Annual Research Report

2012

PNG Oil Palm Research Association Inc.
Dami Research Station, P.O. Box 97, Kimbe, West New Britain Province 621, Papua New Guinea
Tel +675 9854009 • Fax +675 9854040 • enquiries@pngopra.org.pg

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Dami Research Station, P.O. Box 97, Kimbe, West New Britain Province, Papua New Guinea
Telephone +675 9854009 & 9854015 ◆ Facsimile +675 9854040

REPORT BY THE ACTING DIRECTOR OF RESEARCH

Acting Director of Research, Charles Dewhurst.

June 2013

INTRODUCTION

2012 was a difficult year for the PNG Oil Palm industry with continuing changes and re-organisation of many of its operations. The weather was inclement, and the world price of oil was lower. FFB production in 2012 was also less than in 2011by almost 5% (Table 1).

Table 1. FFB production (MT) 2012 and comparison with 2011 production

Project Area	Plantation	Smallholders	Other Outgrowers	Total		
Hoskins (NBPOL, WNB)	841,806	433,585	6221	1,281,613	49.6%	82.3
Ponpondetta (NBPOL, Kula Group)	185,655	186,579	0	372,325	14.4%	
Milne Bay (NBPOL, Kula Group)	214,876	16,945	0	231,822	9.0%	
New Ireland (NBPOL, Kula Group)	116,309	22,832	0	139,141	5.4%	
Ramu (NBPOL, RAI)	99,184	2,522		101,706	3.9%	
Bialla (Hargy Oil Palms)	244,563	177,438	36,231	458,232	17.7	
TOTAL	1,702,393	839,902	42,452	2,584,748		
	65.9%	32.5%	1.6%			
FFB Production (MT) 2011						
TOTAL	1,844,851	825,875	48,079	2,718,805		
2011 to 2012 change	-7.7%	1.7%	-11.7%	-4.9%		

Source: PNG- POC (2013)

Table 2. Planted Area of Oil palmin Production (ha) – December 2012

Project Area	Plantation	Smallholders	Other Outgrowers	Total		
Hoskins (NBPOL, WNB)	36,819	28,369	540	65,768	45.6%	82.6
Ponpondetta (NBPOL, Kula Group)	8,449	13,346	0	21,795	15.1%	
Milne Bay (NBPOL, Kula Group)	10,267	1,901	0	12,168	8.4%	
New Ireland (NBPOL, Kula Group)	5,659	2,518	0	8,177	5.7%	
Ramu (NBPOL, RAI)	11,035	260	0	11,295	7.8%	
Bialla (Hargy Oil Palms)	11,584	11,488	1,948	25,020	17.4	
TOTAL	83,813	57,882	2,488	144,183		
	58.1%	40.1%	1.7%			

Source: PNG-POC (2013).

In spite of the lower productivity, areas under oil palm increased in 2012 (Table 2).
The major focus of the industry was with ensuring the continued sustainable production of palm oil which continues to be strengthened. All of the NBPOL Plantations and Estates, Ramu Agri-industries Ltd. and Hargy Oil Palms Ltd. are now all fully RSPO certified.
PNGOPRA is an Affiliate Member of the RSPO, and has an important role to play in supporting plantations and smallholders in PNG in their commitment to improving their commitment to sustainable development, particularly in the area of continuous improvement. The research programme at PNGOPRA continues to be fully aligned with the RSPO Principles and Criteria and these are indicated for the various components of the research in this report.
PNGOPRA is an incorporated 'not-for-profit' research Association - a non-governmental organisation (NGO). The current Association membership consists of New Britain Palm Oil Limited (NBPOL), Kula Palm Oil Limited (part of the NBPOL Group comprising Higaturu Oil Palms, Milne Bay Estates, and Poliamba Ltd.), Ramu Agri-Industries Ltd. (part of the NBPOL Group), Hargy Oil Palms Ltd, and the Oil Palm Industry Corporation (OPIC). OPIC, through its Membership, represents the smallholder oil palm growers of PNG.
The Members of the PNGOPRA have full say in the direction and operation of the organisation and this ensures that PNGOPRA is responsive and accountable to the needs of its stakeholders. This Association is truly demand driven. On the Board of Directors, NBPOL currently have one representative who represents all of NBPOL interests while the other two organisations each have one representative. Each Member holds voting rights within the Board that reflect the Member's financial input to the organisation; this is calculated on the previous year's FFB production (the PNGOPRA Member's Levy is charged on a FFB basis). Voting rights for 2011 are presented in Table 3.

Table 3. PNGOPRA Members Voting Rights in 2013.

MEMBER	FFB Produced in 2012	VOTES Number	VOTES %
New Britain Palm Oil Limited	841,806	9	31.0
Smallholders (OPIC)	882,354	9	31.0
Kula Palm Oil Ltd (ex. CTP (PNG) Ltd)	516,841	6	20.7
Hargy Oil Palms Pty Ltd	244,563	3	10.3
Ramu Agri-Industries Ltd	99,184	1	3.4
Acting Director of Research[1]	n/a	1	3.4
TOTAL	2,584,748	29	100

A sub-committee of the Board of Directors, the Scientific Advisory Committee (SAC), meets once a year. It reviews and recommends to the Board the research programme for the coming year. Thus the Members can directly incorporate their research and technical service needs into the work programme of PNGOPRA. Inputs by the SAC are essential for the research and technical service provided by PNGOPRA. Members voting rights within the SAC meeting are the same as those for the Board of Directors meeting.
OPIC is a statutory organisation responsible for the provision of agricultural extension for smallholder oil palm growers. The link between PNGOPRA and smallholder extension is strong. As part of the PNG National Agriculture Research System (NARS), both PNGOPRA and OPIC are included together as servicing PNG smallholder oil palm growers.
PNGOPRA is financed by a levy paid by all oil palm growers, and also by external grants (Project funding). The total budgeted operating expenditure for PNGOPRA in 2012 was lower than the previous year at K5.54 million.

The Association Member levies finance 96.9% of this expenditure while external grants were lower at 3.1%. The Member levy is set at a rate of K2.00 per tonne of FFB for all growers, (15 toea/tonne is for POC). PNGOPRA therefore received K1.85/tonne of FFB. In 2012 expenditure by PNGOPRA was distributed as follows: Agronomy research, 40.8%, up slightly from 39.4% last year, Entomology research, 22.2% (down from 23.5%), Plant Pathology research 12.1%, (down from 12.9%) with Management and centralised overheads at 24.9%. up slightly from 24.1% last year. No budget was set for Socio-economics.

The Palm Oil Council (POC) is now operational with Ian Orrell as CEO, while he also remains as the Public Officer of the PNGOPRA Board.

PNGOPRA RESEARCH IN 2012

PNGOPRA continues to provide technical input for the stakeholders in the Association. This means that PNGOPRA remains flexible to meet the research and technical services needs of all those involved in oil palm sector in PNG, both smallholders and plantation companies.

Representatives of all stakeholders are represented on the Scientific Advisory Committee (SAC) that meets annually to review the current work of PNGOPRA and decide on and prioritise future research proposals. The Association addresses the most significant restraints to the sustainable production of palm oil.

With the increasing influence of the Round Table On Sustainable Palm Oil (RSPO) PNGOPRA, as an Affiliate Member, has fully embraced the Principals and Criteria set by RSPO, and is actively involved working with plantations and smallholders achieve certification and improve over time by research on improving plantation and smallholder practices, undertaking research on improved insecticides and IPM technologies, environmental indicators, smallholder food security and understanding the constraints of smallholders. Training relevant for smallholders and plantation companies remains a continuous involvement for all Sections.

The text of this Annual Report shows which main RSPO Principals and Criteria are being addressed for each research and technical services section of work. As was done previously, a summary of the RSPO Principals and Criteria, as adopted by the PNG National Implementation Working Group (NWIG) and approved by RSPO Executive Board, may be found at the end of this Annual Report in Appendix 1.

A matrix for which RSPO Principles and Criteria are addressed by each PNGOPRA study is also provided in Appendix 2.

AGRONOMY PROGRAMME

During 2012, a great deal of emphasis was put into the determination of optimum nutrient levels for oil palm while understanding the biological and physical processes which influence nutrient uptake. Trials on fertiliser uptake continued with collaborative work with Companies and the Smallholder section.

The number of trials has been reduced in NBPOL plantations; however some new trials have been set in place with HOPL, involving investigations into the progeny effects of oil palm responses to fertiliser application.

Trials investigating the effects of reduced density of oil palm planting through spacing trials and the effect on yield of FFB were also continued. The ACIAR funded project investigating the sustainability of oil palm production in PNG continued during the year with a wide range of inputs reported in this Annual Report. This project, (SMCN-2009-013, *Sustainable management of soil and water resources for oil palm production systems in PNG*), is due to be completed in mid-2013.

One of our Agronomy staff (Ms Rachel Pipai, based at Higaturu Centre) completed her Masters degree from Adelaide as a part of this project. A summary of her work is provided in the Agronomy section of this annual report.

An additional 2 AIGS projects investigating smallholder food security issues were also undertaken, and were completed during the year. One project investigated intercropping with food crops and the other investigated the development of fish ponds in Oro Province.

The international company biotechnology company Valent Biosciences worked with us (Agronomy Section) in developing a project to investigate the possibilities of using Plant Growth Regulators (PGR) to prevent fruit fall from FFB. All costs were borne by the company. This work continued and is reported upon here with a report from the Valent Biosciences.
Smallholder fertiliser-demonstration blocks were set up in Hoskins, food security activities started and are continuing to be monitored in Oro, Hargy and Poliamba.
Fertiliser use demonstration blocks at were set up at Milne Bay Estates and Poliamba (New Ireland) during the year to encourage increased production aiming for 25 tonnes/yr, while leaf tissue analysis was started for Oro growers and at HOPL.

ENTOMOLOGY PROGRAMME
2012 was characterised by a reduction in reported infestations. This was due to more efficient reporting, rapid responses to requests and effective Targeted Trunk Injection (TTI) by Smallholder Affairs (SHA), nevertheless there were still areas where control was wanting and these shortcomings are being addressed. OPIC Divisional Managers (Hoskins Project) continued to provide samples of pest taxa and "sexavae" eggs from smallholder blocks that were being harvested from areas agreed for sampling during the weekly pest management meetings. This material is systematically dissected to enable us to improve our understanding of embryonic development and the development of field populations of sexavae. Good collaboration with OPIC Bialla provided regular feedback from that Project Area. The number of treatment teams was reduced as report numbers dropped, and at the end of 2012 there were 2 operational teams at SHA who were also taking over responsibilities for TTI in plantations. Control operations in Bialla were organised by HOPL. PNGOPRA retains and encourages a close working relationship with OPIC, and all Plantation operational personnel.
Staff numbers remained unchanged during 2012. Our lab technician was encouraged to apply for an M.Phil. at UNITECH (Lae) and this was facilitated by HoE and Dr Ero who has strong university connections. It is expected that her registration will be completed in early 2013. Strong collaboration with local and overseas research personnel continued. There was no response received from the Department of Environment and Conservation (DEC) in Port Moresby for requests dealing with Queen Alexandra Birdwing Butterfly project while NAQIA did not take the Notifiable Pest Status further for gazettal, although a draft has been sighted. The staff member working on his M.Phil. degree through Charles Sturt University, Orange (Deane Woruba) had not completed his thesis by the time he resigned in December; however it is expected that he will complete it and submit it during early 2013.

Pest outbreaks
Fifty **infestation reports** were received an acted upon in 2012. This resulted in <3,000ha being treated in 2012 in WNB while 6,500ha were treated in smallholder blocks in WNB. It is WNB which remains the centre of pest related activities. In New Ireland, 7 infestation reports were received and some 1,200ha were treated. Wet periods benefit sexavae and stick insect population development while at the same time and probably more importantly hindering the effective use of TTI for their control.
Further detailed work on **insecticide trials** Dimehypo did not start until late 2012, as the insecticide took so long to arrive in PNG. This work which is high on the list of essential items will continue in 2013. Neither formulations of imidacloprid were as effective as our standard insecticide Monitor (methamidophos), principally as they take a long time to kill sexavae.
The work on the survival and reproduction of **sexavae** reported here has highlighted the results are showing considerable differences but with some similarities between *S. defoliaria* and *S. decoratus*. It is now accepted that New Ireland hosts a sub-species of *S.defoliaria*, known as *S.defoliaria gracilis*. It should be referred to as *S.d.gracilis*. **Egg parasitoids** of sexavae (*Leefmansia bicolor* Waterston and *Doirania leefmansi* Waterston) continued to be reared in the laboratory and released in both plantations and smallholder blocks during the year. The culture of *Doirania* was lost in mid-year, but field collected material is now being reared. Periodic crashes of populations of this parasitoid are common.

Infestations of the damaging **stick insect**, *E. calcarata* were regularly reported. Regular "roost" sites have been identified in the field, and the recently described parasitoids are now being released at these sites. The parasitoids (*Anastatus eurycanthae*) are reared from eggs collected from wild caught insects.
The all important **pollinating weevil**, *Elaeidobius kamerunicus* study was on-going with monthly monitoring of pollinating weevils from ten sites in WNB during 2012. Lolokoru, Kumbango (until August), and Dami were regularly sampled, while Galewale, Kavui and Siki smallholder blocks were sampled until the end of August. Subsequently regular monitoring continued at Lolokoru and Barema where fruit set has been, populations are being monitored, however it is suspected that the cause may be due to other factors.
There were no **weevil** pest reports received in 2012 neither were there were any reports of R**ough bagworm** (*M.corbetti*) in 2012. Routine monitoring of the populations of *Manatha* sp.E (to be named *Manatha conglacia*) at Ambogo continued throughout 2012. There were no reports of Finschhafen Disorder (FD) received in 2012. (Causal agent is *Zophiuma butawengi*)(Hemiptera: Lophopidae). The Dynastine beetle, ***Oryctes rhinoceros*** continued to be of concern in plantations on New Ireland. Pheromone traps in one area of young plantings at the Luburua replant caught 22,026 beetles during a period of 9 months. No palms were reported to have been killed by beetle activity, although about 26% were slightly damaged. There was no structured action against **weed pests** during the year, however *ad hoc* releases of arthropod biological control agents continued, against *Eichornia, Pistia* and *Sida*. The cultures were a useful educational item, as examples of all of them are maintained at the Entomology labs.
The **destructive sampling of palms** (DPS) undertaken to estimate population numbers and their distribution within the palms ceased, and was being collated at the time the company biometrician who was assisting the section was relieved of his duties. The services of a biometrician are required to complete this work.
The **water quality monitoring project** funded by the World Bank and managed through the SADP/OPIC staff input was finally completed in February and was operational by June. Regular monthly updates on the work were submitted to SADP/OPIC in Port Moresby. Sampling of waterways went ahead and methodologies are being prepared for utilising invertebrate taxa as water quality indicators. The Project is in line with the agreed timelines.
The large Review paper on **Queen Alexandra's Birdwing Butterfly (QABB)** was still with Conservation International, and there was no further progress on technical developments.
Training Field days were beginning to become erratic in 2012. Those that were organised by OPIC (Hoskins and Bialla) were attended by PNGOPRA staff. None were held in Popondetta.

PLANT PATHOLOGY PROGRAMME
Ganoderma disease levels and control continue to be monitored in all plantations. Data presented here has been summarized from that received from Milne Bay Estates Ltd., Poliamba Ltd., Higaturu Oil Palms Ltd. and New Britain Palm Oil Ltd.
Studies on **Disease epidemiology** continued with levels in Milne Bay below 1% for most Divisions in 2012. Disease levels at Poliamba appeared to be increasing; at Higaturu disease incidence was less than 0.4% but highest levels recorded at Sumberipa. At Numundo plantation (WNB), disease levels continued to increase. From diseased palms at Numundo, there was an apparent increase in the size of FFB harvested from these palms; reasons for this anomaly are being investigated.
Work on biological control of **Ganoderma** continued during 2012, while Screening for Ganoderma Resistance (Incorporating ACIAR Ganoderma Project PC-2007/039) was not done and no testing was carried out in 2012 due to the non-availability of seed from Dami OPRS. Solomon Islands Field trials; the ACIAR-funded project continued during the year and funding is expected to continue next year.
Bogia Coconut Syndrome (BCS) study continued with input from Entomology Section in the Furan area of Madang Province where plants and insects were sampled in August 2012 to test for phytoplasmas. A total of 575 insect and plant samples were processed and tested for the phytoplasma associated with BCS. Results of the sequencing os material sent to a lab in New Zealand are awaited. Plant pathology and Entomology worked closely together.

SOCIO-ECONOMICS

There was a change of leadership for the Socio-economics group in 2012, and although the main thrusts were continued, details of the work focussed more on what was required by the growers and companies, with a lot of effort going into completing field surveys, data collation and collation. Work within the SADP Project was continued with support from George Curry and Gina Koczberski from Curtin University, Australia. A summary of the SE work is provided below and it must be noted that much of this work is on-going and results slow to provide meaningful application-nevertheless areas such as the Mobile cards and CLUA have received much attention and progress made.

Smallholder FFB Annual Production 2005-2011 Fresh Fruit Bunch price monitoring2012; Smallholder Round-Table On Sustainable Palm Oil (RSPO) Bonus scheme; Mama Loose Fruit data analysis. . Food Security Projects ACIAR (ASEM/2006/127) project investigated Food Security in the Oil Palm Land Settlement Scheme(s); held Mobile Card Awareness programmes and participated in Commemoration of the World Food Day

Agricultural Innovative Grant Scheme (AIGS No# 9120), involved Food Security Spacing Trial (with Agronomy); involved food availability surveys from Local markets. Much effort was placed with attempting to clarify Customary Land User Agreement (CLUA) and this work centered on CLUA Awareness field meetings and Customary Rights Purchase (CRP) blocks through household surveys.

There was a Joint programmes between PNGOPRA Socio-economic Section and Oil Palm Industry Corporation (OPIC) were OPIC sponsored Radio Programmes, discussions and workshop on Income generating opportunities were held. There was close collaboration with the SADP research on Smallholder Engagement and OPIC Education and extension strategies programme and surveys on plantation workers was completed in Bialla Area 8. Smallholder productivity in the Hoskins project of WNB increased considerably, as did the production from all other projects after a dip in production in the Popondetta Project areas. A dramatic increase was recorded from the Ramu area as new areas came into production. Other project areas also showed significant increases in FFB production. Encouraging women to earn from the collection of loose fruit resulted in large amounts of the loose fruit to be collected and sold for their benefit. This amounted to 141,159 tonnes (Hoskins project 113,393 tonnes and Bialla 27,765 tonnes). An incentive scheme implemented by HOPL and NBPOL within the RSPO framework was implemented to encourage smallholder growers to improve their FFB production. Many growers appear to have welcomed this novel idea. The Section also maintained a high profile in the various HIV/AIDS in PNGOPRA programmes.

Four awareness programmes were carried out during the year in the Bialla Project area, and more than 200 booklets explaining the working and benefits of the mobile card were issued. Some 200 growers have signed up to the card in the Bialla area. The awareness meetings highlighted a number of areas of difficulty that are being addressed, while the transfer of OPIC officers to Bialla from the Hoskins project site has created a knowledge gap in the understanding of the mobile card concept, as Mobile Card is only used in Bialla and not in Hoskins.

There is a lack of understanding on the purpose of the mobile card system both by OPIC field officers and LSS oil palm growers. And although most LSS oil palm growers having signed up for the Mobile Card subsequently cancel their membership due to a lack of understanding.

Fluctuation of FFB price and particularly when the price is low, results in arguments between the mobile card holders and the mobile card users because some mobile card users felt they are not paid enough money to compensate the amount of effort put into working in the block. Lack of literacy by the growers to understand values of percentage split with the monetary value. People understood split calculated in actual monetary figure compared to payment made in percentage.

