	1545
4	Maliki Maliso	Mulisos	1133
5	Heron Mai	Kandep	1126
6	Frank Mataia	Pilikambi	987
7	Was Ipal	Pilikambi	876
8	Joseph Newman	Kaipare	566
9	Tukai Puli	Yango	443
		Total	**10,289**

Smallholders direct delivery to Wabag Buying Centre

The local pyrethrum industry is still recovering slowly from the shock of collapse of the industry. This is indicated by the relatively small number of people supplying pyrethrum on weekly bases, an average of 55 smallholders per week. This is shown in Figure 1, where the number of smallholders supplying to the buying centre ranges from least of 20 to maximum of 110 smallholders per week. This trend is the similar for smallholders supplying to the co-operatives and the private buyers. The number of smallholders delivering to the Wabag Buying Centre increased from 712 in 2007 to 5,420 in 2008 and 5,928 in 2009.

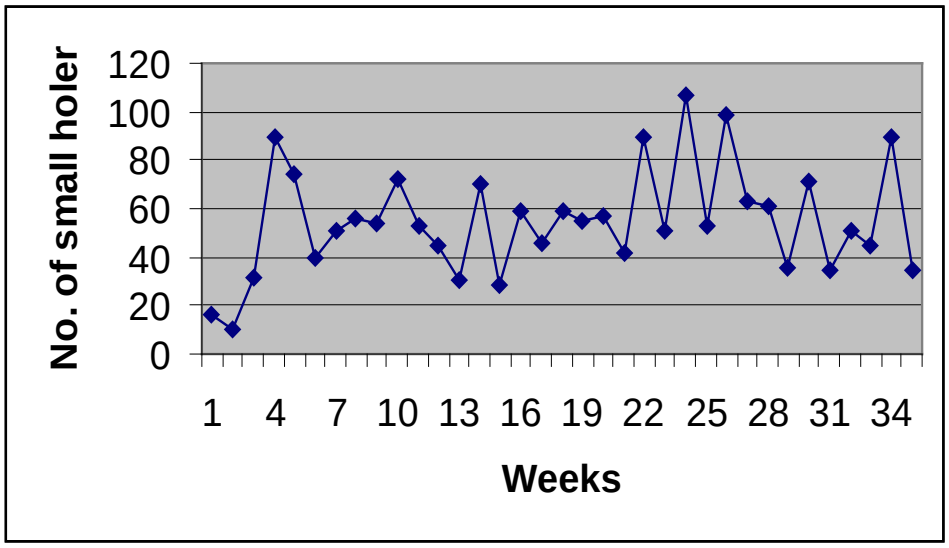


Figure1. The number of smallholders supplying pyrethrum on a weekly basis in 2009

From the extension records it is estimated that there are 5-10,000 households under pyrethrum production in Enga alone. This is just a quarter of the estimated 50-60,000 in the 1980s. However, the actual estimated number of suppliers is less than 6,000. Also, there are few smallholders in Chimbu Province as well as in Western Highlands Province. A total 101 kg and 14 kg were received from these areas respectively. Poor record keeping, lack of transport, lack of extension capacity, and other socio-economic constants have made it difficult to determine the exact number of smallholders who are growing pyrethrum at this time.

Pricing / Payments

The pricing for pyrethrum flowers paid to growers has increased since the start of this project. It was K1.50 to K2.00 per kg in 2007 but has risen to the following prices in 2009.

- Factory price K3.00 per kg
- Buying Centre K 2.50 to K2.70 per kg
- Roadside purchase K2.00 per kg
- Cooperatives and private buyers K1.50 to K2.00 per kg

When pyrethrum is brought to the buying centre, a formal EPC company receipt is issued and cash payments are made based on the value of the receipts (Photo 3 & 4.).

Pyrethrum Packing and Delivery

Pyrethrum delivered to the buying centre is packed into large bales for delivery to the Kagamuga factory. The bales are reweighed and labelled before being sent. A bale weighs on average 126 kg. Each delivery consists of 12 bales and averaged a total of about 1,500 kg. Deliveries are made once or twice a week.