Customary Land Use Agreement (CLUA). An important component in the new CLUA is in mobilizing and ensuring that all the clan members and villagers know all land transactions, whether free from disputes, at what price is it going to be sold, how is the payment going to be done and who will receive or benefit from the income. The new CLUA ensures there is transparency in the process of leasing land. Importantly, it is for all CRP growers to sign the new CLUA form as part of a group of financial institutions that can be used as guarantors by growers to acquire tools and other farm inputs from the milling companies on their smallholder credit schemes. Awareness on this important development was undertaken at Waisissi (Hoskins Project), and will need to be carefully rolled out in all areas where there are potential land usage issues, that are certain to increase with the increasing land pressure from rapidly expanding populations.

The objective of Household socioeconomic and demographic surveys was to identify how land transaction was undertaken, conditions of the land agreement and population of the block and the relationship of individuals living in the block to the title holder. These surveys highlighted the needs for the use of the CLUA to reduce possible conflicts.

Technical services provision by PNGOPRA staff

Staff continued to provide technical services to the oil palm industry in Papua New Guinea through the provision of advisory material, recommendations, training and direct technical inputs such as the production of biological control agents. The OPRAtive Word and Technical reports remain our main outputs, however a number of peer reviewed scientific papers were published during the year,

The PNGOPRA Information Services (IS) section continued to provide all sites with the required IT connectivity and especially the sterility of our computer systems as we were recipients of a bad cyber attack originating in China. All computers are now regularly serviced. Our website is still non-functional, and this important issue will be addressed in 2013.

1. AGRONOMY SECTION

HEAD OF SECTION I: MUROM BANABAS

OVERVIEW

The main task of PNGOPRA Agronomy Section is to determine the optimum nutrient requirements for oil palm from trials and at the same time understanding the processes within the soil which influence and regulate plant nutrient uptake and communicate the information to the oil palm industry. In addition to optimising oil palm yield, activities are in place to determine the long term sustainability of the system.

The bulk of the work undertaken by the Agronomy Team is undertaking fertiliser response studies. At each of the plantations we have set up a number of trials in collaboration with our funding partners (Plantation Companies and Smallholder Sector). The types of trials established vary between the different areas and depend on where the gaps in knowledge are and soil type differences. The number of trials has been reduced in the NBPOL plantations, while several new trials have started during the last 2-3 years with Hargy Oil Palm Plantations. The new trials are planted with consideration to possible progeny effects on the palm responses to fertilisers.

There are several experiments looking at a) the effects of different spacing arrangements on yield, b) the effects of reduced density on yield by poisoning and c) yield monitoring and forecasting, however the yield monitoring trials were closed at the end of 2009. These non-fertiliser-related trials are very important in providing management information to the industry.

Two important donor funded projects, N Loss and Mg/Cation, were closed, and have been reported upon. There is now an additional donor funded project (ACIAR) that started May 2010 and will be closing in June/July 2013 investigating the sustainability of oil palm production in PNG. As part of this project, Rachel Pipai studied for her Masters degree at University of Adelaide in Australia studying mechanisms for nitrogen fixation by legume cover crops under the oil palm systems in PNG. A brief of the work she did is reported in this report.

Two other projects investigated food security in smallholder farming systems. These were approved by AIGS (ARDSF project funded by AusAID) however they ended in April 2012. The first project looked at intercropping food crops with oil palm in Northern, WNB and New Ireland Provinces. The second project looked at raising fish in fish ponds in smallholder blocks in Oro Province. Another project is being undertaken jointly with Valent Biosciences and was initiated in 2011. This project is being managed in WNB the project is looking into the effect of plant growth regulators on ripening bunches, and a report was prepared by Dr Andrew Rath, and a report is attached.

There was increased involvement in smallholder related activities. Smallholder fertiliser-demonstration blocks were set up in Hoskins, food security activities started and are continuing to be monitored in Oro, Hargy and Poliamba. The collection of leaf tissues for analysis continued in Oro and has also started at Hargy. Fertiliser use demonstration blocks at Milne Bay Estates and Poliamba were set up during the year, the aim was to increase FFB yields in the smallholder sector from 10-15 t/ha/year to >25t/ha/year.

Across all sites, there is continuous involvement in training for the industry. PNGOPRA is involved with OPIC in smallholder field days and radio broadcasts. Training was also carried out in the Plantations on leaf sampling techniques.

ABBREVIATIONS

AMC	Ammonium chloride (NH_4Cl)
AN	Ammonium nitrate (NH_4NO_3)
ANOVA	Analysis of variance (Statistical test used for factorial trials)
BA	Bunch ash (burnt EFB)
BNO	Number of bunches
$cmol_c/kg$	Centimoles of charge per kg, numerically equal to meq % or meq/100g
CV	Coefficient of variation
DM	Dry matter
EFB	Empty fruit bunch
FA	Area of frond
FFB	Fresh fruit bunch
GM	Grand mean (average over all treatments
KIE	Kieserite (mostly magnesium sulphate, $MgSO_4$)
LAI	Leaf area index
l.s.d	Least significant difference
mM	(millimoles per litre)
MOP	Muriate of potash (KCl)
n.s	See Sig.
p	Significance (probability that treatment affect is due to chance)
SBW	Single bunch weight
s.d	Standard deviation
s.e	Standard error
s.e.d	Standard error of the difference of the means
Sig.	Level of significance (n.s. not significant, * $p<0.05$, ** $p<0.01$, *** $p<0.001$
SOA	Ammonium sulphate ($(NH_4)_2SO_4$)
SOP	Potassium sulphate (K_2SO_4)
TSP	Triple superphosphate (mostly calcium phosphate, $CaHPO_4$)

Soil analytical methods used (Hill Laboratories, NZ)

Parameter	Method
Preparation	Air dried at 35^0C overnight, crushed through 2mm sieve
pH	pH electrode in 1:2 (v/v) soil: water slurry
‘Available’ P	Olsen extraction,det.by molybdenum blue colorimetry
Anion storage capacity /P ret	Equilibration with 0.02M K_2PO_4 followed by ICP-OES
Total P	Nitric/ perchloric acid digestion, by ICP-OES
Exch. Ca, Mg, K & Na	IM NH4 acetate extraction (pH7), meas. By ICP- OES
Exch. Al	IM KCI extraction, det. By ICP-OES
CEC	Sum of exchangeable cations plus exch. acidity
Volume weight	Weight/ volume of dried, ground soil
Base saturation	Calculated from exchangeable cations and CEC
Reserve’ K	IM nitric scid extraction, det. By AA
Reserve’ Mg	IM HCI extraction, det. AA,exch. Mg subtracted
Total N	Dumas combustion
‘Available’ N	7 day anaerobic incubation, 2M KCI extraction of NH_4^+
Organic S	0.02 M K_2 PO_4 extraction followed by ICP-OES for total S, then subtraction of sulphate-S
Sulphate-S	0.02 M K_2PO_4 extraction followed by ion chromatography
Hot water soluble B	0.01IM $CaCI_2$ extraction, det. By ICP-OES
Organic matter	Dumas combustion. Calculated at 1.72 x total carbon

Fertiliser composition

Fertiliser and abbreviation	Approximate elemental content (% mass)						
	N	P	K	S	Mg	CI	B
Ammonium sulphate (SOA)	21			24			
Ammonium chloride (AC)	25					66	
Ammonium nitrate (AN)	35						
Urea	46						
Diammonium phosphate	18	20					
Potassium sulphate (SOP)			14	17			
Triple superphosphate (TSP)		20		2			
Kieserite (KIE)				23	16		
Potassium chloride (MOP)			50			47	
Sodium chlorde						61	
Borax							11
Ulexite							10

HARGY OIL PALM LIMITED
(Susan Tomda and Steven Nake)

Summary
Fertiliser Response Trials with Hargy comprised of two main interests:

1. Factorial trial response to N, P, K and Mg: three factorial trials have been operational at Hargy for many years. One of the factorial trials (T205) did not include nitrogen fertiliser treatments however, in 2007 two different rates of N were applied to this trial on half of the replicates.

2. Systematic N trials: two systematic N trials have been established (one at Hargy and the other at Navo) to determine the optimum N rate for the volcanic soils at Hargy Oil Palm. The systematic trials are of similar design to those at NBPOL (see close trial report-NBPOL).
   Outcome: the systematic trials are showing N fertiliser response of increasing N rate. The response of N fertiliser will continue to increase as the tissue N levels in the control plots are starting to decrease.

Due to Hargy Oil Palm Limited (HOPL) expansion three new trials have been established since 2009.

- A new P rate and placement trial was established in October 2008 (**T214**)
- A new NxPxK Central Composite Design trial at Barema in 2009 (**T216**)
- A new NxPxK Central Composite Design trial at Navo in 2011 (**T217**)
- A new NxPxKxMg Facorial trial at Alaba in 2011 (**T220**)

A synopsis for the trial work undertaken with Hargy Oil Palms Limited is provided (Table 4 & Table 5). A short recommendation for trial work operation and plantation management based on our results is also provided.

Table 4. HargyOil Palms Ltd: Synopsis of 2012 PNGOPRA trial results and recommendations.

Trial	Palm Age	Yield t/ha	Yield Components	Tissue (% dm)	Vegetative	Notes
205 Hargy EFB,TSP,KIE,AMC (factorial) Soil: Volcanic ash	19	27.5–28.2	BHA: 1018 SBW: 28 kg	LN:2.39-2.42 RN:0.33-0.36 LP:0.144-0.147 RP:0.081-0.103 LK:0.65-0.66 RK:1.47-1.62 LMg:0.16-0.20 LB:16ppm	PCS: 56.9 FA:15.8 FP:22 LAI:7.2	Decline in yield and BHA by 2-3 t/ha and 112 bunches respectively in 2012.
211 Navo AN (Sytematic) Soil: Volcanic ash	14	27.1-39.4	BHA:1226-1616 SBW:22.2-24.8kg	LN:2.13-2.41 RN:0.35-0.41 LP:0.127-0.136 RP:0.06-0.08 LK:0.68-0.74 RK:1.84-2.05 LMg:0.16-0.22 LB:16ppm	PCS:35.7-52.7 FP:19.4-22.7(NS) LAI:4.8-5.8	Drop of 4t/ha in 2010 but 5 t/ha increase in 2012 36.3t/ha archived at 2.96kg AN/palm Significant response to N fertiliser over time Boron adequate RK is high
212 Hargy AN (Systematic) Soil: Volcanic ash	14	25.6-32.1	BHA:1008-1241 SBW:23.4-26.8kg	LN:2.21-2.43 RN:0.30-0.34 LP:0.133-0.138 RP:0.035-0.042 LK:0.62-0.69 RK:1.45-1.63 LMg:0.160-0.20 LB:16ppm	PCS:42.7-50.3 FP:21-22(NS) LAI:5.5-6.6 BDM:19.5-26.3	4 t/ha increase in 2012 30.4 t/ha archived at 2.96kg AN/palm
214 Hargy TSP placement Soil: Volcanic ash	18	25.9-27.3	BHA:1030-1143 SBW:24.2-25.1	LN:2.21-2.28 RN:0.29-0.32 LP:0.137-0.144 RP:0.043-0.064 LK:0.59-0.65 RK:1.19-1.38 LMg:0.167-0.182 LB:21ppm	PCS:48.1-51.2 FP:21-22(NS) LAI:6.5-6.7 BDM:13.2-14.1	4t/ha increase in yield in 2012. No significant response in yield, its components and all nutrient concentrations except Rachis P

Table 5. Apparent adequate tissue nutrient levels:

Leaflet (% DM)					**Rachis (% DM)**		
N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
2.45-2.50	0.145	0.65	0.20	15ppm	0.3	0.08	1.3

Recommendations to Hargy Oil Palm:

- At Hargy more than 30t/ha FFB should be attainable in mature plantations. Improved plantation standards in harvesting, pruning, weeding and overall maintenance has resulted in much crop recovery, and there are now trials with treatment yields in excess of 35t/ha.
- Plantation management (harvest time, pruning, clean weeded circles, fertiliser application and timing etc) all play a large role in the potential to optimize production.
- Tissue testing and vegetative measurement criteria will help in determining deficiencies of particular nutrients.
- Most of the focus for nutrition should be on N, followed by K and P. Tissue Mg levels appear to be adequate. Nutrients do not act in isolation and a full response to each nutrient is supplied according to the physiological needs of the palm.

Trial 205: EFB x P x Mg x N Fertiliser Trial on Volcanic soils, Hargy
(RSPO 4.2, 4.3, 4.6, 8.1)

Summary
The fertiliser treatments did not have any significant effect on both the FFB yields and its parameters (BHA and SBW) in 2012. While the yields and BHA declined in 2012 by 2-3 t/ha and 112 bunches per hectare respectively, the SBW continued to increase steadily. In 2012, individual bunch weighed around 28 kg. Some nutrient levels in the leaflets and rachis were increased by the fertiliser treatments in 2012. N leaf levels were increased by EFB and KIE applications, while TSP increased leaflet P and KIE increased leaflet Mg. While the concentrations of all the nutrients in the leaflets and the rachis were above their critical levels, leaflet N and Mg levels were slightly below their adequate mark. The number of green fronds were significantly increased with AN and TSP applications.

Background
The purpose of the trial is to investigate the response of oil palm to the application of EFB and nitrogen, and to investigate whether the uptake of phosphorus (P) and magnesium (Mg) from TSP and KIE can be improved by applying the fertilizer in conjunction with EFB. Fertilizer responses in trials can lead to more accurate fertilizer recommendations for oil palm grown on volcanic soils at Bialla. Table 6 provides background information to the trial.

Table 6. Trial 205 background information.

Trial number	205	Company	Hargy Oil Palm Ltd
Estate	Hargy	Block No.	Area 9, Blocks 7 & 8
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Free draining
Date planted	1993	Topography	Gently sloping
Age after planting	18 years	Altitude	135 m asl
Treatments 1st applied	June 1997	Previous Land-use	Oil Palm
Progeny	Known*	Area under trial soil type (ha)	
Planting material	Dami D x P	Assistant Agronomist in charge	Susan Tomda

** 16 different identified Dami DxP progenies arranged in a random spatial configuration in each plot.*

Methods

Experimental design and treatments
The EFB x P x Mg x N trial was set up with two rates of each organic/inorganic fertilizer in a factorial design, replicated three times resulting with 48 plots (Table 7). The N treatment was included in late 2007 because the palms were found to be N deficient (based on tissue test analysis). Nitrogen was then applied at a basal rate of AC at 3kg/palm in previous years. On half the number of replicates (i.e.

on three out of the six original replicates) the N rate was increased to 9 kg of AC/palm for 2008 only (the other replicates continued to receive 3 kg AC/palm). After 2008, the high AC treatment was reduced 6 kg/palm and applied at that rate since then. Extra N fertilizer (6 kg/palm) was applied on replicates 2, 4 and 6; while replicates 1, 3 and 5 continued to receive 3 kg/palm. In 2011, N source was changed to Ammonium nitrate (AN).
Each plot contained 36 palms and recordings and measurements were taken on the central 16 palms. The palms recorded consist of 16 different identified Dami DxP progenies, which were arranged in a random spatial configuration in each plot.
Statistical Analysis
Yield and its components and tissue nutrient concentration were analysed using ANOVA (General Analysis of Variance with four treatments, each applied at two rates).
Basal fertilizer applied in 2012 was MOP at 2kg/palm and Borate at 150g/palm.

Table 7. Fertilizer and EFB treatments applied in Trial 205 in 2012

Treatment	EFB (kg/palm/yr)	AN* (kg/palm/yr)	TSP (kg/palm/yr)	KIE (kg/palm/yr)
1	0	2.3	0	0
2	0	4.6	0	0
3	0	2.3	0	3
4	0	4.6	0	3
5	0	2.3	3	0
6	0	4.6	3	0
7	0	2.3	3	3
8	0	4.6	3	3
9	230	2.3	0	0
10	230	4.6	0	0
11	230	2.3	0	3
12	230	4.6	0	3
13	230	2.3	3	0
14	230	4.6	3	0
15	230	2.3	3	3
16	230	4.6	3	3

** Note that AN replaced AC as N source in 2011.*

Data Collection
The number of bunches and bunch weights were recorded fortnightly on an individual palm basis and totalled for each plot, then totalled for each harvest and yield was expressed as tonne per ha per year. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Leaf measurements (frond length, petiole cross section, leaflet width and length, number of leaflets on one side of the frond) were done on frond 17. Frond production was done twice a year (every 6 months). The palm height was also measured to calculate height increment each palm per year.

Results
FFB yield and its components - mean trend over time
After a drastic drop (about 11t/ha) in FFB yield in 2002, it remained at greater than 25t/ha. Single bunch weights increased steadily with time while the number of bunches did the opposite (Figure 1). In 2012, the average single bunch weight was 28 kg.

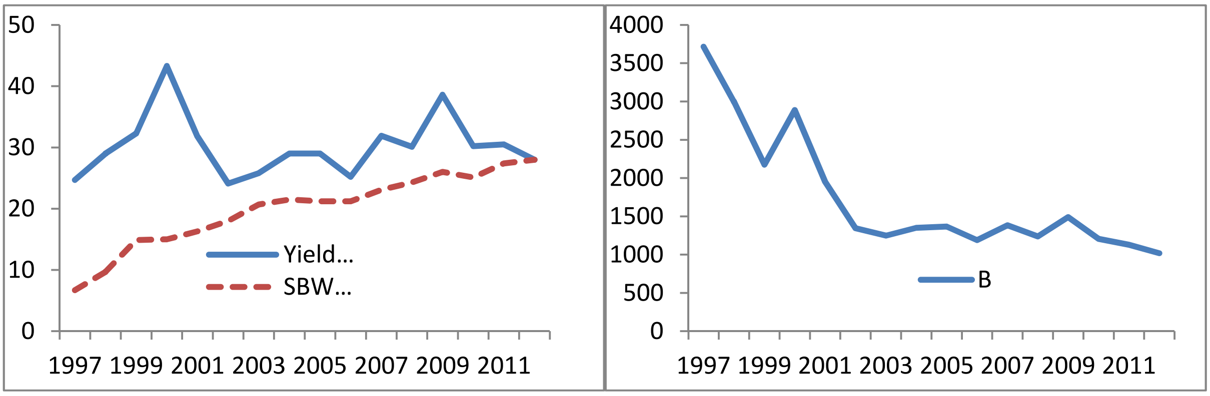


Figure 1. Average yield (t/ha), SBW (kg) and BHA from 1997 to 2012

Yield response to fertiliser treatments in 2012

There was no significant effect of fertilizers on yield and yield components in 2012 and 2010-2012 period (Table 8). Similar to 2010 and 2011 results, application of AN, TSP and KIE somehow reduced the FFB yields. The mean FFB yield in 2012 was 27.5t/ha.

Table 8. **Treatment effects (main) on yield and its parameters in 2012 and 2010-2012.**
(*Significant effects (values) are shown in bold).*

		2012			2010-2012		
Treat Levels	**Rate (kg/palm)**	**Yield (t/ha)**	**BHA (bunch/ha)**	**SBW (kg/bunch)**	**Yield (t/ha)**	**BHA (bunch/ha)**	**SBW (kg/bunch)**
AN-1	2.3	28.3	1025	28.2	31.1	1190	26.5
AN-2	4.6	27.7	1011	27.9	32.6	1233	26.7
EFB-0	0	27.9	1022	27.9	32.1	1220	26.5
EFB-1	230	28.1	1014	28.1	31.7	1202	26.7
TSP-0	0	28.5	1042	28.0	32.2	1231	26.5
TSP-1	3	27.5	994	28.1	31.5	1192	26.7
Kie-0	0	28.2	1041	28.0	31.9	1220	26.6
Kie-1	3	27.8	995	28.0	31.8	1202	26.6
Significance		NS	NS	NS	NS	NS	NS
LSD		-	-	-	-	-	-
CV %		12.7	13.0	6.6	9.2	9.1	4.7

Effect of fertilizer treatments on Tissue nutrient concentration in 2012
The leaflet and rachis nutrient contents are presented in Table 9. EFB and Kieserite application had significant effects on leaflet N contents. Similarly, Kieserite significantly raised Mg contents to 0.20 % dm while TSP significantly increased P level in the leaflets. Leaflet N concentrations were elevated by AN but not statistically significant. In the rachis, AN increased N levels, while EFB and TSP elevated K and P contents respectively.
Figure 2 depicts the long term effect of the fertilizer treatments on nutrient concentrations in both the leaflets and the rachis. The trial experienced peaks and troughs in the nutrient levels through the duration of the trial. In 2011, leaflet N, P and K were far above their adequate levels and similarly for the rachis N, P and K. In 2012, leaflet N and P declined dramatically, while that of K and Mg did not change. Rachis P and K dropped dramatically in 2012 (rachis N experienced slight decline). Leaf Mg levels have not reached its adequate mark of 0.2 % since 2002.

Table 9. Tissue nutrient concentration for Trial 205 in 2012

Fertiliser Level	Leaflet (% dm)				Rachis (% dm)		
	N	P	K	Mg	N	P	K
AN-1	2.39	0.144	0.65	0.18	**0.33**	**0.099**	1.53
AN-2	2.41	0.144	0.66	0.18	**0.35**	**0.084**	1.57
EFB-0	**2.38**	0.145	0.65	0.18	0.34	0.090	**1.47**
EFB-1	**2.42**	0.145	0.65	0.18	0.35	0.093	**1.62**
TSP-0	2.39	**0.142**	0.66	0.18	0.34	**0.081**	**1.60**
TSP-1	2.40	**0.147**	0.65	0.18	0.34	**0.103**	**1.50**
KIE-0	**2.39**	0.145	0.65	**0.16**	0.36	0.094	1.55
KIE-1	**2.41**	0.144	0.66	**0.20**	0.33	0.090	1.54
LSD$_{0.05}$	0.04	0.001	NS	0.01	0.02	0.01	0.09
CV%	2.7	2.7	5.5	12.8	9.6	13.3	9.7

(figures in bold are significantly different).

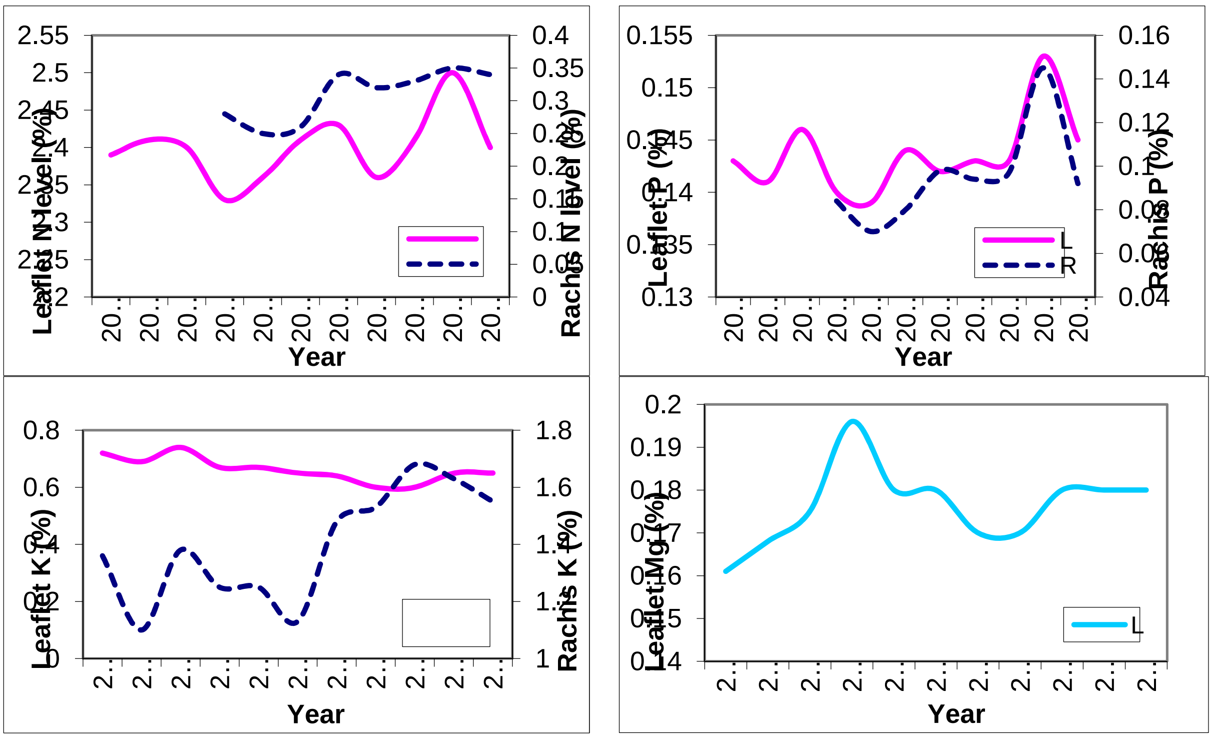


Figure 2. **Long term effect fertiliser treatments on leaflet and rachis nutrient levels (2002-2012).**

Effects of fertilizer treatments on vegetative growth parameters

In 2012, AN and TSP application significantly ($p<0.05$) increased the number of green fronds (GF) on the palm (Table 10& Table 11). Similarly, the number of green fronds (GF) and the bunch dry matter

(BDM) also responded significantly ($p<0.05$) to the treatment interactions (Table 10). All the other physiological parameters did not respond to the fertiliser treatments.

Table 10. Effect (*p* values) of treatments on vegetative growth parameters in 2012.

Fertilizer	PCS	Radiation Interception				Dry Matter Production (t/ha)			
	(cm^2)	GF	FP	FA	LAI	FDM	BDM	TDM	VDM
AN	0.711	**0.008**	0.986	0.668	0.088	0.83	0.657	0.844	0.791
EFB	0.762	0.093	0.858	0.452	0.312	0.788	0.999	0.633	0.847
TSP	0.318	**0.004**	0.093	0.638	0.22	0.885	0.269	0.682	0.806
KIE	0.837	0.871	0.068	0.369	0.185	0.712	0.515	0.367	0.653
EFB.KIE	0.819	0.349	0.518	0.426	0.194	0.747	0.155	0.558	0.836
EFB.N	0.320	0.314	0.709	0.627	0.905	0.378	**0.050**	0.621	0.474
KIE.N	0.350	0.312	0.988	0.561	0.999	0.351	**0.046**	0.627	0.446
EFB.TSP	0.379	**0.012**	0.786	0.946	0.142	0.335	0.762	0.593	0.355
KIE.TSP	0.388	0.478	0.553	0.353	0.189	0.296	0.232	0.937	0.348
N.TSP	0.671	0.636	0.95	0.110	0.169	0.678	0.392	0.851	0.732
EFB.KIE.N	0.592	**0.035**	0.488	0.364	0.724	0.459	0.286	0.252	0.417
EFB.KIE.TSP	0.206	0.974	0.425	0.521	0.505	0.308	0.452	0.243	0.289
EFB.N.TSP	0.630	**0.047**	0.568	0.568	0.203	0.79	0.484	0.553	0.752
KIE.N.TSP	0.371	0.966	0.746	0.807	0.753	0.458	0.861	0.521	0.457
CV %	**14.4**	**3.5**	**4.6**	**5.9**	**5.9**	**13.6**	**14.2**	**10.6**	**12.8**

P values less than 0.05 are in bold.
PCS = Petiole cross-section of the rachis (cm^2); GF = number of green fronds (fronds per palm); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production (t/ha/yr); BDM = Bunch Dry Matter production (t/ha/yr); TDM = Total Dry Matter production (t/ha/yr); VDM = Vegetative Dry Matter production (t/ha/yr).

Table 11. Effect of AN and TSP on number of green fronds

Fertiliser (kg/palm)	Number of Green Fronds
AN2.3	33.0*b*
AN4.6	34.0*a*
LSD	*0.70*
TSP0	33.0*b*
TSP3	34.0*a*
LSD	*0.70*

Note: Same letter denote means are not different, while different letters indicate the means differ statistically.

Discussion

The initial objective of the trial was to investigate if EFB when applied in combination with TSP and KIE will have any positive effects on both yield and growth of the oil palm. Nitrogen was incorporated as a treatment in late 2007, when palms showed signs of N deficiency. In 2012, the response in terms of yield parameters, leaf tissue concentrations and palm growth in relation to the treatments were not pronounced. While the yield parameters (FFB yield, SBW and BHA) did not respond to the treatments, some responses were observed in the leaflet and rachis concentrations as well as number of green fronds and BDM. For the last 5 years (2007 – 2011), an average FFB yield of 31 t/ha was produced from the trial block. These reasonably high yields could mean more nutrients being mobilised towards the production of bunches than the vegetative growth of the palms. This could be the reason why the yields were lower in 2012 and no significant responses on the yield and its parameters because resources are now being concentrated towards the vegetative growth of the palm and not towards the growth of the bunches.

Conclusions

In 2012, the FFB yields, BHA and SBW did not respond to the fertiliser treatments. Similarly, no significant interaction between EFB application and the other inorganic fertilisers (AN, TSP, KIE) on FFB yields were observed in 2012 either. Some responses were observed on the leaf tissue levels and physiological parameters of the palm. The FFB yields were slightly lower (difference of 2 t/ha) in 2012 compared to 2011. Similarly, the leaflet N and P with rachis K and P declined in 2012. The number of green fronds was increased slightly with AN and TSP applications.

Trial 211: Systematic N Fertiliser Trial on Volcanic soils, Navo Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

Nitrogen (N) is an important nutrient for both oil palm yield and growth. This systematic N fertiliser trial was established to investigate effects of applying 9 different rates of N (0-2.0 kg N/palm) on oil palm growth and production. There was a drop in yield of between 2-4t/ha in 2010 but increase in 2012, due to bunches collected (bunches/ha), however single bunch weight (kg/ha) remained steady. An increase of 12t/ha yield response resulted from the application of 5.18kg/palm AN (1.75kg N/palm) in 2012. Regardless of the N fertiliser rates, the average optimum yield of 36t/ha was achieved at a rate of 2.96kg of AN/palm. Even some of the trial treatments archived a yield of around 39t/ha. N application had a significant effect on leaflet N and most of the dry matter production parameters of the oil palm.

Introduction

Factorial fertiliser trials with randomised spatial allocation of treatments generally showed poor responses to fertilisers in NBPOL trials since late 1980s. Yields and tissue nutrient concentrations in control plots were generally higher than would be expected. It was suspected that fertiliser may be moving from plot to plot (nutrient poaching). Large plots, guard rows and trenches between plots were introduced to avoid poaching of nutrients between plots, but a lack of response persisted.

Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of fertiliser are not adjacent. The purpose of the trial was to provide a response curve to N fertiliser that will be used to determine optimum N input in the Navo area.

Table 12. Trial 211 background information.

Trial number	**211**	Company	Hargy Oil Palm Ltd -HOPL
Plantation	Navo	Block No.	Field 11, Rd 6-7, Ave 11 to 13
Planting Density	115 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Poor
Date planted	March 1998	Topography	Flat and swampy
Age after planting	14 years	Altitude	164 m asl
Treatments 1st applied	Nov 2001	Previous Land-use	Sago and forest
Progeny	unknown	Area under trial soil type (ha)	37.16
Planting material	Dami D x P	Assistant Agronomist in charge	Susan Tomda

Methods

Experimental Design and Treatments

This trial was established at Navo Plantation in 2001 (Table 12). Nitrogen systematic trials were designed especially for coarse textured volcanic soils to minimize the effect of fertiliser applied to one plot having an effect on the adjacent plot. The systematic design received 9 rates of N replicated 8 times , resulting in 72 plots. For each replicate, 9 treatments were randomly allocated to 72 plots. The rates applied increase from 0 to 2kg N/palm with 0.25kg N/palm increments (equivalent to 0 to 5.92kg AN/palm at 0.74kg AN/palm increments). The trial was designed such that in each adjacent replicate block the N rates increase or decrease systematically (Figure 3). Each plot consisted of 4 measured rows of palms with 13 palms each resulting in 52 palms/plot. This trial at Hargy followed the same design as trials 137 and 138 with NBPOL and 212 at Hargy Area 8.

Ammonium nitrate (AN) is used in this trial and applied in two split doses during the year. All palms within the trial field received an annual blanket application of MOP, kieserite, TSP and calcium borate (B), at 2.0kg, 1.5kg, 0.5kg and 0.150kg per palm respectively.

Replicate 1									Replicate 2								
N8	N7	N6	N5	N4	N3	N2	N1	N0	N0	N1	N2	N3	N4	N5	N6	N7	N8

decrease - increase

increase - decrease

Figure 3. N rate increase and decrease systematically (N rate increments are at 0.25kg N/palm)

Table 13. Nitrogen treatments and rates

N Fertiliser Code	N0	N1	N2	N3	N4	N5	N6	N7	N8
Ammonium Nitrate (kg/palm/year)	0	0.74	1.48	2.22	2.96	3.70	4.44	5.18	5.92
N rate (equivalent) (N kg/palm/year)	0	0.25	0.50	0.75	1.0	1.25	1.50	1.75	2.0

Data Collection

Field data (yield and vegetative) were taken from 52 palms in the 4 rows within each treatment in each plot. The number of bunches and bunch weights were recorded at 10 day harvesting intervals (started in 2011) in line with company practice on an individual palm basis and totalled for each plot, then totalled for each harvest and expressed as per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Vegetative measurements, including height measurement and frond production (frond mark and frond count) were also done annually.

Quality checks were also done every month on yield recording and other vegetative parameters (leaf sampling, height measurement, frond production and trial block assessment.

Statistical Analysis

Analysis of variance (One-way ANOVA) of the main effects of fertiliser and their interactions were carried out for each of the variables of interest using the GenStat statistical program.

Results

Effects of treatments on FFB yield and its components

N fertiliser treatment had a significant effect ($p<0.001$) on FFB yield and its components in 2012 and the combined 2010-2012 period (Table 14 & Table 15). There was an increase in the grand mean of 5t/ha in 2012 compare to 2011. The significant effect on yield was mainly due to increase number of bunches per hectare (BNO/ha).(correlation = 0.993 & highly significant <0.001). Generally, the yields increased with increasing rates of AN fertiliser with a yield response of 3.0 to 12.0t/ha in 2012 and 3.0 to 10.0t/ha in 2010-2012 respectively (Table 14). FFB yield and its components had significant response in the last five years (2007-2011) running average.

Table 14. Main effects of treatments on FFB yield (t/ha), Bunch number (b/palm and b/ha) and SBW (kg/bunch) by N rate for 2012 and 2010-2012.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	2012 FFB yield (t/ha)	2012 BHA	2012 SBW (kg)	2010-2012 FFB yield (t/ha)	2010-2012 BHA	2010-2012 SBW (kg)
0	0.0	**27.1**	**1226**	**22.2**	**28.1**	**1348**	**20.9**
0.25	0.74	**30.2**	**1312**	**23.2**	**31.1**	**1426**	**21.9**
0.5	1.48	**32.6**	**1381**	**23.8**	**33.0**	**1484**	**22.4**
0.75	2.22	**35.6**	**1483**	**24.3**	**35.0**	**1542**	**22.8**
1.0	2.96	**36.3**	**1508**	**24.3**	**36.2**	**1598**	**22.8**
1.25	3.70	**37.6**	**1532**	**24.8**	**37.5**	**1612**	**23.4**
1.5	4.44	**37.4**	**1567**	**24.1**	**36.5**	**1593**	**23.0**
1.75	5.18	**39.4**	**1616**	**24.7**	**38.3**	**1649**	**23.4**
2.0	5.92	**38.7**	**1612**	**24.3**	**37.6**	**1639**	**23.0**
	Grand Mean	35.0	1471	24.0	34.8	1544	22.6
	Significance	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	LSD	3.4	124	0.75	2.9	102.	0.80
	CV%	9.6	8.4	3.1	8.3	6.6	3.5

P values <0.05 are in bold.

Yield response over time

There was a gradual increase in yield with increasing N since 2003 (palm age: 5 years) to 2009 (palm age: 11 years) (Figure 4). The differences between the AN rates increase with time however Control plot with no N fertiliser continued to produce reasonably high yields.

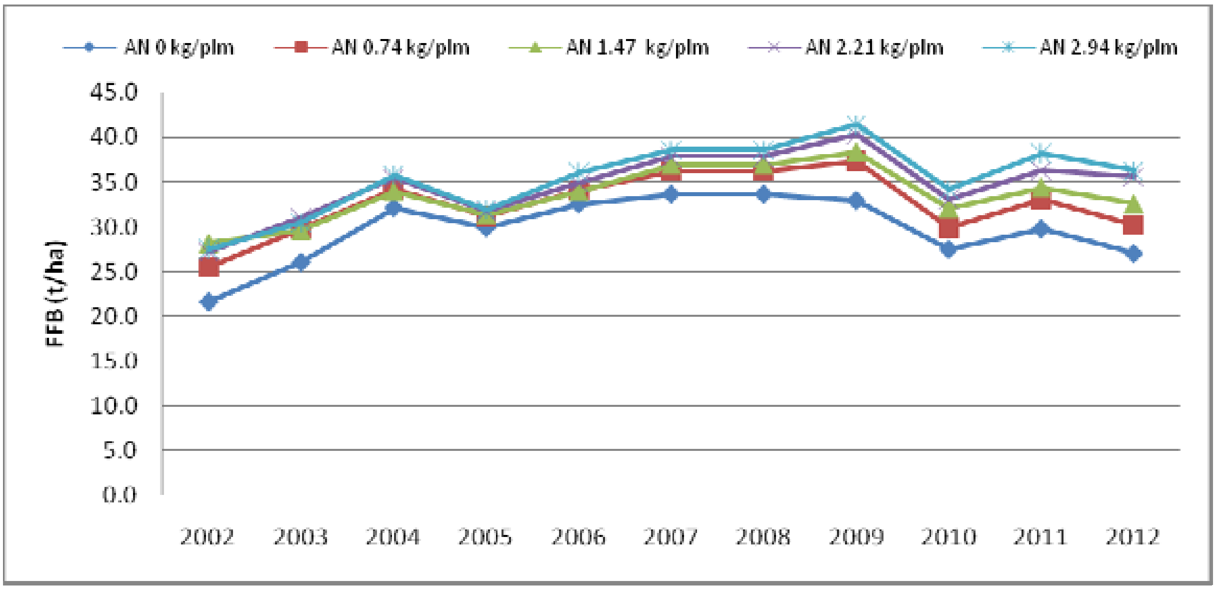


Figure 4. Yield trend from 2002 to 2012 for 5 rates of N (kg/palm) with optimum rate of 2.94kg AN/palm maintaining above 30t/ha after 3 years of maturity.

Effects of treatments on leaf (F17) nutrient concentrations

AN application significantly ($p<0.001$) increased leaflet N and P and rachis N. Leaflet Mg and rachis P levels were reduced with N application. Both leaflet and rachis K did not show a significant response to AN treatment (Table 15). Similarly, B level was also not significant. Though statistically significant, most nutrient contents were below their respective critical concentrations for leaflet except for rachis N and K.