Data collection and record keeping

At the end of 2008 and beginning 2009, the management of Enga Vegetable Marketing Deport (Manday Yaso) began to manage the pyrethrum purchasing and also data collection, record keeping and data analysis. Most of the information gathered has assisted to compile this report and will also be used to monitor and assess the progress of the revitalization programs of the pyrethrum industry. Records are kept on the following main areas:

- Volume of pyrethrum produced and supplied on an timely basis to EPC
- Number of productions sites
- Farmer profiling

7.11 History and management of the Kagamuga pyrethrum extraction factory

History of factory operation prior to the start of the ACIAR project

- The factory was commissioned in 1966, then called the Kagamuga Natural Products factory, with equipment also suitable for extraction of other natural products, though pyrethrum was the only product used
- The factory was then supported with a well equipped laboratory, declining after 1984, with the NARI laboratory doing pyrethrum testing by HPLC.
- The factory was modernized in 1982 with a completely new, more efficient extraction plant, imported pre-fabricated in four containers from Ireland. Only the flower grinders were retained.
- The factory ceased operations for various reasons in 1995
- The defunct factory was transferred from the Department of Finance in Port Moresby to the Enga Provincial government in 1998

- About this time the Enga Provincial Government initiated the restoration of the factory, with re-commissioning in 2003, using the same process equipment but much better and more trouble free manually operated controls. The large backlog of dried flowers was then processed.
- Flower production peaked at 590 tonnes in 1967, from 288 tonnes in 1966, then to 502 tonnes in 1968, then a gradual decline until it ceased operations.
- Shipments until closure were made to MGK, a major pyrethrum buyer, in Chicago, USA.
- Concentrate testing was done by the NARI laboratory to check MGK buyer test results and the results were generally consistent, with the assay of the oleoresin at 32%
- In 1985 the NARI laboratory was given 30 prospective clones from the Sirinki Research Station for evaluation and 46 clones from Enga gardens. 10 of these, from the research trials, had a pyrethrum content of greater than 2.0%. The highest, clone TP12, had a content of 2.41%. Testing was by HPLC.

Outcomes of this support to the factory are significant in enhancing the sustainability of both crop production and post-harvest processing into a high quality exportable extract. As a result of the laboratory testing of factory extraction processes, close assessment of the efficiency of the factory operation has taken place, and advice was given as necessary to the factory supervisor. The pyrethrum content in oleoresin has increased from 27% to 30% and finally to 32%. This improvement in the pyrethrins content of the oleoresin will reduce the storage and shipping costs and will also improve the efficiency of the refining process.

This improvement is coupled with reduced pyrethrins content in the marc, (waste flowers after processing), now down to 0.1%, from 0.3%, and lower hexane use (the solvent used for extraction), now about 80% of extract produced (70 litres hexane use per 100 litres extract produced), and should reduce further with more experience in operation by the factory supervisor. Inefficient extraction had result in high levels of hexane residue in the oleoresin as assessed by flash point testing. Excess hexane content in the oleoresin is costly in the loss of hexane and more importantly, will affect the transport and refining of the oleoresin because of the potential health and safety issues. As this project has progressed, the hexane content of the oleoresin has been reduced to a relatively acceptable level.

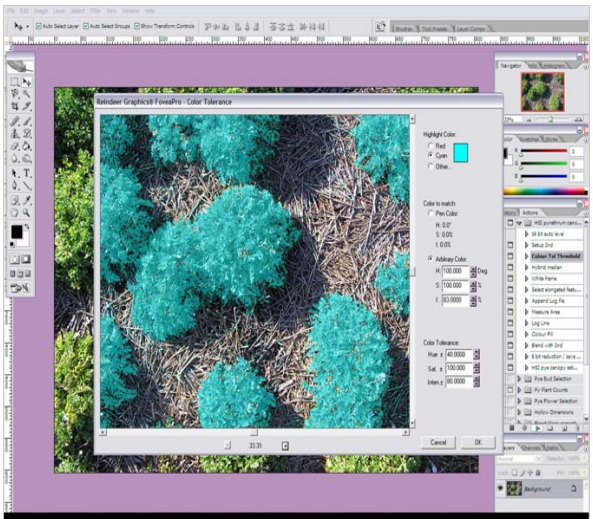
Apart from pyrethrum content, other laboratory tests are also required. Drying is an essential post-harvest step and must be tested on flowers, along with pyrethrum content. Flowers should be dried to have 10% moisture content. Insufficient drying allows biological decomposition and mould formation. If too dry, fire risks are an issue. Testing during this project has confirmed drying by farmers is adequate. To check pyrethrum extraction efficiency in the factory, it is also necessary to know if the flower pulverizing machines are working properly. This is done in the laboratory by a sieving test. Now about 55% of the material is between 0.5 and 2.0 mm, with the rest mostly between 0.2 and 0.5 mm. This is satisfactory and the grinder has been maintained to meet this quality requirement.