Table 15. Effects (p values) of treatments on frond 17 nutrient concentrations in 2012.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaf (% dm)					Rachis (% dm)		
		N	P	K	Mg	B (ppm)	N	P	K
0.00	0.00	**2.17**	**0.128**	0.68	**0.22**	18.4	**0.36**	**0.08**	2.05
0.25	0.74	**2.13**	**0.127**	0.70	**0.20**	17.3	**0.35**	**0.07**	1.92
0.50	1.48	**2.21**	**0.129**	0.70	**0.18**	17.3	**0.35**	**0.07**	1.95
0.75	2.22	**2.25**	**0.130**	0.71	**0.18**	16.4	**0.37**	**0.06**	1.83
1.00	2.96	**2.36**	**0.134**	0.72	**0.16**	15.4	**0.39**	**0.06**	1.92
1.25	3.70	**2.38**	**0.133**	0.74	**0.16**	14.9	**0.39**	**0.06**	1.86
1.50	4.44	**2.39**	**0.135**	0.73	**0.16**	15.7	**0.41**	**0.06**	1.88
1.75	5.18	**2.39**	**0.135**	0.71	**0.16**	15.2	**0.40**	**0.06**	1.85
2.00	5.92	**2.41**	**0.136**	0.72	**0.16**	15.4	**0.39**	**0.07**	1.84
Grand Mean		2.30	0.132	0.71	0.17	16.2	0.38	0.06	1.90
Significance		**<0.001**	**<0.001**	0.06	**<0.001**	0.13	**<0.001**	**0.048**	0.09
LSD		0.07	0.034	-	0.02	-	0.039	0.013	-
CV%		3.2	2.6	4.9	12.9	11.4	10.3	19.4	7.5

(p values less than 0.05 are in bold).

Tissue N concentration over time - 2004 to 2012

The mean leaflet N content fell with time from 2.70% in 2004 to 2.30% in 2012 (Table 16). The low N rates (0, 0.25 and 0.75kg N/palm) have fallen below critical levels in 2012. Leaflet N levels slowly change over time with the Control treatment (0kg/palm) reaching low levels whereas the highest rates of N is maintaining good leaflet N status from 2004 to 2009 but below critical level in 2010, 2011 and 2012.

Table 16 ***Leaflet N (% dm) over time.***

N rate (kg/plm)	Equivalent AN rate (kg/plm)	Leaflet N (%DM)								
		2004	2005	2006	2007	2008	2009	2010	2011	2012
0	0	2.66	2.6	2.44	2.4	2.36	2.25	2.2	2.26	2.17
0.25	0.74	2.67	2.63	2.46	2.48	2.38	2.29	2.21	2.15	2.13
0.5	1.48	2.72	2.65	2.51	2.51	2.46	2.37	2.31	2.26	2.21
0.75	2.22	2.72	2.67	2.5	2.53	2.49	2.42	2.34	2.34	2.25
1	2.96	2.71	2.68	2.52	2.57	2.54	2.45	2.4	2.42	2.36
1.25	3.7	2.71	2.66	2.51	2.56	2.56	2.5	2.4	2.47	2.38
1.5	4.44	2.67	2.69	2.54	2.6	2.57	2.46	2.38	2.47	2.39
1.75	5.18	2.69	2.68	2.5	2.57	2.57	2.52	2.41	2.49	2.39
2	5.92	2.72	2.65	2.52	2.56	2.46	2.54	2.4	2.41	2.41
Grand	mean	2.7	2.66	2.5	2.53	2.49	2.42	2.34	2.37	2.30
Significance		**NS**	**p=0.02**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD		-	0.05	0.08	0.04	0.09	0.08	0.08	0.09	0.07
CV %		2.1	1.9	2.2	1.5	3.6	3.3	3.3	4	3.2

Fertiliser effects on vegetative growth parameters in 2012

Increasing rates of AN had a positive and significant effect on LAI and VDM (p=0.02) FA, BDM, TDM and PCS (p<0.001) (Table 17). However, N fertiliser had no effect on total green fronds (GF), frond production and fresh dry matter. An average of 20 new fronds were produced in 2012 (one in every 18 days), indication of good growing conditions during the year. Total green fronds counted per palm averaged at 35 fronds which is slightly low (could be lower pruning standard). The two assessments of canopy coverage, Frond area (based on leaflet length and width) and LAI (Leaf Area Index) were affected by the AN fertiliser applied (p=0.001 and p=0.002) respectively.

Table 17. Main effects of N treatments on vegetative growth parameters in 2012.

N rate Kg/palm	Equiv-AN rate kg/palm	Radiation Interception					Dry matter production (t/ha/yr)			
		PCS	GF	FP	FA	LAI	FDM	BDM	TDM	VDM
0.00	0.00	**35.7**	34.8	21.0	**11.9**	**4.8**	9.30	**14.3**	**26.3**	**12**
0.25	0.74	**38.0**	35.5	21.5	**12.7**	**5.2**	10.1	**16.2**	**29.2**	**13**
0.50	1.48	**42.2**	35.4	21.2	**13.6**	**5.5**	10.9	**17.2**	**31.3**	**14.1**
0.75	2.22	**43.7**	36.1	22.7	**13.5**	**5.6**	12.1	**18.8**	**34.4**	**15.6**
1.00	2.96	**45.1**	36.1	20.7	**13.4**	**5.6**	11.4	**19.3**	**34.2**	**14.9**
1.25	3.70	**48.8**	35.2	21.3	**13.6**	**5.5**	12.6	**21.4**	**37.8**	**16.4**
1.50	4.44	**45.0**	35.9	19.4	**13.5**	**5.6**	10.7	**21.1**	**35.3**	**14.2**
1.75	5.18	**46.1**	35.2	19.5	**13.6**	**5.5**	11.0	**22.2**	**36.9**	**14.7**
2.00	5.92	**52.7**	36.0	20.1	**13.9**	**5.8**	12.8	**21.9**	**38.5**	**16.7**
Grand Mean		44.1	35.6	20.8	13.3	5.4	11.2	19.1	33.8	14.6
Significance		**<0.001**	0.526	0.752	**0.001**	**0.002**	0.06	**<0.001**	**<0.001**	**0.02**
LSD		6.5	-	-	0.91	0.45	-	2.75	4.46	2.65
CV %		14.7	4	17.7	6.8	8.2	20.5	14.4	13.2	18.1

(Significant effects ($p<0.05$) are shown in bold)

PCS = Petiole cross-section of the rachis (cm^2); GF = number of green fronds (fronds per palm); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond dry matter production (t/ha/yr); BDM = Bunch dry matter production (t/ha/yr); TDM = Total dry matter production (t/ha/yr); VDM = Vegetable dry matter production (t/ha/yr)

Discussion

Application of N fertiliser of increasing N levels elevated yields to more than 35t/ha in 2012. Yields of over 30t/ha was realized at N rates more than 0.7kg N/palm (equivalent of more than 2.0 kg AN/palm). The optimum yield of 36.3t/ha was achieved at 1.0kg N/palm (equivalent of 2.96kg/palm AN). Effects of treatments (N) on FFB yield (t/ha) were significant in 2012 and this positive response had been consistent since 2003 which was 2 years after first application of N treatments.

Leaflet N, P, Mg and rachis N and P are had a significant response to N treatment (p=0.05) except leaflet K and rachis K. Although K is not significant, critical levels were found to be adequate, (LK (0.71) and RK (1.90)).

For the physiological parameters, PCS, FA, LAI, BDM, TFD and VDM were significant (p=0.002) with increasing N treatment. N fertiliser increased the PCS which is a primary indicator of good growth.

Conclusion

N fertiliser had a significant effect on yield and it components in 2012 and over the combined 2010-2012 period. Tissue N, P, Mg and most physiological growth parameters were also significant. Increasing the N rate from 0.74 – 5.92kg/palm increased yield, PCS, GF, FA, LAI, FDM, BDM, TDM and VDM. Although statistically significant, leaflet N contents and yield in the low N rate plots have been falling with time. Results from 2010 and 2012 indicated that N leaflet levels in the three lowest N treatments plots (0.00, 0.25, & 0.50kg N/palm) were deficient, (critical level 2.45%). This was also clear with visible symptoms of deficiency seen in the field.

Trial 212: Systematic N Fertiliser Trial on Volcanic soils, Hargy Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

Trial 212 is a systematic N fertiliser trial established to investigate effects of applying 9 different rates of N (0-2.0kg N/palm) on oil palm growth and production. There was a significant effect on yield and its components in 2012 ($p<0.001$). There was a gradual increase of N treatments with increasing N. A 4t /ha increase in yield was observed in 2012 period. An optimum yield of 31.2t/ha for the trial block was achieved at a rate of 1.44kg AN/palm. N application had a significant effect in leaflet N and rachis N and most of the physiological parameters ($p<0.001$).

Introduction

Factorial fertiliser trials with randomised spatial allocation of treatments generally showed poor responses to fertilisers in NBPOL trials since late 1980s. Yields and tissue nutrient concentrations in control plots were generally higher than would be expected. It was suspected that fertiliser may be moving from plot to plot (nutrient poaching). Large plots, guard rows and trenches between plots were introduced to avoid poaching of nutrients between plots, but lack of response persisted.

Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of fertiliser are not adjacent. The purpose of the trial is to provide a response curve to N fertiliser that will be used to determine optimum N input in the Hargy area.

Table 18. Trial 212 background information.

Trial number	**212**	Company	Hargy Oil Palms Ltd.
Estate	Hargy	Block No.	Area 8, blocks 10 and 11
Planting Density	140 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Free draining
Date planted	Feb 1996	Topography	Moderate slope
Age after planting	16 years	Altitude	103 m asl
Treatments 1st applied	2002	PreviousLand use	Oil palm
Progeny	unknown	Area under trial soil type (ha)	
Planting material	Dami D x P	Assistant Agronomist in charge	Susan Tomda

Methods

Experimental Design and Treatments

The Nitrogen (N) Systematic trial has a structure of 9 N rates applied in 8 replicated blocks, resulting in a total of 72 plots. The rates applied increase from 0 to 2kg N/palm in 0.25kg N/palm increments (equivalent to 0 to 5.92kg AN/palm at 0.74kg AN/palm increments). The trial is designed such that in each adjacent replicate block the N rates increase or decrease systematically (Figure 5). It is purposely set out that way so that any nutrient shift from high to low N rate underground can be detected. This trial is similar in design to Trial 211, however, unlike Trial 211, Trial 212 has 2 measured rows (middle rows) of 15 palms each (30 palms/plot) and one guard row palm at both ends (3-4 guard row palms in a plot).

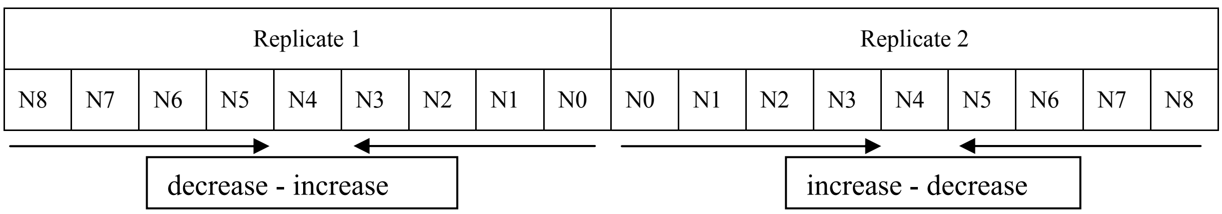


Figure 5. N rate increase/decrease systematically (N rate increments are at 0.25kg N/palm)

Table 19. Nitrogen treatments and rates.

N Fertiliser Code	N0	N1	N2	N3	N4	N5	N6	N7	N8
Ammonium Nitrate (kg/palm/year)	0	0.74	1.48	2.22	2.96	3.70	4.44	5.18	5.92
N rate (equivalent) (N kg/palm/year)	0	0.25	0.50	0.75	1.0	1.25	1.50	1.75	2.0

Ammonium nitrate (AN) was applied in two split doses in the middle and towards the end of the year. In 2009 a basal application of MOP (2kg), KIE (3.0kg), TSP (0.5kg) and Borate (0.150kg/palm) was applied.

Data Collection
Field data (yield and vegetative) were taken from 30 palms in the 2 rows within each treatment in each plot. The number of bunches and bunch weights were recorded at 10 day harvesting intervals (started in 2011) in line with company practice on an individual palm basis and totalled for each plot, then totalled for each harvest and expressed as per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Vegetative measurements, including height measurement and frond production (frond mark and frond count) were also done annually.

Quality checks were also done every month on yield recording and other vegetative parameters (leaf sampling, height measurement, frond production and trial block assessment.

Statistical Analysis
Analysis of variance (One-way ANOVA) of the main effects of fertiliser and their interactions were carried out for each of the variables of interest using the GenStat statistical program.

Effects of treatment and FFB yield and its components
AN had a significant effect ($p<0.001$) on yield and its components in 2012 and combined 2010-2012 period (Table 20). The increase in yield was due to significant increases in the number of bunches and single bunch weight. A yield response of 0.7 – 6.5t/ha was obtained from AN application in 2012. Despite a 2t/ha drop in yield in 2010 in the grand mean, there was an increase of 4t/ha in the FFB yield mainly due to the increasing number of bunches as observed in 2012. Though, SBW differs significantly ($p<0.001$), the weights remain the steady. The highest yield increase of 7t/ha was archived at 4.4kg AN/palm, an increase from 4 tonnes in 2011.

Table 20. Main effects of N treatments on FFB yield (t/ha) for 2012 and 2010-2012.

		2012			2010-2012		
N rate (kg/palm)	**Equivalent AN rate (kg/palm)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW(kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW(kg)**
0.00	0.0	**25.6**	**1093**	**23.4**	**23.9**	**1056**	**22.6**
0.25	0.74	**23.8**	**1008**	**24.1**	**23.5**	**1013**	**23.4**
0.50	1.48	**26.3**	**1062**	**24.8**	**26.1**	**1082**	**24.2**
0.75	2.22	**28.2**	**1064**	**25.6**	**26.8**	**1077**	**25.0**
1.00	2.96	**30.4**	**1110**	**26.8**	**27.0**	**1056**	**25.7**
1.25	3.70	**31.1**	**1142**	**25.9**	**28.2**	**1135**	**24.9**
1.50	4.44	**32.1**	**1205**	**25.9**	**29.6**	**1170**	**25.3**
1.75	5.18	**30.9**	**1241**	**26.2**	**28.9**	**1148**	**25.2**
2.00	5.92	**32.0**	**1185**	**25.8**	**29.2**	**1185**	**24.8**
Grand Mean		28.9	1144	25.4	27.0	1103	24.6
Significance		**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD		3.05	115.7	1.23	1.92	85.1	1.15
CV%		10.5	10.1	4.8	7.1	7.7	4.7

p values <0.05 are shown in bold.

Yield response over time

There was a significant effect ($p<0.001$) of applying N on yield two years (2004) after N was first applied as treatment in the trial. The yearly yield response to N fertiliser has been gradually increasing over time. There has been a decrease in yield of 2t/ha in 2012 in all N treatments including the control plots.

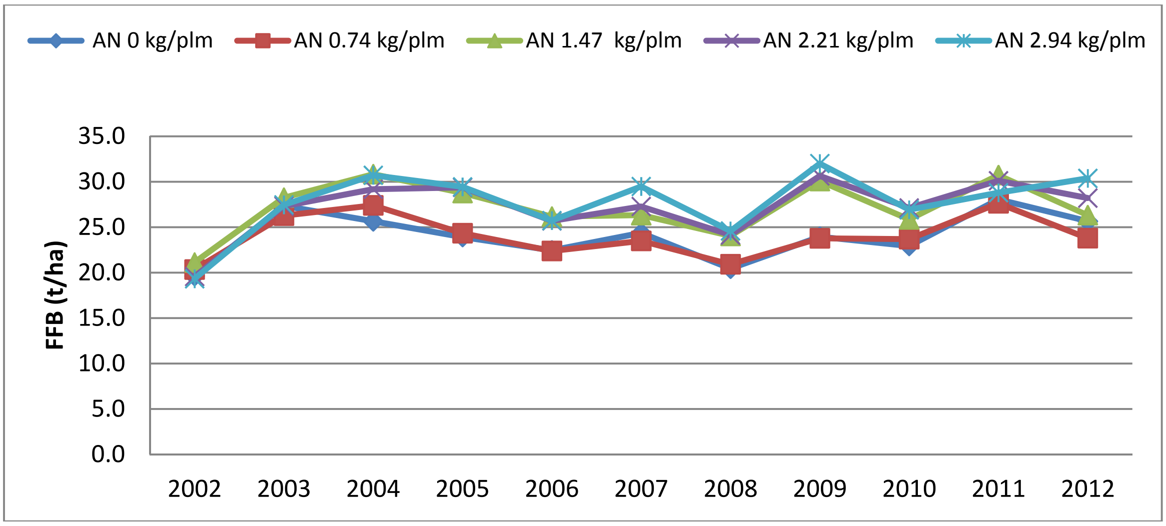


Figure 6. Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in 2002).

Effects of treatments on leaf (F17) nutrient concentrations

N treatment had a significant effect on the concentration of leaflet N ($p<0.001$), P ($p=0.002$) and Mg ($p<0.001$) contents only (Table 21), however N application decreased B leaflet levels. Leaflet K and B with rachis N, P and K contents did not respond to the N treatment. Leaflet N concentrations were generally low and below the optimum range (2.45 – 2.50 %). Similarly, the leaflet P contents were also below the adequate level of 0.145. The rachis N and K contents were adequate.

Table 21. Main effects of treatments on frond 17 nutrient concentrations in 2012, in units of % dry matter.

Nrate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet nutrient concentration (% DM)					Rachis nutrient concentration (% DM)		
		N	P	K	Mg	B	N	P	K
0.00	0.00	**2.21**	**0.133**	0.67	**0.203**	17.6	0.30	0.035	1.63
0.25	0.74	**2.22**	**0.131**	0.67	**0.199**	16.7	0.30	0.042	1.56
0.50	1.48	**2.25**	**0.132**	0.62	**0.191**	16.9	0.30	0.037	1.51
0.75	2.22	**2.29**	**0.132**	0.64	**0.185**	16.7	0.31	0.037	1.50
1.00	2.96	**2.32**	**0.132**	0.66	**0.179**	15.8	0.31	0.036	1.45
1.25	3.70	**2.35**	**0.134**	0.64	**0.178**	15.3	0.33	0.041	1.47
1.50	4.44	**2.39**	**0.136**	0.66	**0.168**	16.3	0.31	0.042	1.52
1.75	5.18	**2.42**	**0.135**	0.68	**0.170**	16.6	0.33	0.040	1.48
2.00	5.92	**2.43**	**0.138**	0.69	**0.160**	15.6	0.34	0.042	1.52
Grand mean		2.32	0.134	0.66	0.181	16.4	0.31	0.040	1.52
Significance		**<0.001**	**0.003**	0.16	**<0.001**	0.18	0.16	0.44	0.18
LSD		0.062	0.004	-	0.02	-	-	-	-
CV%		2.7	3.1	7.0	9.9	10.2	9.2	16.9	11.7

p values <0.05 are shown in bold.

Tissue N concentration over time 2004 to 2012

There was a significant effect ($p<0.001$) in N rate treatments from 2004 to 2012. In each year, leaflet N levels increased with increasing rates of applied N but gradually decrease over time (Table 22). The mean leaflet N contents fell with time from 2.43% in 2004 to 2.32% DM in 2012. Leaflet N levels in most of the N rates treatment (0-1.75kg N/palm) fell below critical levels with time (Table 22).

Table 22. Leaflet N (% DM) from 2004 to 2012

N rate (kg/palm)	*Equivalent AN rate (kg/palm)*	*Leaflet N (% DM)*								
		2004	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***
0.00	0.00	2.35	2.30	2.25	2.21	2.20	2.18	2.26	2.25	2.21
0.25	0.74	2.38	2.35	2.29	2.24	2.20	2.15	2.28	2.31	2.22
0.50	1.48	2.45	2.44	2.36	2.33	2.29	2.24	2.27	2.34	2.25
0.75	2.22	2.43	2.45	2.36	2.35	2.30	2.28	2.34	2.32	2.29
1.50	2.96	2.42	2.47	2.41	2.39	2.34	2.33	2.36	2.41	2.32
1.25	3.70	2.45	2.51	2.41	2.36	2.34	2.35	2.40	2.43	2.35
1.50	4.44	2.46	2.51	2.43	2.40	2.36	2.38	2.44	2.42	2.39
1.75	5.18	2.45	2.5	2.44	2.45	2.40	2.40	2.46	2.44	2.42
2.00	5.92	2.48	2.54	2.43	2.42	2.39	2.41	2.43	2.47	2.43
Grand mean		2.43	2.45	2.37	2.35	2.31	2.30	2.36	2.39	2.32
Significance		**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD		0.05	0.05	0.04	0.05	0.06	0.04	0.06	0.06	0.06
CV %		2.3	2.1	1.8	2	2.4	1.9	2.7	2.4	2.7

Effects of fertiliser treatments on vegetative growth parameters

The N fertiliser treatment had significant effects ($p<0.05$) on all the vegetative growth parameters except fronds produced per year (FP) and frond area (FA) (Table 23). PCS was increased by 1 to nearly 10 cm^2, similarly the dry matter production was also increased with N fertiliser. The frond area (though not significant) and the LAI were also elevated with N fertiliser treatment.

An average of 22 fronds was produced (one in every 15 days). Total green fronds counted per palm averaged at 31 fronds which was lower than 2011 (34 fronds).

Table 23. Main effects of treatments on vegetative growth parameters in 2012.

N rate kg/palm	Equiv. AN rate kg/palm	Radiation Interception					Dry Matter Production (t/ha)			
		PCS	GF	FP	FA	LAI	FDM	BDM	TDM	VDM
0.00	0.00	42.7	29	22	13.4	5.5	13.9	21.0	38.9	17.8
0.25	0.74	44.3	30	21	13.4	5.7	14.2	19.5	38.74	17.9
0.50	1.48	46.4	30	22	14.4	6.1	14.9	21.6	40.5	19.0
0.75	2.22	48.8	31	22	14.5	6.4	15.8	23.1	43.2	20.1
1.00	2.96	53.5	31	22	14.5	6.2	17.4	24.9	47.0	22.1
1.25	3.70	51.4	31	22	14.8	6.5	16.4	25.5	46.5	21.1
1.50	4.44	52.2	32	22	14.4	6.5	16.9	26.3	48.1	21.7
1.75	5.18	51.6	33	21	14.4	6.6	16.4	25.4	46.4	21.1
2.00	5.92	50.3	33	22	14.4	6.5	16.4	26.2	47.3	21.1
Mean		49.0	31	22	14.2	6.2	15.8	23.7	43.9	20.2
Significance		**p<0.001**	**p=0.05**	NS	NS	**p=0.008**	**p=0.002**	**<0.001**	**<0.001**	**<0.001**
LSD		5.31	2.2	-	-	0.65	1.81	2.5	3.79	2.1
CV %		10.8	7.2	3.4	7.8	10.4	11.5	10.5	8.6	10.4

Significant effects (p<0.05) are shown in bold
PCS = Petiole cross-section of the rachis (cm^2); GF = number of green fronds (fronds per palm); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production (t/ha/yr); BDM = Bunch Dry Matter production (t/ha/yr); TDM = Total Dry Matter production (t/ha/yr); VDM = Vegetative Dry Matter production (t/ha/yr).

Discussion

Nitrogen (N) is an important nutrient for both oil palm yield and growth. By applying N fertiliser, yields had significantly increased. Yields of 32.1t/ha were achieved at N rate 1.5kg N/palm (equivalent of 4.44 kg AN/palm). Yield from the nil N fertilised plots produced on average 24t/ha for the last 10years. The leaf N levels in these plots (nil N) are lower than 2.45% (deficient) for the last eight years, as was expected. Leaf N levels at each of the treatment levels has been gradually falling over time and could be attributed to palm age. The results in 2012 also indicate that in the first four (4) low N treatments plots (0.00, 0.25, 0.50 & 0.75kg N/palm) leaflet N contents were deficient (critical level 2.45%) and this was evident with visible symptoms in the field.

Most of the vegetative growth were also significant except annual frond production and frond area. LAI is adequate with 6.2 and FA (14.2) indicated that the canopy has a good cover. Total green fronds produced was low, this is could related to poor upkeep (over pruning) in the field. An average of 40-48 fronds per palm should be ideal for a good growing condition here.

Conclusions

N fertilisers had significant effect on yield and its components in 2012 and combined 2010-2012 (p<0.001). There was an increase of 4t/ha in FFB yield as observed in 2012. This was mainly due to the increased number of bunches (BHA).

N rate treatment had a significant effect on leaflet N, P, Mg and most physiological growth parameters, PCS, GF, LAI, FDM, BDM, TDM and VDM. Leaflet N contents in the leaflets had been falling with time.

Trial 214: Phosphorous (TSP) Fertiliser Placement Trial on Volcanic soils, Hargy Plantation
(RSPO 4.2, 4.3, 4.6, 8.1)

Summary
P treatments had significant effect on P level in oil palm rachis only in 2012 tissue analysis results, but no significant effects on the yields, other tissue nutrient levels and vegetative growth of the palms since the treatments started in 2008. Though not significant statistically, FFB yields increased by 4t/ha in 2012 due to the increasing number of bunches, unlike single bunch weight which remained steady at an average of 24kg. There was a drop in nutrient concentrations in N leaflets (2.24%) and K (0.63%) and P (0.140%) but not in rachis P (0.05%). P treatments did not have a significant effect on any physiological parameters.

Introduction
The trial was originally set up as a Magnesium trial in 2007; however it was changed to a P (TSP) placement trial in 2008. The two most important influences on P nutrition on volcanic soils are:

(i) high allophane content of these soils
(ii) soil acidification caused by the use of N based fertilisers.

Allophane will bind phosphate making it unavailable for plant uptake, thus it is important to minimise the direct contact of phosphate with the mineral soil (which is where the allophone material is). Volcanic ash soils have moderate to very low CEC with variable charge and contain allophone and iron oxides which fix phosphates (by forming complexes such as aluminium and iron phosphates). The topsoil at the site contained 6 – 8% allophone (high) and the subsoil around 12% (very high). In addition, soils around the weeded circle are being acidified and hence P in phosphate is becoming less available for uptake. Applying P on the frond pile where the soil is high in organic matter, low in mineral soil and where there are an abundance of palm feeder roots should enable more rapid uptake of P as phosphate.

The aim of the trial was to identify the best option for the placement of TSP in light of volcanic soils containing high levels of allophane.

The initial work on pre-treatment data and soil samples were collected in 2007. The application of treatment fertilisers commenced in October 2008. Trial information are presented in Table 24.

Table 24. Trial 214 back ground information

Trial number	**214**	Company	Hargy Oil Palms Ltd
Estate	Hargy	Block No.	Area 4, block 2
Planting Density	129 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Well drained
Date planted	1994	Topography	Rising and hilly
Age after planting	18 years	Altitude	263 m asl
Recording Started	2006	Previous Land use	Oil palm
Progeny	Unknown	Area under trial soil type (ha)	13.34
Planting material	Dami D x P	Agronomist	Susan Tomda

Pre- treatment Data
Pre-treatment yield (Table 25) and tissue nutrient data (for use as co-variate in following years) were all done in 2007. Plot layout and first round of P fertiliser application (as treatment) was done in October 2008. Soil sampling was also done on selected sites and samples were sent to New Zealand for chemical analysis and allophane content determination (result not available for this report).

Table 25. Pre-treatment yield, PCS and nutrient concentrations for leaflets and rachis in 2007

Treatment	P rates/Placement	Yield	PCS (cm^2)	2007							
	(kg/placement)	(t/ha)		Leaflets (% DM)					Rachis (% DM)		
				N	P	K	Mg	B	N	P	K
1	0.0 – Control	27.5	41.9	2.29	0.134	0.61	0.175	13.8	0.22	0.04	1.10
2	1.0-Weeded circle	29.4	41.1	2.39	0.137	0.63	0.167	15.5	0.22	0.04	1.03
3	1.0 -Frond Pile	27.8	40.9	2.35	0.136	0.65	0.18	15.7	0.23	0.04	1.07
4	2.0 -Weeded circle	27.4	44.1	2.38	0.136	0.64	0.173	14.9	0.23	0.04	1.11
5	2.0 -Frond Pile	29.9	42.9	2.32	0.135	0.63	0.175	15	0.22	0.04	1.05
	Mean	28.4	42.2	2.35	0.136	0.63	0.175	14.9	0.22	0.04	1.07
	Significance	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
	CV(%)	13.5	6.1	3.2	2.7	4.5	11.9	12	5.5	12.2	8.1

Methods

Experimental design and Treatment

The trial had a structure treatment of 5 levels of TSP fertiliser applied in two zones (WC- weeded circle and FP- frond pile) around the palms in each plot (Table 26). In 2012, new rates of TSP were introduced to the trial (Table 27). Treatment fertilizers were applied in split application every year. Basal application in 2010 N (AC) - 4kg/palm/year, MOP (K) – 2kg/palm/year, Kie (Mg) 1kg/palm/year and Borate (B) 150g/palm/year.

Table 26. Fertiliser treatments and rates since 2007 (old TSP rates)

Fertiliser	TSP (kg/palm/yr)				
Levels	1	2	3	4	5
Rates/Placement	0.0 -Nil	1.0 - WC	1.0 - FP	2.0-WC	2.0 - FP

Table 27. Fertiliser treatments and rates since 2012 (new ammended TSP rates)

Fertiliser	TSP (kg/palm/yr)				
Levels	1	2	3	4	5
Rates/Placement	0.0 -Nil	2.0 - WC	2.0 - FP	4.0-WC	4.0 - FP

Statistical Analysis

Yield, its components and tissue nutrient concentration were analysed using ANOVA (General Analysis of Variance with four treatments, each applied at two rates).

Results

There was no significant effect of TSP treatment and placement on yield and its components in 2012 and combined 2010-2012 period. TSP treatments have not shown any significant response since the application of the first treatment in 2007. In addition, BHA and SBW have not shown any significant response to the treatments since the application commenced.

An average of 25.4t/ha was observed in 2010-2012 period as compared to 2009-2011 FFB yield of 24t/ha. Bunch number increased slightly from an average of 907 in 2011 to 1073 bunches/ha in 2012. The average single bunch weight was 22.4kg in 2011 and increased slightly to 26.1kg in 2012. The 2009-2012 data also showed no response to the treatments (Table 28).

Table 28. Effects of yield and its components in 2012 and 2010-2012.

			2012			2010-2012		
levels	(kg/palm/yr)		(t/ha)	(bunch/ha)	(kg/bunch)	(t/ha)	(bunch/ha)	(kg/bunch)
1	0	Control	25.9	1057	24.9	25.6	1027	23.3
2	1	1 - WC	26.8	1098	24.8	26.4	1070	23.9
3	1	2 - FP	25.1	1039	24.6	23.8	1060	23.7
4	2	1 - WC	25.2	1030	25.1	25.4	1033	24.7
5	2	2 - FP	27.3	1143	24.2	26.0	1143	23.4
Mean			26.1	1073	24.7	25.4	1067	23.8
Significance			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV %			16.0	12.9	7.6	31.0	8.1	6.4

(WC- Weeded circle, FP – Frond pile)

Yield response over time

Yield responses were not significant with time, however mean yield increased for all P treatment levels from 2008 -2010 but decrease with 4 t/ha in 2011 then elevated by 4t/h in 2012 (Table 29).

Table 29. FFB yield trend from 2008 to 2012

Treatment levels	P rates kg/palm/yr	Placement	Yield (t/ha)				
			2008	2009	2010	2011	2012
1	0	Control	18.5	23.5	25.2	22.4	25.9
2	1	1 - WC	22.1	25.6	26.9	19.96	26.8
3	1	2 - FP	18.5	23.9	27.2	21.48	25.1
4	2	1 - WC	20.0	23.3	25.0	24.85	25.2
5	2	2 - FP	19.1	24.7	28.4	23.33	27.3
Mean			19.6	24.2	26.6	22.4	26.1
Significance			**NS**	**NS**	**NS**	**NS**	**NS**
CV %			16.8	19.9	10.1	24.3	16.0

Effects of treatments on leaf (frond17) nutrient concentrations

The effects of P placement treatments on leaf tissue nutrient contents are presented in Table 30. Leaflet P did not show a response in 2012 however, rachis P content was significantly increased in 2012 (p=0.002). Both leaflet and rachis P levels appeared to be slightly lower than the adequate level of 0.145% and 0.08% respectively. There appears to be no difference in P contents between 1 and 2 kg TSP and between the two zones (weeded circle and frond pile). Most of the nutrient contents are low except RN which adequate (0.30% dm) and high Boron 21ppm.

Table 30. Tissue nutrient concentrations for leaflet N, P, K, Mg, B and rachis N, P, K in 2012

Treatment levels	Prates/placement kg/palm	2012 Leaflet (%dm) N	P	K	Mg	B	Rachis (%dm) N	P	K
1	Control	2.26	0.137	0.65	0.182	21.1	0.32	**0.043**	1.37
2	1 – WC	2.28	0.140	0.62	0.178	23.7	0.30	**0.048**	1.38
3	2 – FP	2.23	0.138	0.63	0.177	21.2	0.29	**0.053**	1.24
4	1 – WC	2.25	0.144	0.63	0.167	21.3	0.31	**0.060**	1.28
5	2 – FP	2.21	0.142	0.59	0.180	20.9	0.29	**0.064**	1.19
Mean		2.24	0.140	0.63	0.177	21.7	0.30	0.054	1.29
Significance		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**p=0.002**	**NS**
LSD		**-**	**-**	**-**	**-**	**-**	**-**	**0.012**	**-**
CV %		5.3	4.2	5.9	10.6	11.4	7.8	16.8	11.0

Effects of fertiliser treatments on vegetative parameters

Similarly to the other parameters, there was no significant effect on the vegetative growth of the palm to the P rates and fertiliser application zones (Table 31). On average of 21 new fronds were produced in 2012 (one every 17 days). Total green fronds counted per palm averaged 35 fronds, which is low indicating possible over-pruning.

Frond area (FA) and Leaf Area Index (LAI) were not affected by either P treatment and placement (average frond area 14.7m^2 and LAI of 6.7). Regardless of the treatments, there was an increase in PCS and all dry matter production parameters in 2012 (FDM, BDM, TDM and VDM) compared to 2011.

Table 31. Effects of N treatments on vegetative growth parameters in 2012

TSP(P)Levels	P rate / placement (kg/palm)	PCS	Radiation Interception GF	FP	FA	LAI	Dry Matter Production (t/ha) FDM	BDM	TDM	VDM
1	0.0 - Nil	49.5	36	21	14.3	6.7	14.5	13.6	31.2	17.6
2	1.0 - WC	48.1	35	22	14.5	6.5	14.2	14.0	31.3	17.3
3	1.0 - FP	48.4	36	21	14.3	6.7	14.2	13.4	30.6	17.2
4	2.0 - WC	50.7	34	21	15.2	6.7	14.7	13.2	31.0	17.7
5	2.0 - FP	51.2	35	21	15.0	6.7	14.7	14.1	32.0	17.9
	Mean	49.6	35	21	14.7	6.7	14.4	13.7	31.2	17.6
Significance:		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV%		**5.2**	**5.7**	**5.5**	**4.8**	**6.6**	**8.0**	**15.9**	**10.5**	**8.1**

PCS = Petiole cross-section of the rachis (cm^2); GF = number of green fronds (fronds per palm); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production (t/ha/yr); BDM = Bunch Dry Matter production (t/ha/yr); TDM = Total Dry Matter production (t/ha/yr); VDM = Vegetative Dry Matter production (t/ha/yr)

Discussion

There was no significant response in yield or its components since treatment started in 2008. P was significant in rachis but not significant in leaflet tissue levels in 2012. The P levels in both the leaflets and rachis were below the adequate levels and this could have contributed to the nil response in yield and its components. Presence of allophane material in the soil which fixes P in large quantities could mean that the previous P application rates would not be adequate enough to cause any response. In 2012, P rates were increased from 1 to 2kg/palm and 2 to 4kg/palm and we may see some positive responses in the near future. There were no significant responses from the other nutrient concentration and the overall vegetative growth of the palms.

However, application of N as basal since the inception of the trial has improved the N levels in the leaflets over time. The rachis N levels are reasonably high (adequate) due to eventual translocation of N to the leaflets from the rachis, which had boosted the N concentration in the leaflets in 2010- 2012. Rachis N, P, K nutrient concentrations have increased since 2010.

Conclusion

There was no response of TSP and placement on yield, its components and vegetative growth parameters except on rachis P concentrations. After 5 years of treatment application fertiliser type (TSP) and placement showed no difference in yield and its components (BHA and SBW), nutrient levels in leaflets or rachis, or in vegetative parameters such as PCS, frond production or LAI.

Trial 216: N x P x K Trial on Volcanic soils at Barema Plantation
(RSPO 4.2, 4.3, 4.6, 8.1)

Introduction
The trial was set out in March 2009 where unknown progenies of 2 year olds were growing in the field. Twenty four (24) plots were marked out and the 16 core palms were removed and replaced with four known commercial progeny palms (Dami material: 0710226N; 0791065N; 0791195C and 0709668C). The same four progeny planted in each plot will remove progeny effect from the fertiliser response, using central Composite Design requiring 24 plots (see Verdooren in Oil Palm, Management for Large and Sustainable Yields, Fairhurst and Hardter, 2003). Yield recording commenced in December 2012 and fertiliser treatment application is programmed to start in March 2013 (year 4 after planting).

This trial is set up to develop robust fertiliser recommendations using nutrient response curves by applying N x P x K at three rates each.

Table 32. Basic information on trial 216

Trial number	**216**	Company	Hargy Oil Palms Ltd
Estate	Barema	Block No.	Field 14
Planting Density	135 palms/ha	Soil Type	Gravel old Barema river
Pattern	Triangular	Drainage	Freely draining
Date planted	2009	Topography	flat
Age after planting	3 years	Altitude	40 m asl
Recording Started	Dec 2012	Previous Land-use	Forest
Progeny	Known*	Area under trial soil type (ha)	10.7
Planting material	Dami D x P	Assistant Agronomist in charge	Susan Tomda

Note: 4 different identified Dami DxP progenies planted randomly in each plot

Methods

Design and Treatment
Four (4) known progenies were identified/selected (from the commercial Dami material) and planted randomly in each plot including the guard row palms from the same progeny. TSP (100g/palm) was applied at the bottom of the planting hole. Guard row can be any progeny. A total of 50 plots were planted, after the petiole cross section was determined, the final 24 plots was selected for proper treatments. Each plot has 16 monitored palms with 20 guard palms.

The N P K trial was set up as a 3 x 3x 3 Central Composite arrangement, resulting in 24 treatments with 36 palms per plot. Palms that were not in plots but were in the same block were termed perimeter palms, and were fertilised according to plantation practice. The trial area received a basal application of borate at 50 g/palm/year. Data will be collected on the central 16 palms in each plot. The number of bunches and bunch weights will be recorded on a 14 day harvesting intervals in line with company practice on an individual palms and totalled for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight (SBW) will be calculated from these data. Initial leaf sampling was carried out in 2011 and analysed for nutrient concentrations using standard analytical procedures (2012 tissues was not done as it was not budgeted for).