7.12 Plant factors influencing the yield and yield forecasting in Tasmania

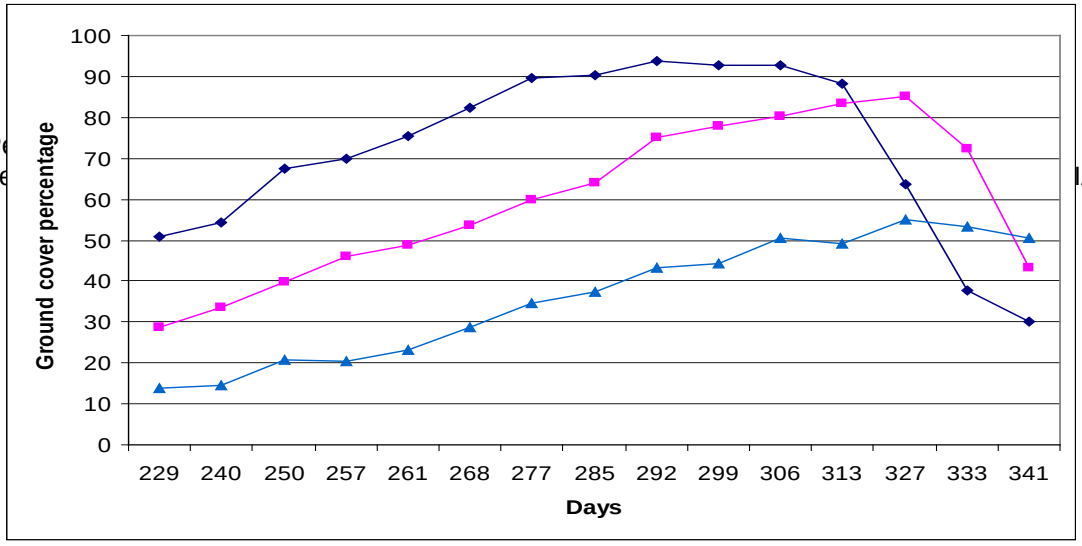
Variability in yield between and within fields and between seasons has been observed in pyrethrum production in Tasmania. In many crops, yield is related to the accumulated light interception by the crop canopy during the growing season. A study was conducted to investigate the potential of using a non-destructive method to monitor pyrethrum crop between canopy and final yield and whether this or some other plant factors can be used to estimate yield early in the season to assist with early marketing by BRA. Digital image analysis (DIA) of data recorded by the use of a digital camera on the same plot during the

season was found to useful in recording crop canopy during the season, but once full ground cover was reached, this method was less useful because the digital camera can take just two dimensional photographs. However, a reasonable relationship was found between stem density and final yield. As stems are formed relatively early during spring under Tasmanian conditions, this method can be used as an early season estimate of yield potential of crops. The important outcomes of this study are shown in the figures and graphs below.