Analysis of variance of the main effects of fertiliser and their interactions will be carried out for each of the variables of interest using the GenStat statistical program.

Table 33. Fertiliser levels and rates used in Trial 216

Fertiliser treatments	Amount (kg/palm/year)		
	Level 1	Level 2	Level 3
AMC	1	4	7
TSP	0	1	2
MOP	0	2.5	5

Table 34. Block layout (including randomisation of treatments)

Block 1		Block 2		Block 3	
Plot no	Treatment	Plot no	Treatment	Plot no	Treatment
1	4	9	22	17	12
2	15	10	7	18	9
3	18	11	20	19	23
4	1	12	5	20	14
5	3	13	21	21	10
6	17	14	6	22	13
7	2	15	8	23	24
8	16	16	19	24	11

Work progress so far;

In 2009:

- 16 central palms planted with four identified progenies
- Guard rows, perimeters also planted
- GPS reference each 'supply' palm
- GPS reference every palm 1 in each plot for future plot/palm location
- Replaced dead core palms with the same spare progenies as supply palms planted nearby after five months of initial planting.
- 1 x three monthly periodic checks to ensure that cover crops and weed are not over grown in the trial
- Palm census once a year.
- Ensure trial upkeep up to plantation standard

In 2010:

- Continue to liaise with plantation on upkeep and other trial maintenance work
- Palm census done at the end of the year
- Periodic checks to ensure that cover crops and weed are not over grown in the trial
- Monthly field visits and trial standard checks

In 2011:

- Continue to liaise with plantation on upkeep and other trial maintenance work
- Palm census done at the end of the year
- Periodic checks to ensure that cover crops and weed are not over grown in the trial
- Monthly field visits and trial standard checks
- Ensure that fertiliser application is done as per plantation schedule
- Plot numbering and painting
- Scout harvesting in July (14 day harvesting interval) until November 2011
- Leaf and rachis samples collected (not sent in for analysis)

In 2012:

- Continue to liaise with plantation on upkeep and other trial maintenance work
- Palm census done at the end of the year

- Periodic checks to ensure that cover crops and weed are not over grown in the trial
- Monthly field visits and trial standard checks
- Ensure that fertiliser application is done as per plantation schedule
- Plot Numbering and Painting (GRs- Blue, Perimeter palms-red, Core palms-black)
- Formal yield recording in December 2012

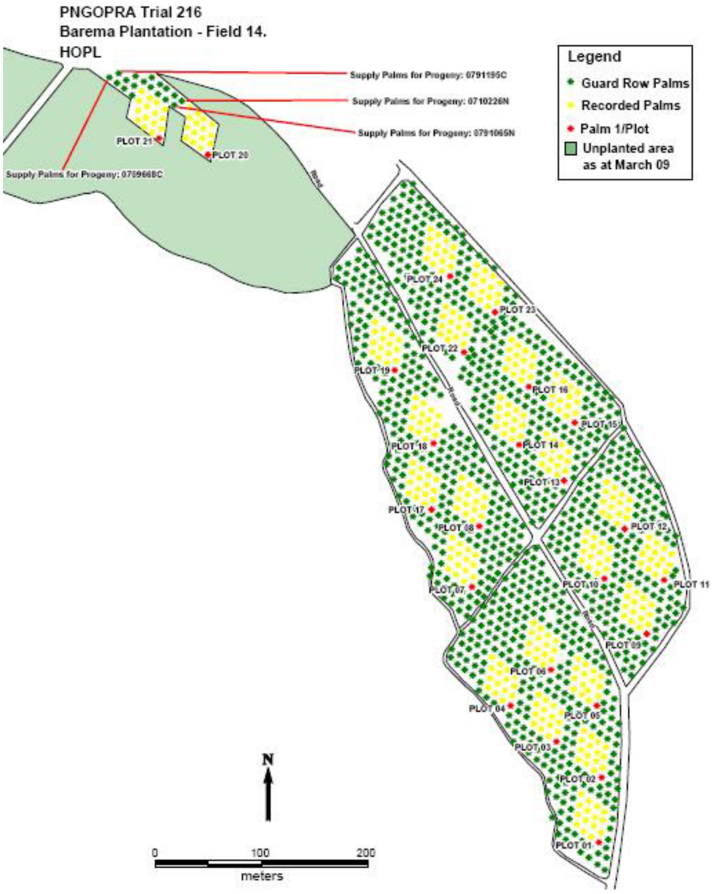


Figure 7. **Map showing T216 – plots and palm numbers**

Trial 217: N x P x K trial on Volcanic soils at Navo Estate,
(RSPO 4.2, 4.3, 4.6, 8.1)

Introduction
The trial was established in December 2011 where four (4) known progenies *(09080221,09070112,09071493,09110165) in* 24 plots were marked out and the 16 core palms were removed and replaced with four known commercial progeny palms (Dami material: 0710226N; 0791065N; 0791195C and 0709668C). The same four progeny planted in each plot will remove progeny effect from the fertiliser response, using central Composite Design requiring 24 plots (see Verdooren in Oil Palm, Management for Large and Sustainable Yields, Fairhurst and Hardter, 2003). Commercial trial fertiliser application will be in March 2015 (year 4 after planting). Trial 217 is a replica of Trial 216 but established on a different soil.

This trial is set up to develop robust fertiliser recommendations using nutrient response curves by applying N x P x K at three rates each.

Table 35. **Basic information on trial 217**

Trial number	**217**	Company	Hargy Oil Palms Ltd
Estate	Navo	Block No.	Navo, Field5 –Block K
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Well drained
Date planted	December 2011	Topography	Flat
Age after planting	14 months	Altitude	40 masl
Recording Started	2015	Previous Land-use	Oil Palm
Progeny	Known*	Area under trial soil type (ha)	17.84
Planting material	Dami D x P	Assistant Agronomist in charge	Susan Tomda

Note: different identified Dami DxP progenies planted randomly in each plot.

Methods

Design and Treatment
Four (4) known progenies were selected (from the commercial Dami material) and planted randomly in each plot including the guard row palms from the same progeny. TSP (100g/plm) was applied at the bottom of the planting hole. Guard row can be any progeny. A total of 50 plots were planted, after petiole cross section is determined, the final 24 plots will be selected for proper treatments. Each plot has 16 monitored palms with 20 guard palms. The N P K trial was set up as a 3 x 3x 3 Central Composite arrangement, resulting in 24 treatments with 36 palms per plot. Palms that were not in plots but were in the same block were termed perimeter palms, and were fertilised according to plantation practice. The trial area received a basal application of borate at 50 g/palm/year in 2012.

Data will be taken on the central 16 palms in each plot. The number of bunches and bunch weights will be recorded on a 14 day harvesting intervals in line with company practice on an individual palms and totalled for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight (SBW) will be calculated from these data. Tissue sampling will be carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Analysis of variance of the main effects of fertiliser and their interactions will be carried out for each of the variables of interest using the GenStat statistical program.

Trial design (Central Composite Design)
Similar to Trial 216 at Barema – refer to Trial design for Trial 216

Work progress so far;

In 2012:

- 16 central palms planted with four identified progenies
- Plots and core palms identification

- Painting of guard rows and core palms
- Isometric map done
- GPS reference each plot soil location
- 1 x three monthly periodic checks to ensure that cover crops and weed are not over grown in the trial
- Palm census done on quarterly basis
- Ensure trial upkeep up to plantation standard
- EFB application (plantation standard)
- Plot identification and pegging
- Ensure that fertiliser application is done as per plantation schedule
- Continue to liaise with plantation on upkeep and other trial maintenance work

Trial 220: N x P x K x Mg trial on Volcanic soils at Alaba Estate,
(RSPO 4.2, 4.3, 4.6, 8.1)

Introduction
N.P.K.Mg factorial trial was setup at Alaba Estate in July 2011. Sixteen (16) known progenies were selected from the commercial Dami material and planted randomly in each plot including the guard row palms from the same progeny. TSP (100g/plm) was placed at the bottom of the hole.
This trial was established purposely to develop robust fertilizer recommendations using for the soils in the area. The same 16 progeny planted in each plot will remove progeny effect from the fertilizer response over time.

Table 36. **Basic information on trial 220**

Trial number	**220**	Company	Hargy Oil Palms Ltd
Estate	Navo	Block No.	Alaba,Field5-B_03
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Well drained
Date planted	2011	Topography	Moderate slope
Age after planting	20 months	Altitude	90 m asl
Recording Started	2015	Previous Land-use	Forest
Progeny	Known*	Area under trial soil type (ha)	31.95
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

Note: 16 different identified Dami DxP progenies planted randomly in each plot.

Methods

Experimental Design and Treatment
Each plot has 16 monitored palms with 20 guard palms. A total of 100 plots were planted.
The trial design and respective treatments are yet to be decided from the soil analysis.

Work progress so far;

In 2011:
- 16 central palms planted with four identified progenies
- Guard rows, perimeters also planted
- GPS reference each plot soil location
- GPS of plots, guard rows and perimeter palms
- 1 x three monthly periodic checks to ensure that cover crops and weed are not over grown in the trial
- Palm census done on quarterly basis
- Ensure trial upkeep up to plantation standard
- Ensure that fertiliser application is done as per plantation schedule
- Continue to liaise with plantation on upkeep and other trial maintenance work
- Palm census done at the end of the year

In 2012:
- Plots and core palms identification
- Painting of guard rows and core palms
- Isometric map done
- GPS reference each plot soil location
- 1 x three monthly periodic checks to ensure that cover crops and weed are not over grown in the trial
- Palm census done on quarterly basis
- Ensure trial upkeep up to plantation standard
- Plot identification and pegging
- Ensure that fertiliser application is done as per plantation schedule
- Continue to liaise with plantation on upkeep and other trial maintenance work

SMALLHOLDER HARGY OIL PALM BIALLA

(Susan Tomda and Steven Nake)

OVERVIEW

PNGOPRA also conducts smallholder holder research and extension throughout smallholder blocks in PNG. This is done in collaboration with OPIC and the smallholder affairs department within the milling companies. This report highlights what was carried out for smallholder section in Bialla Oil Palm Project in 2012.

Main activities of smallholder in the Bialla project in 2012 were:

- Smallholder leaf sampling including physiological measurements (71 blocks)
- Fields days
- Food Security demonstration block
- Best Managed Practise (BMP) blocks
- NBC Radio program for Oil Palm Growers in West New Britain Province

Smallholder work in Hargy comprised of activities;

1. Tissue sampling blocks: 71 selected blocks from 3 divisions (Ceneka, Maututu and Meramera). Tissue sampling started in 2009

   Outcome: The nutrient concentration of leaflet N,P,K and rachis P,K were all below the adequate level except rachis N (0.30 % DM).

2. Smallholder block Assessment: 71 blocks were assessed on visible nutrient deficiency and the upkeep standards.

   Outcome: The assessments indicate that there is average scores in agronomic upkeep standards across all divisions.

3. Food Security (Intercropping Oil Palm and food crop)

   Outcome: Food crops harvested, sampled and processed.

4. Fertiliser Demonstration –BMP

   Outcome: 10 blocks will be selected within all divisions. Work in progress

NEW BRITAIN PALM OIL LTD, WEST NEW BRITAIN
Steven Nake and Murom Banabas

Trial 139: Palm Spacing Trial, Kumbango
(RSPO 4.2, 4.3, 8.1)

Summary
A trial with varying Avenue widths of 8.2, 9.5 and 10.6m at a constant palm density of 128 palms/ha was planted in 1999 to investigate effects of different spacing and avenue widths on yield, nutrient levels in the leaf and the growth of the palm. In 2012, only Single Bunch Weight (SBW) and palm height showed significant ($p<0.05$) response to the treatments. The SBW decreased with increasing Avenue width while palm height increased with increasing Avenue width. The other parameters (Yield, Bunches per hectare (BHA), leaf nutrients, radiation interception and dry matter production) continued to show no response to the treatments. An average block yield of 28.5t/ha was obtained in 2012, which was 2.8t/ha lower than the 2011 production. Leaf K was adequate while N, P, Mg and B were slightly lower than the critical levels, whereas all tested elements in the rachis were within the adequate range.

Background
The purposes of this trial was to investigate opportunities for different field planting arrangements, and how to make use of increased inter-row spacing to facilitate mechanised in-field collection of fresh fruit bunches (FFB). If there was no large yield penalty between the different spacing configurations, then in a smallholder context it may be possible to use the wider avenue widths for planting with either cash crops (e.g. vanilla) or a variety of food crops. Mechanical removal of FFB from the field after harvest is now a common practice in some plantations. This is intended to reduce harvesting labour cost and speed up the operation of getting freshly harvested fruit to the mill. Little is known about the impact of machine traffic on compaction and associated physical properties of volcanic soils. Background information for the trial is shown in Table 37.

Table 37. Background information on trial 139.

Trial number	**139**	Company	NBPOL
Estate	Kumbango	Block No.	Division 1, Field B
Planting Density	128 palms/ha	Soil Type	Volcanic
Pattern	Triangular (see treatments).	Drainage	Good
Date planted	1999	Topography	Flat
Age after planting	9	Altitude	19m asl
Recording Started	Jan 2003	Previous Land use	Oil Palm
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	unknown	Agronomist in charge	Steven Nake

Basal fertilisers applied in 2011: AN 2.0kg/palm, TSP 0.5kg/palm, MOP 2kg/palm and Boron 0.15kg/palm.

Materials and methods
The field layout comprises three replicates for each of the three spacing arrangements (treatments), giving a total of nine plots, each 10.6 ha in area. The planting density remains constant at 128 palms per hectare. The three spacing treatments are shown in Table 38. Leaf sampling, frond marking and vegetative measurements are being done in every 5th palm per recorded row per plot.

Table 38. Spacing treatments in Trial 139.

Treatment	Spacing (m)	Density (palms/ha)	Avenue width (m)	Inter-row width (m)
1	9.5 x 9.5 x 9.5 (standard)	128	8.2	8.2
2	9.0 x 9.0 x 9.0 (Intermediate)	128	9.5	7.8
3	8.6 x 8.6 x 8.6 (Wide)	128	10.6	7.5

Data Collection
There were 12 rows of palms in each treatment or plot. Each row for each plot/treatment was surrounded by two "guard rows" on both sides. Loose fruits were also collected and weighed with their respective bunches. Bunches from the guard row palms were not weighed. The data were recorded onto yield record sheets in the field and entered onto a database using Microsoft Access. Yields were then converted into tonnes per hectare, bunches per hectare and the single bunch weight (SBW) per hectare. Yield was recorded every fortnight (14 day round) on all palms in the plots/treatment.

Leaf samples (leaflet and rachis) were taken from Frond 17 following standard procedures, processed, oven dried and ground into powdered form and sent to AAR (Malaysia) for analysis. Leaf measurements included frond length, PCS, total number of leaflets; leaflet length and width were also done on frond 17. Frond production counts were done twice a year to determine frond production rate. The height of the palms was also measured to determine the height incremental growth. Leaf samples, vegetative measurements and frond production counts were done on every 5th palm in the 12 rows.

Trial maintenance and upkeep
The three trial blocks (3 reps) were maintained regularly by Kumbango Plantation Division 2. This covered pruning, weed control (either herbicide spraying or slashing), wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Fertilisers (MOP, Kieserite, Triple super-phosphate (TSP) and Borate) were applied by the Plantation workers.

Results

Spacing treatment effect on yield in 2012
The spacing treatment showed no significant effect (p>0.05) on yield and BHA (?) in 2012 (Table 39). The SBW however responded significantly (p=0.046) to the spacing treatments (different avenue widths) in 2012. Average SBW from the standard avenue width (9.5m x 9.5 m x 9.5m) was significantly greater than those from the other two treatments (intermediate and wide avenues). The Intermediate and Wide avenue spacing were slightly lower in yield and number of bunches per hectare compared to the Standard spacing (but statistically not significantly different).

Table 39. Impact on yield, bunch number and single bunch weight from three row spacing treatments in 2011

Avenue width	Yield t/ha	Bunch number per hectare	Single bunch weight (kg/bunch)
Standard	29.3 (32.0)	1269 (1414)	24.7 (23.2)
Intermediate	28.4 (30.5)	1185 (1306)	23.7 (23.9)
Wide	27.8 (31.3)	1188 (1373)	23.8 (23.3)
Significant difference	**NS**	**NS**	**p=0.046**
LSD	**-**	**-**	**0.72**
CV%	**2.5**	**3.4**	**1.3**

2011yields in brackets for comparison.

The effect of the different avenue widths on yield (2003-2012)
Irrespective of the different avenue widths, the FFB yields reached its maximum peak in 2007 (average of 32.3 t/ha) after a steady increase from 2003, 2004, 2005 and 2006. From 2008 to 2010, the trial experience fluctuations in the FFB yield. In 2011, the trial recovered from a drop in yield in 2010 by an increase of about 6 t/ha pushing the average FFB yield for the trial to 31.2 t/ha, making 2011 the second highest yielding year in the history of the trial block. The yield increase in 2011 is more generated by the increased in the number of bunches (Figure 9), which increased from 1085 bunches in 2010 to 1364 bunches in 2011 (Figure 9). In 2012, the FFB yield plummeted by 2.7 t/ha which resulted from a subsequent decline in the BHA (Figure 9). Despite the drop in yield and BHA, SBW continued to incline over 24 kg per bunch in 2012.

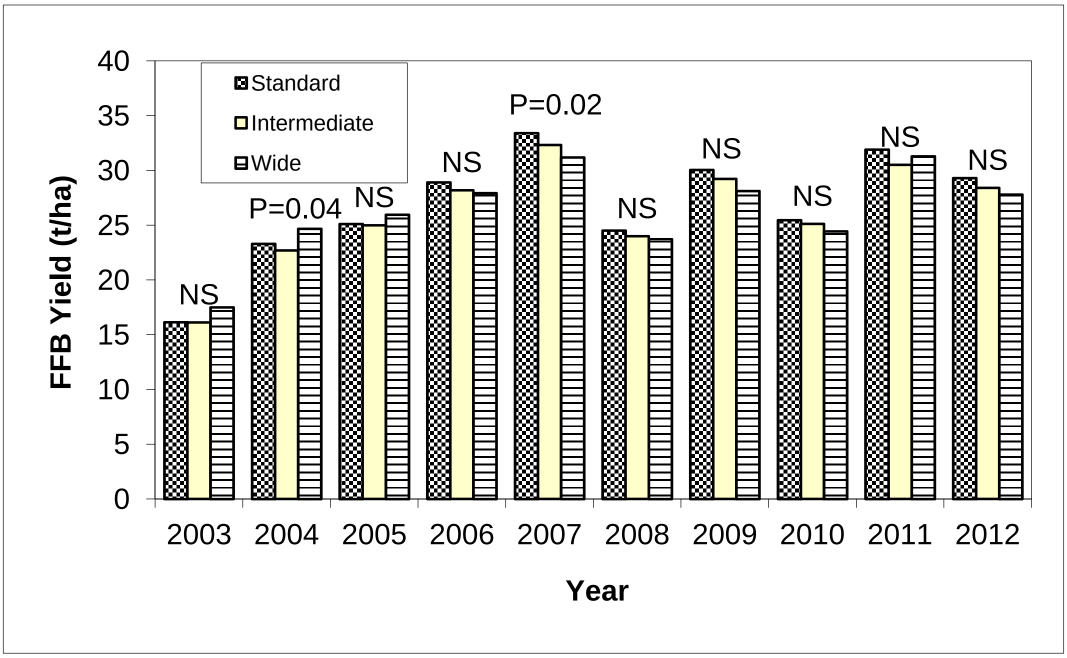


Figure 8. The effect of avenue widths on yield (keeping planting density the same), 2003-2012.

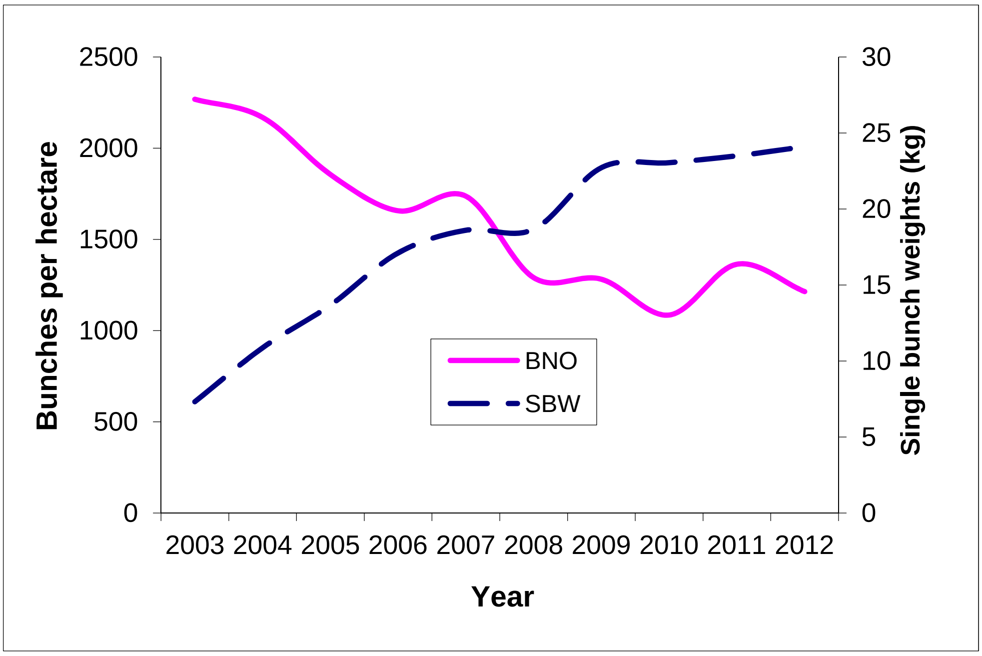


Figure 9. Mean bunch number per hectare (BHA) and SBW (kg/bunch) over the trial duration.

Spacing treatment effect on tissue nutrient levels

The spacing treatments (affecting the avenue spacing) did not have any significant effects on both the leaflet and rachis nutrient levels (Table 40). Irrespective to the spacing treatments (affecting the avenue spacing), leaflet N, P, Mg and B were slightly below the adequate levels, whereas leaflet K was within the adequate level. Rachis N, P and K concentrations were all within the adequate levels.

Table 40. Leaflet and rachis nutrient status for three different Avenue widths in 2012

Avenue Width	Leaflet nutrient concentration (% dm)					Rachis nutrient concentration (% dm)		
	N	P	K	Mg	B (ppm)	N	P	K
Standard	2.36	0.143	0.68	0.17	13.9	0.47	0.12	2.24
Intermediate	2.33	0.143	0.68	0.17	12.5	0.47	0.13	2.16
Wide	2.38	0.144	0.69	0.17	14.3	0.47	0.13	2.27
Adequate level:	2.45	0.145	0.65	0.20	15.0	0.32	0.10	1.2
Significance:	NS	NS	NS	NS	NS	NS	NS	NS
CV %	1.8	1.8	3.8	4.6	4.6	5.4	5.5	9.2

Spacing treatment effects on vegetative growth parameters

The spacing treatment (affecting avenue widths) had significant effect (p=0.022) on the palm height in 2012 (Table 41). Generally the palm height increased with avenue widths (Figure 10). At the standard spacing of 9.5m x 9.5m x 9.5m, the average palm height was 813 cm (8.13 m). As the avenue width was increased from 9.5m to 10.6m as a results of decreasing inter-row width (and spacing between individual palms), the average palm height increased from 821cm (8.21m) to 843cm (8.43m). All the other growth parameters (HI, PCS, radiation interception and dry matter production) showed no response to the spacing treatment (Table 41).

Table 41. Effects of the different Avenue widths on vegetative growth, radiation interception and dry matter production in 2012

	HT (cm)	HI (cm)	PCS (cm^2)	Radiation interception				Dry matter production (t/ha)			
				FA	GF	FP	LAI	FDM	BDM	TDM	VDM
Means	**826**	72.7	48	13.6	37	25	6.4	15.9	15.3	34.6	19.4
Significance	**P=0.022**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lsd	**18**	-	-	-	-	-	-	-	-	-	-
CV%	**1.0**	17.1	2.7	3.6	3.0	2.0	4.5	3.7	2.3	1.9	3.4

HT = Height; HI = Height increment(cm); PCS = Petiole cross-section of the rachis (cm^2); FA = Frond Area (m^2); GF = number of green fronds (fronds per palm); FP = annual frond production (new fronds/year); LAI = Leaf Area Index; FDM = Frond Dry Matter production (t/ha/yr); BDM = Bunch Dry Matter production (t/ha/yr); TDM = Total Dry Matter production (t/ha/yr); VDM = Vegetative Dry Matter production (t/ha/yr)

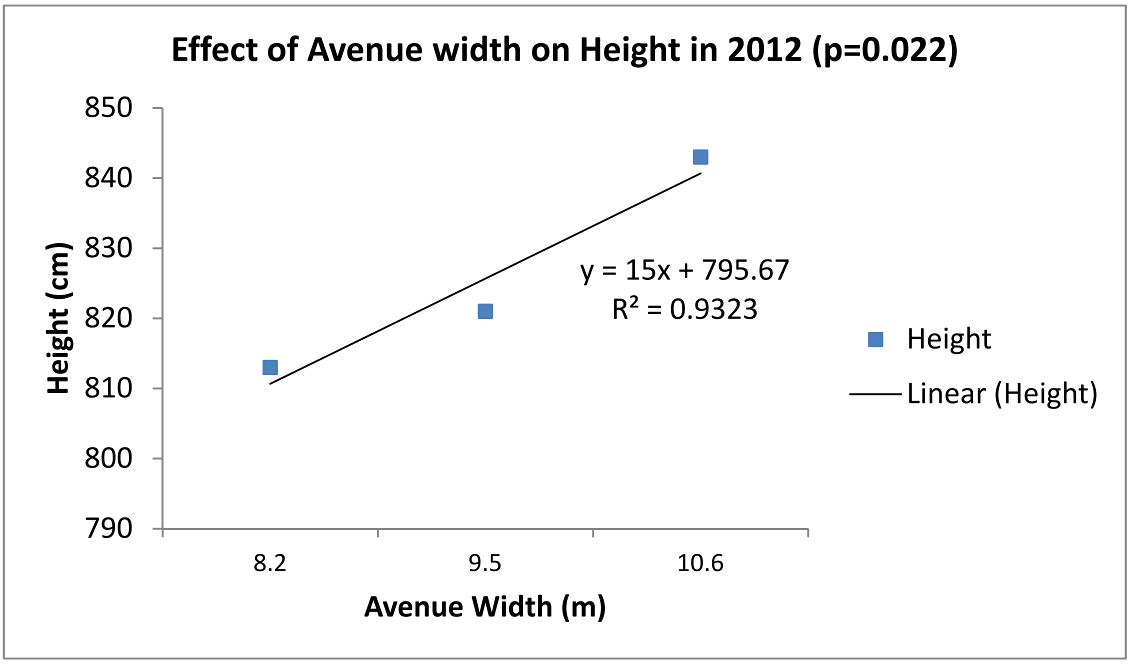


Figure 10. Relationship between palm height and avenue widths in Trial 139 in 2012.

Frond production and frond number
In 2012, the palms produced on average 25 fronds (one every 15 days). Total green fronds on the palms dropped from 38 in 2011 to 37 in 2012. This probably due to proper pruning standards emphasised in the same year.

Frond and canopy size
Frond area (based on frond length, leaflet number, leaflet length and width) and LAI (Leaf Area Index calculated from frond area, frond number and palms per ha) are two parameters determining canopy coverage. Both the frond area and LAI in 2012 was increased from 13.6m^2 and 6.4m^2 respectively.

Vegetative dry matter production
Petiole cross section (PCS) is a primary determinant of vegetative dry matter production. PCS (Petiole cross-section) was maintained at an average of 48cm^2 in 2012. The other parameters for foliar vegetative dry matter production (FDM, TDM and VDM) all dropped in 2012 but not related to the spacing treatments (Table 41).

Discussion
The spacing treatment (which affects the avenue widths) continued to have lesser effect on yield, tissue and physiological parameters of the palms in Trial 139 in 2012. Of all the parameters, only SBW and palm height in 2012 responded significantly to the treatments. A positive and strong relationship (r^2=0.9323) existed between height and the avenue widths, which implied that as avenue widths are widened causing the inter-row widths to narrow, the palm heights increased. At the highest avenue widths, the palm spacing is reduced causing palms to compete for sunlight which could have attributed to the increase in heights.

From field observation, the canopy cover is similar regardless of the spacing treatments (avenue width) since the palm canopy closed up several years ago, hence the insignificant difference in the amount of radiation interception by the palms at the different spacing treatments. Radiation interception is important for the process of photosynthesis which produces carbohydrate ($C_6H_{12}O_6$), which is used by the palms for vegetative growth and production of flowers and subsequent yields (bunches). Thus, the obvious reason why yields have not differed between treatments is because the amount of light intercepted from the sun was more or less the same. Despite that, the yields tend to decline with increasing avenue widths (and decreasing inter-rows spacing), but not significant.

Conclusion
The response of the measured parameters (yield and components, leaf nutrient concentration and growth) to the spacing treatments not marked in 2012. The SBW and the palm height responded significantly ($p<0.05$) to the treatments. The negative response could be due to the fact that the palms have reached maturity and the canopy has fully closed regardless of the spacing treatments. The overall FFB yields decreased from an average of 31.3 t/ha in 2011 to 28.5 t/ha in 2012 (2.8t/ha difference). Leaf K was adequate while N, P, Mg and B were slightly lower than the critical levels, whereas all tested elements in the rachis were within the adequate range.

NBPOL, KULA GROUP, MILNE BAY ESTATES

Murom Banabas and Wawada Kanama

Trial 517: New K placement trial at Maiwara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

In the first full year of treatment application there were no differences in application method for MOP in yield or in tissue K content.

Introduction

Two new trials were established in 2007 at Maiwara. Trial 516 is a NxK factorial trial; and Trial 517 is a replicated K placement trial. The trial site was selected in 2005 and pre-treatment yield data was collected for eighteen months until the first fertiliser treatments were applied in May 2007. Site details are presented in Table 42.

Table 42. Trial 517 background information.

Trial number	**517**	Company	Milne Bay Estates
Estate	Hagita, Maiwara	Block No.	AJ 1290
Planting Density	143 p/ha	Soil Type	Alluvial
Pattern	Triangular	Drainage	Site is often waterlogged
Date planted	2001	Topography	Flat
Age after planting	12	Altitude	Not known
Recording started	2005	Previous Land-use	Forest
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Mix	Supervisor in charge	Wawada Kanama

Basal fertiliser applied in 2010: 0.5kg/palm TSP

Methods

Plots were marked out in 2005 and pre-treatment data were collected throughout 2006 and 2007. First treatments were applied in May 2007 and hence 2008 was the first full year with treatments imposed. Plots consisted of 16 recorded palms surrounded by a single guard row (total 36 palms per plot). The trial site was split in two and two trials were established in May 2007 (516 and 517).

Trial 517 – K placement: had the aim to identify the optimum placement of MOP (K fertiliser) on the deep clay soils at Milne Bay. It was known from other trials (specifically 502) that K was an essential nutrient, however there were some indications that even with high amounts applied that uptake was not optimum, this could be due to ineffective placement. Currently MOP is applied to the edge of the weeded circle and in this trial we are investigating alternatives such as application on the frond tips and frond pile where uptake could be more efficient. There was also talk about using mechanical spreaders for spreading MOP and this was included as a treatment (simulated mechanical spreading by throwing the fertiliser throughout the plot). The trial consisted of 16 plots with one rate of K (MOP at 7.5kg/palm) and four placements, replicated four times. Placements were: (i) weeded circle, (ii) frond tips and frond pile, (iii) edge of weeded circle, and (iv) broadcast. Three additional plots were available and two of these did not receive any K fertiliser and the third plot received a higher rate of 12kg/palm. These three plots were not part of the analysis but could provide additional information especially when interpreting tissue K levels. One way Anova was used for trial analysis.

Results and discussion

Analysed yield data for 2012 and 2010-2012 are presented in Table 43. Yield data for the nil fertilised and the highest MOP rate plots are also presented in the same table. There was no effect of K placement on yield and yield components in 2012. Yield in the nil fertilised plot was 2 tonnes less than highest MOP fertilised plot. Mean FFB yield was 30.9t/ha in 2012.

Table 43. Main effects of fertiliser placement treatments on FFB yield (t/ha) and its components for 2012 and 2010 to 2012 (three years averaged data).

	2012			**2010-2012**		
	Yield (t/ha)	**BN (bunches/ha)**	**SBW (kg)**	**Yield (t/ha)**	**BN (bunches/ha)**	**SBW (kg)**
Nil fertiliser	28.3	1306	21.7	30.7	1467	20.9
Highest MOP rate	30.3	1390.4	21.8	27.9	1421	19.7
Edge of weeded circle	30.7	1291	23.8	29.3	1366	21.6
Weeded circle	28.7	1227	23.5	28.2	1377	20.6
Broadcast	31.8	1361	23.4	29.8	1472	20.3
Frond tips and piles	32.3	1452	22.3	30.1	1498	20.2
P values	*0.279*	*0.188*	*0.130*	*0.342*	*0.201*	*0.236*
GM	30.9	1333	23.2	29.4	1428	20.7
SE	2.661	140.9	0.907	1.52	99.6	0.98
C.V.%	8.6	10.6	3.9	5.2	7.0	4.7

***P** values less than 0.05 are presented in bold.*

Summary

There were no yield responses to K placement treatments in 2012.

Trial 516: New NxK trial at Maiwara Estate
(RSPO 4.2, 4.3, 4.6, 8.1)

Introduction
Two new trials were established in 2007 at Maiwara. Trial 516 is an N x K factorial trial; and Trial 517 is a replicated K placement trial. The trial site was selected in 2005 and pre-treatment yield data was collected for eighteen months until the first fertiliser treatments were applied in May 2007. Site details are presented in Table 44.

Table 44. Trial 516 back ground information

Trial number	**516**	Company	Milne Bay Estates
Estate	Hagita, Maiwara	Block No.	AJ 1290
Planting Density	143 p/ha	Soil Type	Alluvial
Pattern	Triangular	Drainage	Site is often waterlogged
Date planted	2001	Topography	Flat
Age after planting	10	Altitude	Not known
Recording started	2005	Previous Land-use	Forest
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Mix	Supervisor in charge	Wawada Kanama

Basal fertiliser applied in 2010: 0.5 kg TSP

Methods
Plots were marked out in 2005 and pre-treatment data were collected throughout 2006 and 2007. First treatments were applied in May 2007 and hence 2008 was the first full year with treatments imposed. Plots consisted of 16 recorded palms surrounded by a single guard row (total 36 palms per plot). The trial site was split in two and two trials were established in May 2007 (516 and 517).

Trial 516 – NxK: Had the aim to identify the optimum economic return for N and K fertiliser application on alluvial soils at MBE. The trial consisted of 13 plots with 5 treatment rates of both N and K (N range: SOA from 0 to 9kg/palm and MOP from 0 to 7kg/palm). A uniform precision rotatable central composite trial design was established, this design is standard for generating fertiliser response surfaces. For a 2-factor (k = 2) central composite design, the treatments consist of (a) 2^k (= 4 treatments) factorial, (b) 2k (= 4) star or axial points and (c) 5 centre points. Linear multiple regression was used to analyze the yearly influence of fertiliser N and K on yield. In the regression equation, yield is the dependent variable, and the N and K fertilisers the independent variables. The equation used was:

Equation 1

$$\textbf{Yield} = a + bN + cN^2 + dK + eK^2 + fN.K$$

where a, b, c, d, e, f and g are the parameters to be calculated. The last term, f, represents the linear by linear interaction between N and K fertilisers.

Results
Yield data for 2012 and three years running average for 2012-2012 were analysed using polynomial regression using the R-quadratic function in Genstat. The models was:

Equation 2

$$\textbf{Yield (2012)} = 33.2 + 5.99.SOA + 2.91.MOP - 2.30.SOA*SOA - 0.27.MOP*MOP + 0.37.SOA*MOP$$

The model accounted for 76.4% of variance in 2012 with a standard error of 2.99.

Equation 3
Yield (2010-12) = 30.3 + 3.997.SOA + 1.534.MOP – 1.939.SOA*SOA – 0.114.MOP*MOP + 0.350.SOA*MOP

The model accounted for 90.5% of variance in 2010-12 with a SE of 1.21. The three years running average appears better to use for the modeling. A maximum yield of 41.6t/ha/year was obtained at stationary points for SOA at 1.90 and MOP at 9.7. These points will need to be converted to actual fertiliser rates and then agronomic optimum to be determined.

Discussion
The data from this trial will require full statistical analysis and help is sought at the moment.

Trial 513: Spacing and Thinning Trial, Padipadi

(RSPO 4.2, 4.3, 8.1)

Summary

The trial was designed to test the effects of spacing configuration, thinning and planting density on FFB yield. At field planting, there were six density treatments (128, 135, 143, 192, 203 and 215 palms/ha). Thinning took place at 5 years of age (in February 2008), the treatments planted at 192, 203 and 215 palms/ha were thinned to 128, 135 and 143 palms/ha respectively. These are now the replicate of the three original lower densities but with different spacing configurations. Density treatment had a significant effect on yield and number of bunches produced in the combined pre-thinning and post-thinning phase. The highest yielding treatment (April 2006 to December 2008) was the treatment planted at 215 and thinned to 143 palms/ha. Whether this treatment with a relatively high density (143 palms/ha) can maintain its yield advantage compared to the 128 and 135 planting densities remains to be seen.

Introduction

The purpose of the trial was to determine the effects of spacing configuration, thinning and density on palm yield. The theory is that during the immature phase, the yield of palms planted at a high planting density will be higher compared to the lower planting density until canopy closure has been achieved (at approximately 5 years of age). Following thinning of the high density plots the wider avenues will allow more sunlight to penetrate the remaining palm rows and yield should be able to be maintained at a similar levels compared to the lower planting densities. The end result is a higher total yield over the immature phase with the higher planting densities without a subsequent loss in yield after canopy closure has been achieved. In a smallholder situation, it would also be possible to grow food or cash crops for extra income in the wider inter-rows. Back ground information of the trial is presented in Table 45.

Table 45. Trial 513 back ground information.

Trial number	**513**	Company	Milne Bay Estates
Estate	Padipadi	Block No.	1051
Planting Density	See Table 46	Soil Type	Alluvial
Pattern	Triangular	Drainage	Good
Date planted	2003	Topography	Flat
Age after planting	8	Altitude	Not known
Recording started	April 2006	Previous Land-use	Savanna grassland
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Known	Supervisor in charge	Wawada Kanama

Methods

Design and treatments

The design is the same as Trial 331 at Higaturu. There were 6 treatments initially of different planting densities with equilateral triangular spacing (Table 46). In treatments 4, 5 and 6 every third row was removed 5 years after planting and treatments 1, 2 and 3 remain as planted (thinning took place in February, 2008).

The final densities of treatments 4, 5 and 6 were the same as treatments 1, 2 and 3 but they were closely spaced pairs of rows with wider avenues between the pairs. There are 3 replicates of the 6 spacing treatments, giving a total of 18 plots. Each plot has 4 rows of recorded palms and these plots are enclosed by guard palms. Fertiliser application will follow normal plantation practice for an immature fertiliser program up to year 6.