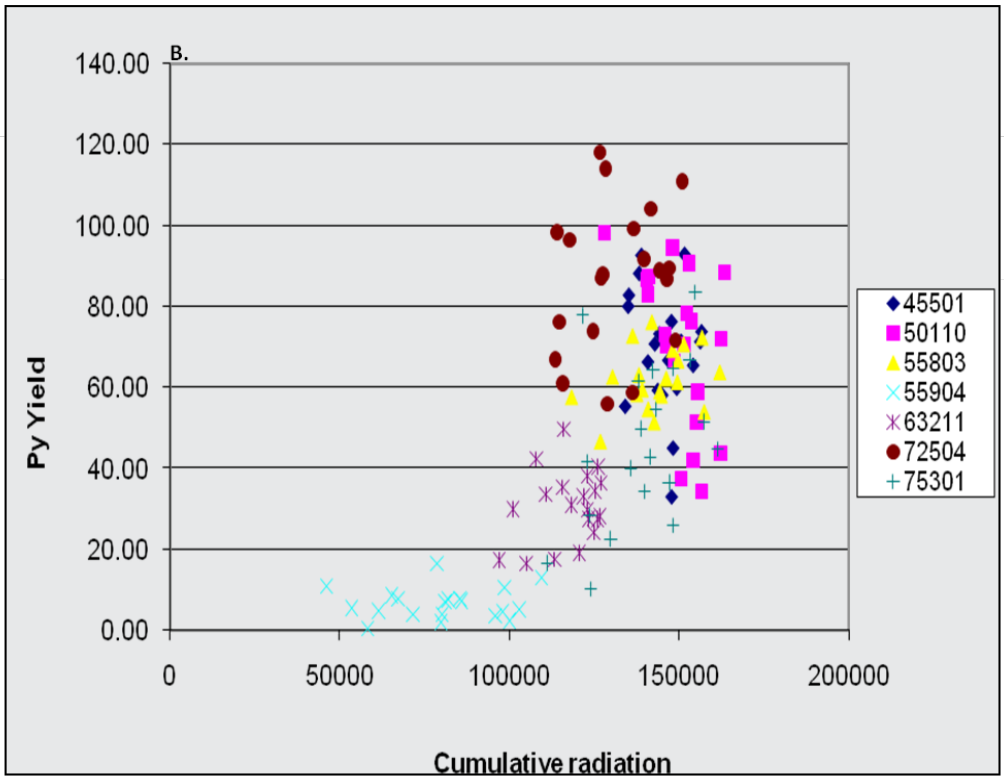
Digital images were taken of 20 plots in each of 10 crops on 10 occasions over the growing season and assessed using Fovea Pro 4.0®.



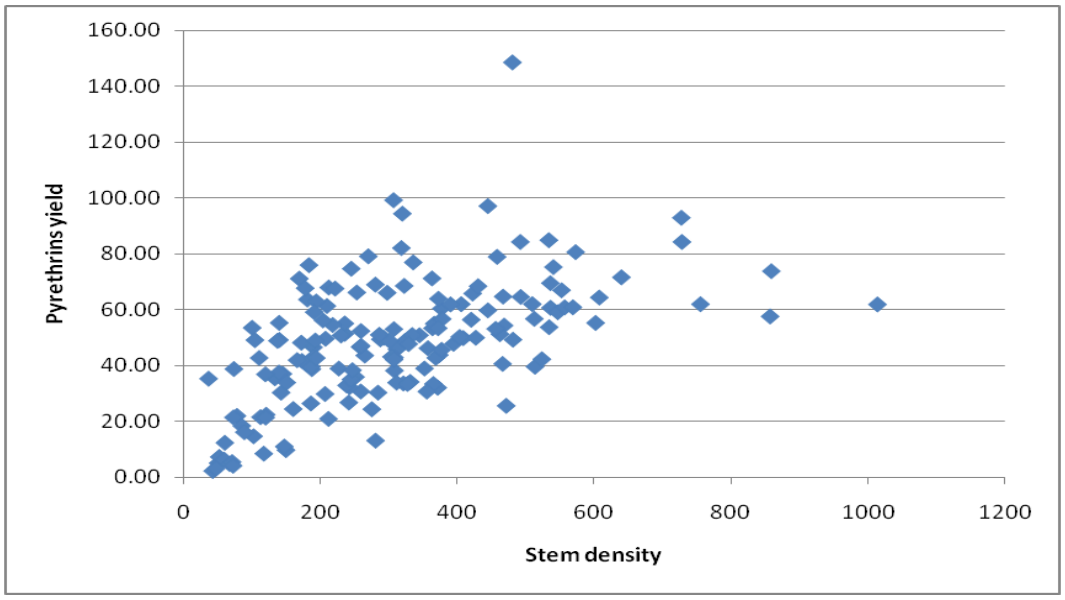
Thresholding in the HSI colour space using the colour tolerance filter. Selected features are cyan.



Percent ground cover during the season for three sites. Flower stems prominent about Day310.



Poor relationship between cumulative radiation during the season and final yield for eight different pyrethrum fields.



Reasonable relationship between stem density (no/m2) and final yield. Data from 20 plots from each of eight pyrethrum fields.

7.13 Scientific impacts – now and in 5 years

The completion of the project to collate and review all of the past reports and extension information in PNG has been a real success. All of the available information on pyrethrum production is now filed at Tambul Station and is readily available to all interested parties. All reports and publications arising from this project will also be filed at Tambul and be available to all interested parties.

The availability of the NIR unit at the Kagamuga factory has allowed NARI to assay all available pyrethrum genetic material in PNG and determine the diversity of the genetic material based on pyrethrins assay. The results indicated that the existing pyrethrum genetic material has a relatively wide range of pyrethrins assay, ranging from 1.0 to 1.8%. From this information, NARI has been able to identify and select individual plants that has a pyrethrins assay equal to and above 1.5% and to bulk up this material for local seed production. The pyrethrins level of these selected plants is similar to the genetic material currently in commercial use by growers in Africa and China. The identification of these higher assay plants will allow a new plant improvement project to be conducted to further improve the pyrethrins assay of the plant material to be made available to PNG growers in the future.

The results have indicated that the current plant density appears to be appropriate to the local PNG industry, but more work is required to confirm these results. Regrowth after slashing was healthy, but flowering was delayed by some three months and hence, slashing may not be a suitable practice for PNG.

This is all new scientific knowledge for PNG and would not be available in the absence of this project. On-going studies in PNG will add to this knowledge and will be used to manage this industry in the future

7.14 Capacity impacts – now and in 5 years

The capacity impact on the key young PNG scientists and extension officers have been one of the major achievements of this project to date. Janet Yando, Manday Yaso and Enopa Lindsay have all written detailed reports on their areas of responsibility. This is probably the first time in their career that they have written such a report and with guidance and prompting from BRA, exceptionally informative reports have been completed and have included as attachments to the 2009 Annual Report. These reports clearly show that these three key young officers have gained immensely in their analytical skills, writing skills and most importantly, their ability to think and act strategically within their own spheres of responsibility. This strengthening of the capacity within PNG would not have been possible without the involvement of this ACIAR project.

Janet prepared a report on the extension activities conducted during this project and discussed the extension approach taken and the achievements as measured by the number of wards/growers visited, the number of splits and seedlings distributed and the area of new crops established. In this report, Janet has also identified the opportunities that are available from the utilisation of state owned land and customarily owned land as well as the barriers to growth, including cultural barriers, criminal/tribal fighting and the limited financial, human and transport resources currently available. Based on these limitations, Janet and her team have identified a new approach of utilising locally based key modelgrowers as “trainers”/part time local extension officers. A “train the trainer” manual has been prepared and was attached to the Annual Report for 2009.

Manday has the key role of buying and paying the growers for the dried flowers. She has developed the skills and understanding to ensure that all sales are fully documented with the name and location of all growers and based on this information, she has prepared a informative and analytical report on the number of growers and production regions/wards,

the means of purchase, grower opinions on pyrethrum production and as with Janet, the opportunities and barriers to further growth of the pyrethrum industry in PNG.

Enopa has very successfully completed the detailed search for past research and extension information and has collated all of this information and completed a detailed final report on this project activity. Enopa has also prepared a progress report on all of the NARI research activities to date, thus showing his ability to prepare a clear and concise summary of a range of activities.

Kud Sitango has successfully achieve a Master degree in Agricultural Science when his John Allwright Fellowship at the University of Tasmania. This Fellowship has been a real challenge for Kud as initially he was very shy and found some difficulties in settling into the academic and social life in Tasmania. Unfortunately, the difficulties he faced in trying to obtain visa for his wife and family to join him in Tasmania was an extra hurdle for him and it is most unfortunate that his family has not been able to join him in Tasmania and have the opportunity to experience some time away from PNG. However, Kud has persevered and he gradually settled very well into life in Tasmania. He has developed a very close circle of friends from the local church community and more particularly, from within the overseas student community at the Agriculture Science Department and the university generally. Kud is now an active member of a university touch football team and he seems to be leading an active social life. The experience gained by Kud will be a real benefit for both himself as well as the improvement in capacity for PNG. In addition to the technical research skills such as the design, conduct and reporting of experiments, the training on the conduct of a plant improvement program for PNG, the close circle of friends/fellow Agricultural Science students he has made will provide Kud with a group of professional peers from Africa, Asia as well as Australia that will be a real benefit for him and PNG into the future.

The successful operation of the NIR and the extraction plant at the Kagamuga factory has been beneficial for the factory manager and his team as well as the NARI Chemistry Laboratory Manager and his staff. Anthony Armban, the factory manager has gained a lot more confidence in his managerial and technical abilities since the start of this ACIAR project. His two visits to the BRA factory in Tasmania as well as on-going communications with key BRA staff have been of real benefits to him. In recent months, Anthony has gained sufficient confidence to dismiss the non-performing members of the factory team, even though some of those dismissed had worked at the factory for many years. Anthony is now more hands-on at the factory and by paying closer attention to the operating manuals (rather than working from memory/perceived past practices), better quality oleoresin and greater operating efficiency has been achieved in recent months. Since Anthony left the factory during mid 2010, Willie Poo, his second in-charge has stepped up easily to become a very effective factory supervisor. Willie has been guided by BRA in the data recording and factory operational matters and the factory has continued to operate in a satisfactorily manner. There is scope for much more improvements at the factory, including the replacement of old and worn/leaking equipment and better understanding and monitoring of various processing steps, such as the length of the actual soaking period and the temperature of the evaporating stage.

Peter Corbett, the Manager of the NARI Laboratory had a project responsibility to assist with the commissioning of the NIR as well as training of the factory operators and interested NARI officers in the efficient use of the NIR. This work has been very successful with the factory manager and one key staff proficient with the use of the NIR and NARI officers also being very proficient in using the NIR. The availability and use of the NIR has been the key factor in the success of the on-going plant improvement study being conducted by NARI. Peter also gained immensely by his visit to the BRA laboratory in Tasmania as a part of this project and he has maintained a good network with the BRA laboratory staff since the commencement of this project. In recent months, the NARI laboratory had been successful in obtaining grants to purchase a very wide range of new and very sophisticated laboratory equipment, including a new HPLC. As a part of this major capital equipment purchase program, Peter visited Melbourne during November 2009 for some training on the operation

of some of these items of equipment. Peter was able to fit in a visit to the BRA laboratory during this visit to Australia and was able to have more in-depth discussion with BRA chemists on the intricacies of pyrethrum analysis. Peter and the NARI laboratory is now able to provide a high quality laboratory analysis service to the pyrethrum factory and will be able to monitor the operation of the NIR as well as the performance of the actual extraction processes. This will be an on-going collaboration between the NARI laboratory the pyrethrum factory and will minimise the need for active involvement by the BRA laboratory.

During this project, a total of four NARI officers and three officers from Enga visited BRA in Tasmania to view the factory operations as well as pyrethrum crops in the field. During these visits, BRA organised for the PNG visitors to spent time with relevant UTas/TIAR scientists on aspects of pyrethrum and vegetable research, such as disease management and nematode collection and identification. For the majority of these PNG officers, this was their first visit overseas and they would have seen aspects of Australian life that would have given them aspirational challenges to duplicate in PNG.

Following on from the obvious benefits gained by Kud Sitango following his period of study in Australia, there would be very beneficial capacity impact from supporting a period **of overseas study for the other three key young officers who have contributed so well to** this project, namely Janet Yando, Manday Yaso and Enopa Lindsay.

7.15 Community impacts – now and in 5 years

There has been a continued substantial community interest and support for the re-commercialisation of the pyrethrum industry in PNG. Many smallholders are keen to grow the pyrethrum plants and benefit from this cash crop. The number of smallholder's actively growing pyrethrum has increased from 2,000 in 2007 to some 10,000 by the end of this project. Limitations to industry growth such as the need for more local extension support has been recognised and the implementation of the "Train-the Trainer/model farmer" program will alleviate some of these limitations. Also, there has been quite some interest by private buyers and generally, this interest has been beneficial in assisting the industry to purchase flowers from growers, especially those from outlying districts. These private buyers have been of particular benefit during most of 2009 when the EPC buying vehicle was stolen and will continue to be of benefit as the industry grows in the future.

The PNG national Government has recognised the importance of the pyrethrum industry and the Prime Minister allocated a sum of several million Kina to a local MP for the development of the pyrethrum industry during a recent visit to Enga. This funding has just been released and some of this funding has been allocated to pyrethrum production.

7.16 Economic impacts

The ACIAR/BRA involvement in this pyrethrum project has already had important economic impact. During the duration of this project, a total of 199,434 kg of flowers have been purchased by EPC. This represents an injection of some Kina 500,000 into the local smallholder community, a source of cash that would not have been available if this project had not proceeded. Similarly, since the commencement of BRA's involvement in PNG during 2006, some Kina 572,000 worth of oleoresin has been purchased by BRA and this injection of funds to the PNG economy has been achieved only because of this ACIAR project. Within the next 5 years, it is likely that flower production will increase to the target of 300 tons per year. If this does eventuate, the cash injection to local growers will be some Kina 750,000 per year, a very significant economic impact.

7.17 Social impacts

The employment and on-going presence and involvement of Janet and Manday with pyrethrum production management has been a positive social achievement, as an example of what is possible for the local woman

Smallholder farmers have benefitted from having cash income for the purchase of extra goods to alleviate poverty, to meet school fees, purchase necessities such as cooking oil, medication and soap and to purchase better quality food to mitigate the effects of AIDS/HIV. The availability of a cash crop has encouraged more people to work together for one common interest with no or fewer complaints over land use and thus law and order and better community relationship is established.

The pyrethrum team members are continuing to distribute condoms and AIDS and HIV pamphlets to outlying villages during their visits promoting pyrethrum production. The smallholders appear to be receptive to the HIV/AIDS message, but it is difficult to assess the effectiveness of this work.

The involvement of local politics and personality has continued to create an area of uncertainty, distrust, envy and potential for conflict. In recent months, there appears to be some indications of possible resolution due to a “coming together” of the two key local ”Big Man”. BRA is very sensitive to this situation and is doing everything possible to be apolitical and be seen to be “above” this local political conflict…..a very challenging situation.

Tribal fighting has unfortunately increased quite substantially during this past year, and more importantly, the tribal fighting has encroached into the main pyrethrum production districts. The election re-run in Kandep caused considerable unrest prior to and especially after the declaration of the polls and the situation has only just started to return to some stability. Tribal fighting occurred for a brief period in the Sirinki area, by far the major pyrethrum production area.

During early 2010, very serious fighting took place directly at the Taluma Research Station, the major research station for pyrethrum studies. This was a very major conflict and a whole Mobile Police Squad was required to just stop the actual fighting, but the tension for serious conflict has continued to this time. As a result of this fighting, the NARI research team based at Taluma has to be escorted out by police and to date, the situation is considered by police to be too dangerous for their return. The unfortunate consequence of this situation is that the major trials and seed production sites located at Tambul had to be abandoned. Hence, NARI has not been able to conduct any harvests/crop inspections since late February 2010, the plants and trials may have been damaged intentionally or even accidentally during the fighting and even if the pyrethrum plants have not been physically damaged, weeds would have grown unchecked since that time.

One beneficial social change that has been beneficial has been the introduction and rapid adoption of the use and ownership of mobile phones, especially from late 2009. The readily availability at an affordable cost of mobile phones has seen many smallholders and all NARI and EPC staff own mobile phones. This has allowed communications and logistics to be managed in a much more efficient manner and has resulted in improvements in work efficiency as well as safety of staff. Smallholders can and do make regular mobile phone contact with EPC staff advising of the location and availability of flowers for collection as well as the possible likelihood and location of any unrest and or anti-social activities. The two local PNG mobile phone providers are to be recognised for the provision of this service at an affordable cost and the benefit of this technology will be fully recognised when these two providers can harmonised their technology.

7.18 Environmental impacts

This project currently has no negative environmental impact. The EPC has purchased a tractor, and has just commenced use at Sirinki Station and local farmer sites.BRA is concern

at the risks of soil compaction and erosion and has advised EPC to be aware of these issues, as well as safety issues for the tractor operator and farm workers. There is a common local tradition of burning unwanted "bush" material during land preparation and BRA has made some efforts to encourage incorporation of this organic matter rather than disposal by burning….a challenging task.

At present, the Kagamuga extraction factory has no major negative environmental impact. All of the marc by product is generally sold to local growers as a soil organic matter and hexane use is at an acceptable rate. As production increases in the future, there will be a need to look at a more robust strategy for productive uses for the marc by product as well as a program of work to minimise hexane usage.

7.19 Communication and dissemination activities

- NARI and EPC have produced a grower handout on flower maturity and the best stage for flower harvest. A second print run of 600 copies of this handout was produced and taken to PNG during November 2009 and February 2010.
- EPC has prepared a very good pyrethrum crop production manual for use by Trainers and Model Farmers. This comprehensive document is almost ready for distribution.
- NARI has contributed to the communication and dissemination of awareness and technical information to growers via a media presentation on NBC Radio and field meetings where seed and splits have been distributed to interested growers. NARI has also prepared final draft leaflets on nursery production and harvesting and these drafts are currently being reviewed by NARI management.
- EPC organised a nursery sowing demonstration at a grower site to coincide with the BRA visit during February. This was a very well attended event and BRA had the opportunity to demonstrate the preparation and sowing of a seed nursery to an audience in excess of 50 smallholders and their family.

8 Conclusions and recommendations

8.1 Conclusions

NARI has been successful in the design, conduct and reporting of four major projects under difficult circumstances. It is unfortunate that a replacement plant pathologist has not been appointed, but fortunately, disease and pests have not been observed to be an important at this stage and hence, there is an acceptable risk in deferring the fungicide and nematode studies. The plant density and slashing studies have indicated that the current practices are adequate, but there is a real need to confirm these outcomes as well as to promote these outcomes via on-farm demonstration trials. The successful collation of all PNG literature on pyrethrum in a readily accessible location at Tambul is a very good achievement. The success in identifying some 12 clones with a pyrethrins assay at or above 1.5% is a real breakthrough. The use of this material as polycross seed production material will very rapidly produce better quality seed for local growers. In addition, this collection of clones can be used as the base population for a plant improvement program. Kud Sitango has the knowledge now to commence this program. These successes have led to very significant scientific and capacity impacts.

The Kagamuga factory has been improved to a position that acceptable quality oleoresin can and is being product on a regular basis. The success of the NIR is a real achievement and will provide a useful tool to monitor the effectiveness of the factory operations as well as a tool that will be used by NARI in assessing the pyrethrins content of their clones and future selections.

The extension activities undertaken by EPC have been very successful and have succeeded in re-commercialising the pyrethrum industry in PNG. The achievement of some 50-60 tons of flowers per year under difficult circumstances is a real achievement and has paved the way for the industry to reach the target of 300 tons per year within the next few years. This achievement has very important social and economic impact on the local community as well major impact on capacity building.

8.2 Recommendations

The momentum that has been achieved during this project would benefit from an extension of support by ACIAR. There is a need to confirm the outcomes from the density and slashing studies as well as a need to demonstrate these outcomes to growers via on farm trials. There is also a need to continue and expand on the seed production and plant improvement program based on the selected high yielding clones. There is also a need for NARI to evaluate the importance of nutrition for pyrethrum production in PNG as well as a need to initiate a cropping systems project to maximise the economic, social and environmental benefits of developing a cropping system where pyrethrum and vegetable crops can be grown in a mixture of rotation and inter-cropping. At the end of this current project, NARI has a balance of some Kina 40,000, funds unspent mainly because of the resignation of the plant pathologist. It is recommended that NARI use this funding to continue with the pyrethrum studies during 2011 as an interim measure until further funding support is available from ACIAR or another source.

EPC would benefit from immediate support to maintain the existing program of extension activities as well as working together with NARI to promote better cropping management as well as developing a cropping system to incorporate a range of crops, including pyrethrum and vegetables.

It is strongly recommended that Janet Yando, Manday Yaso and Enopa Lindsay be supported to undertake a period of formal study at an Australian tertiary institution.

In any future ACIAR supported project, BRA will continue to be involved, more in a mentoring role as NARI and EPC has the capacity to initiate, plan and manage a major project.