Table 46. Treatment allocations in Trial 513. 'Thinning' involved the removal of every third row, 5 years after planting, in treatments 4, 5 and 6 (in February 2008).

Treatment No	Initial density (palms/ha)	Triangular spacing (m)	Initial number of rows/plot*	Density after thinning (palms/ha)	Inter-row width after thinning (m)
1	128	9.50	7	128	8.23
2	135	9.25	7	135	8.01
3	143	9.00	7	143	7.79
4	192	7.75	8	128	13.4 (6.71)
5	203	7.55	9	135	13.08 (6.54)
6	215	7.33	9	143	12.7 (6.35)

( ) avenue width before thinning
** includes guard rows*

Data Collection

Recordings and measurements were taken on 4 rows of palms in each plot. The number of bunches and bunch weights recording commenced in April 2006. Pre-thinning yield was determined from weight recording all bunches in four rows in each plot; the total yield was calculated for each harvest and then expressed per ha per year. Post thinning (February 2008) recorded palms in four palms rows in each plot were numbered and bunch number and SBW were recorded against numbered palms. Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

Statistical Analysis

Analysis of variance (One-way ANOVA) of the main effects of density treatments was carried out for yield and its component variables.

Results and discussion

Density treatments had a significant effect on yield during the pre-thinning years - 2006 and 2007. There was no difference in yield in the treatments post-thinning in 2008, 2009 and 2010 (Table 47).

2006 Yield: treatments 4, 5 and 6 had a significantly higher yield (P=0.006) compared to treatments 1, 2 and 3
2007 Yield: treatment 6 had a significantly higher yield compared to treatments 4 and 5, which in turn had a significantly higher yield compared to treatments 1, 2 and 3 (P<0.001)
2008 Yield: there was no significant difference in yield between the treatments post thinning (P=0.11)
2009 Yield: there was no significant difference in yield between the treatments post thinning
2010 Yield: there was no significant difference in yield between the treatments post thinning
2011 Yield: there was significant difference between thinned and un-thinned palms even at similar densities.
2012 Yield: there was significant difference between thinned and un-thinned palms even at similar densities.

The yields in Treatments 1, 2 and 3 were significantly greater than treatments 4, 5 and 6 after thinning (Table 47). However before thinning, the high density plots were yielding more than the low density treatments (1, 2 and 3) (Figure 11).

Table 47. Trial 513 Main effects of density treatments on FFB yield (t/ha) and its components for 2012 and 2010 to 2012 (3 years average data)

	2012			2010-2012		
Density Treatment	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
128	**34.6**	**2031**	17.2	30.2	2548	15.2
135	**33.4**	**1968**	17.1	30.0	2601	15.0
143	**32.1**	**1925**	16.9	30.7	2563	14.6
128 (192)	**29.2**	**1648**	17.9	27.3	2265	15.7
135 (203)	**29.2**	**1720**	17.1	26.9	2361	14.8
143 (215)	**27.9**	**1650**	17.0	26.6	2375	15.0
$lsd_{0.05}$	*1.62*	*137.8*				
p values	**<0.001**	**<0.001**	0.525	0.094	0.069	0.420
Grand Mean	31.1	1824	17.2	28.8	2452	15.1
SE	0.89	75.8	0.691	1.83	137.97	0.590
CV %	2.9	4.2	4.0	6.4	5.6	3.9

P *values less than 0.05 are presented in bold. (..) previous density*

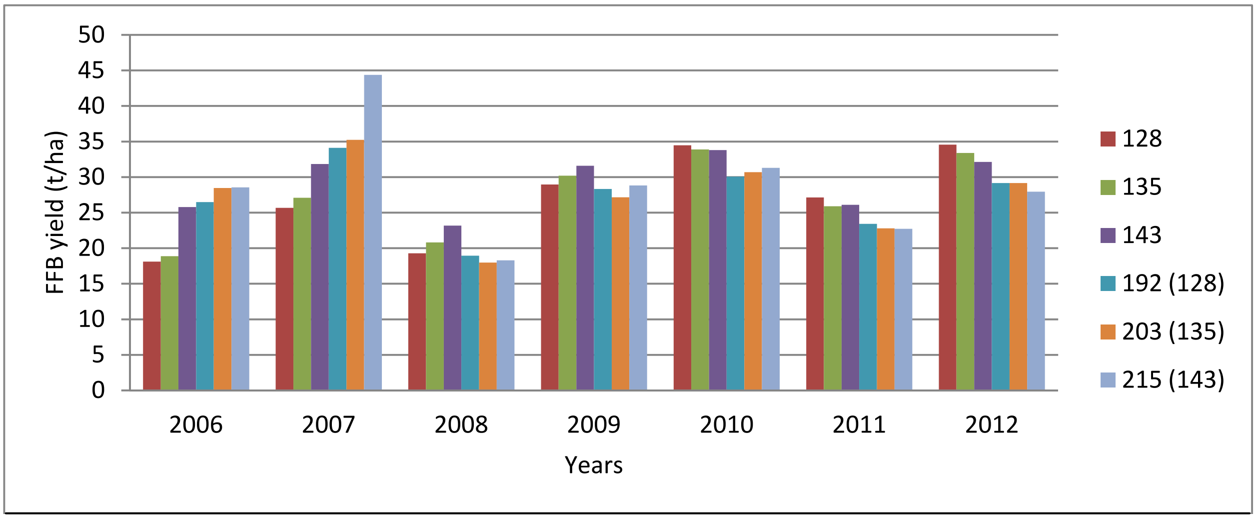


Figure 11. Trial 513: FFB yield for the pre-thinning years (2006 and 2007) and the post-thinning year (2008 - 2012).

Note 1. the planting density in brackets refers to post-thinning
Note 2. in 2006 harvest commenced in April (yield only for April to December)
Note 3. post-thinning in 2008 harvest commenced in April (yield only for April to December)

Conclusion

There were differences in yield between thinned and un-thinned palms even at similar densities.

Trial 331 Spacing and Thinning Trial, Ambogo Estate, Higaturu Oil Palm

(RSPO 4.2, 4.3, 8.1)

Summary

The trial was designed to test the effects of spacing configuration, thinning and planting density on fresh fruit bunch (FFB) yield and other variables of interest. From field planting, there were 6 density treatments (128, 135, 143, 192, 203 and 215 palms/ha), however at 5 years of age (May 2006), the densities 192, 203 and 215 were thinned to 128, 135 and 143, respectively, which became the replicate of the three originally lower densities but with different spacing configurations, that is different avenue widths. Prior to thinning, a significantly higher number of bunches (BNO) were produced from densities 192, 203 and 215 palms/ha when compared to the three lower densities. In 2012, there were no differences between the different planting densities or between the same density plantings in different configurations.

Introduction

The purpose of the trial was to determine the effects of spacing configuration, thinning and density on palms, cover crops and soils, with a view to facilitating mechanical in-field collection. Mechanical removal of FFB from the field after harvest was an issue when the trial started. Mechanical removal is intended to reduce harvesting costs. Little is known about the impact that traffic has on the physical properties and long-term sustainability of the soils. Wider avenue spacing may allow more sunlight, better cover crop growth and less soil damage in the inter-rows used by vehicles. Soils in the trial area belong to the Ambogo/Penderetta families, which are of recent re-deposited alluvial volcanic ash, with loamy topsoil and sandy loam subsoil, and seasonally high water tables. Relevant background information of the trial is presented in Table 48.

Table 48. Trial 331 back ground information

Trial number	**331**	Company	Kula Oil Palms
Estate	Ambogo	Block No.	Ambogo AA0050
Planting Density	See Table 46	Soil Type	Alluvial flood plain
Pattern	Triangular	Drainage	Good
Date planted	2001	Topography	Flat
Age after planting	11	Altitude	79.81m asl
Recording Started	Jan 2002	Previous Land-use	Oil Palm plantation
Planting material	Dami D x P	Area under trial soil type (ha)	
Progeny	Mixed Dami DxP	Agronomist in charge	Winston Eremu

Methods

Design and treatments

Initially there were 6 treatments of different planting densities with equilateral triangular spacing (Table 49). In treatments 4, 5 and 6 every third row was removed 5 years after planting (May 2006) and treatments 1, 2 and 3 remained as planted. The final densities of treatments 4, 5 and 6 were the same as treatments 1, 2 and 3 but they have closely spaced pairs of rows with wide avenues between the pairs. There were 3 replicates of the 6 spacing treatments, giving a total of 18 plots. Each plot had 4 rows of recorded palms and these plots were surrounded by guard palms. In 2002, about a year after the palms were planted, 7 cover crops were sown in small plots throughout replicate 2 of the spacing trial in order to assess their performance under the different light and traffic conditions of the different spacing treatments. The cover crops were *Pueraria*, *Calopogonium*, *Mucuna*, *Vigna*, *Desmodium*, *Centrosema* and *Stylosanthes*. This cover crop trial was discontinued as there was poor germination and establishment.

Table 49. Treatment allocations in Trial 331. 'Thinning' involves the removal of every third row 5 years after planting in treatments 4, 5 and 6.

Treatment No	Initial density (palms/ha)	Triangular spacing (m)	Initial number of rows/plot	Density after thinning (palms/ha)	Inter-row width after thinning (m)
1	128	9.50	7	128	8.2
2	135	9.25	7	135	8.0
3	143	9.00	7	143	7.8
4	192	7.75	8	128	13.4 & 6.7
5	203	7.55	9	135	13.1 & 6.5
6	215	7.33	9	143	12.7 & 6.4

Data collection

Recordings and measurements were taken on the 4 rows of palms in each plot. The number of bunches and bunch weights were recorded fortnightly on an individual palm basis (individual palms were not numbered) and with totals given for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight (SBW) was calculated from these data. During 2007, data from every palm in each plot was added to the computer database. Leaf sampling was carried out once annually and analysed for nutrient concentrations using standard analytical procedures. Leaf samples were taken from every 5th palm in every row of palms and vegetative measurements were also taken.

Statistical analysis

Analysis of variance (One-way ANOVA) of the main effects of density treatments was carried out for each of the variables of interest using the GenStat statistical program.

Results and discussion

Effects of density treatment on yield and yield components

Density treatments did not have any effect on yield and its components in 2012 but affected 2010-2012 average yield (Table 50). Treatments 1, 2 and 3 (un-thinned) produced yields which were not significantly higher than the thinned palms, however yields in palms planted at 143 palms/ha had the highest yield of 33.4t/ha. The narrowing of yield gap between thinned and un-thinned palms in 2012 was most likely due to a fall in yields from the un-thinned treated plots (Table 51).

Table 50. Main effects of treatments on FFB yield (t/ha) in 2012 and combined 2010-20112

	2012			2010 – 2012		
Density Treatment	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
128	31.8	1557	20.7	**33.4**	**1660**	20.4
135	31.1	1595	19.8	**32.5**	**1693**	19.4
143	33.2	1664	20.2	**33.4**	**1710**	19.8
128(192)	31.1	1516	20.8	**32.0**	**1568**	20.6
135(203)	31.0	1511	20.8	**31.2**	**1557**	20.3
143(215)	30.2	1526	20.1	**30.6**	**1563**	19.8
l.s.d.$_{0.05}$				*1.161*	99.8	
p values	0.130	0.154	0.120	0.001	0.015	0.056
GM	31.4	1562	20.4	32.2	1625	20.0
SE	1.168	71.5	0.485	0.638	54.9	0.435
CV %	3.7	4.6	2.4	2.0	3.4	2.2

(treatments which are significantly different at P<0.05 are presented in bold).
(..) previous density

Table 51. FFB yield from the different densities from 2003 to 2012.

Treatment	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
128	15.3	21.4	29.4	29.6	39.4	37.1	36.2	34.7	33.8	31.8
135	14.4	21.4	29.2	29	37.6	35.6	35.1	33.0	33.4	31.1
143	16.0	20.2	28.4	29.9	38.4	35.6	35.3	34.1	33.1	33.2
128(192)	23.2	28.5	32.4	40.2	34.4	33.5	32.6	32.4	32.5	31.1
135(203)	19.5	28.2	26.5	37.8	32.6	32.3	31.4	31.6	31.2	31.0
143(215)	22.7	29.2	28.2	41.4	32.4	32.6	32.6	30.8	30.9	30.2
Significance						ns	Ns	p=0.048	p=0.021	ns
l.s.d.$_{0.05}$								2.546	1.819	
Grand mean	18.5	25.1	29.0	34.7	35.8	34.4	33.9	32.8	32.5	31.4

Leaf tissue nutrient concentrations

There was no difference in leaf tissue nutrient contents in 2012 (Table 52). The nutrient concentrations were above their respective critical values for oil palm.

Table 52. Main effects of treatments on F17 nutrient concentrations in 2012, in % units of dry matter, except for B (mg/kg).

Density	Leaflet nutrient contents								Rachis nutrient contents			
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**Ash**	**N**	**P**	**K**
128	12.2	2.43	0.149	0.77	0.24	0.79	0.48	13.6	5.2	0.31	0.169	1.74
135	12.2	2.42	0.149	0.80	0.26	0.77	0.51	13.8	5.4	0.29	0.168	1.73
143	12.1	2.50	0.150	0.80	0.24	0.83	0.52	14.6	5.0	0.30	0.145	1.64
128 (192)	12.4	2.40	0.151	0.79	0.24	0.81	0.49	14.2	5.8	0.31	0.171	1.95
135 (203)	11.7	2.42	0.151	0.80	0.25	0.80	0.51	14.5	5.1	0.31	0.158	1.69
143 (215)	12.1	2.45	0.151	0.78	0.26	0.83	0.49	14.8	5.7	0.29	0.160	1.87
p value	0.586	0.631	0.776	0.883	0.801	0.587	0.056	0.798	0.475	0.730	0.652	0.488
GM	12.1	2.44	0.150	0.79	0.25	0.804	0.50	14.3	5.4	0.30	0.162	1.77
SE	0.408	0.069	0.0024	0.0421	0.0174	0.0437	0.0147	1.252	0.578	0.0167	0.0202	0.2048
CV%	3.4	2.8	1.6	5.3	7.0	5.4	2.9	8.8	10.7	5.5	12.5	11.6

Effects with p<0.05 are shown in bold.
(..) previous density

Conclusion

The planting density had no significant effect on yield in 2012 but significant (p=0.001) effects were recorded for the combined 2010-2012 period. Leaf tissue nutrient levels were generally adequate.

NBPOL, KULA GROUP, POPONDETTA

Winston Eremu and Murom Banabas

Trial 334: Nitrogen x Phosphorus Trial (Mature Phase) on Volcanic Ash Soils, Sangara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

This trial tested 3 rates of urea and 5 rates of TSP in a factorial combination, resulting in 15 treatments. The trial design was a Randomised Complete Block Design (RCBD). The 15 treatments were randomly allocated and replicated 3 times, resulting in 45 plots. The purpose of the trial was to determine the optimum P and N supply rate and to determine critical P (or N/P ratio) deficiency level in leaflets and rachis of palms of different age and with differing N status. Urea had an effect on FFB yield (p=0.050) and its components (p=0.019), leaf N & Cl and rachis N & P concentrations. TSP showed increased Ash, N and P in rachis nutrient contents but had no effect on FFB yield. Urea x TSP has an effect on rachis P and K. No significant treatment effects on physiological and vegetative growth parameters in 2012. There was an increase in FFB yield from 33.7t/ha to 38.3t/ha in 2012.

Introduction

There was little response to P fertiliser in previous trials in Higaturu. However P leaf levels had been falling over the last few years in Sangara Estate (0.154 in 2000; 0.143 in 2004) whilst the critical level has been increasing (0.158 in 2000; 0.164 in 2004) as a result of improved N nutrition. Critical leaf level of P also changes with palm age. Thus it was decided to start a new trial with a wide range of P supply rates and palms of different age. In addition, N supply may affect the movement of P from rachis to leaflet; such that at low N supply, increasing P supply only results in increase P accumulation in the rachis and not improved P nutrition of leaflets. Thus this trial also had a number of rates of N so that there is a better understanding of the relation between N and P nutrition – especially with respect to leaf and rachis nutrient levels. Background information for trial 324 is presented in Table 53.

Table 53. Trial 334 background information.

Trial number	334	Company	Kula Oil Palms
Estate	Sangara	Block No.	AB0190,AB0210,AB220
Planting Density	135 palms/ha	Soil Type	Volcanic ash
Pattern	Triangular	Drainage	Good
Date planted	1999	Topography	Flat
Age after planting	11	Altitude(m)	104.79
Recording Started	2006	Previous Land-use	Oil palm replant
Planting material	Dami D x P	Area under trial soil type (ha)	30.83
Progeny	Not known	Agronomist in charge	Winston Eremu

Methods

Urea treatment was applied three times per year while TSP was applied twice a year (Table 54). Fertiliser applications started in 2007. Every palm within the trial field received basal applications of 1kg Kieserite, 2 kg MOP per palm as basal. Recordings and measurements are taken on the central 16 palms in each plot. The number of bunches and bunch weights were recorded on 10 days harvesting intervals on an individual palm basis and totaled for each plot, then totalled for each harvest and expressed per ha per year. Leaf sampling is carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Analysis of variance of the main effects of fertiliser and their interactions were carried out for each of the variables of interest using the GenStat statistical program.

Table 54. Fertiliser treatments and levels for Trial 334.

Treatment	Amount (kg/palm/year				
	Level 1	Level 2	Level 3	Level 4	Level 5
Urea	1.0	2.0	5.0	-	-
TSP	0.0	2.0	4.0	6.0	10.0

Results and Discussion

Effects of treatment on FFB yield and its components

Urea had a significant effect on FFB yield and single bunch weight in 2012 and from 2010-2012. The mean FFB yield was 38.3t/ha (Table 55 & Table 56).

Table 55. Stastitical effects (*p* values) of treatments on FFB yield and its components in 2012

Source	2012			2010-2012		
	FFB yield	**BNO**	**SBW**	**FFB yield**	**BNO**	**SBW**
Urea	**0.050**	0.668	**0.019**	0.070	0.846	**0.018**
TSP	0.327	0.510	0.889	0.433	0.323	0.444
Urea.x TSP	0.765	0.883	0.835	0.441	0.534	0.973
CV %	*9.9*	*10.7*	*5.8*	*6.6*	*7.2*	*4.2*

. [*figures in bold are statistically significant at p=<0.05*].

Table 56. Main effects of treatments on FFB yield (t/ha) for the combined harvest for 2010-2012 and 2012.

Treatments	2012			2010-2012		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
Urea 1	**36.3**	1707	**21.3**	34.2	1632	**21.0**
Urea 2	**39.7**	1768	**22.5**	35.4	1632	**21.7**
Urea 3	**39.0**	1735	**22.5**	36.3	1654	**22.0**
TSP 1	37.7	1694	22.3	35.6	1626	22.0
TSP 2	37.1	1709	21.8	35.5	1686	21.1
TSP 3	37.2	1689	22.0	34.0	1572	21.6
TSP 4	40.1	1819	22.1	35.9	1662	21.7
TSP 5	39.6	1772	22.3	35.5	1650	21.6
GM	38.3	1737	22.1	35.3	1639	21.6
SE	3.790	185.6	1.280	2.321	117.8	0.901
CV %	9.9	10.7	5.8	6.6	7.2	4.2

p values <0.05 are shown in bold.

Effects of interaction between treatments on FFB yield

There was no significant interaction between Urea x TSP on FFB yield. The highest yield of 42.5 t/ha was obtained at Urea-2 and TSP-4 levels (Table 57).

Table 57. Effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2012.

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	36.7	36.9	32.5	38.4	37.0
Urea-2	38.2	37.4	39.0	42.5	41.3
Urea-3	38.3	36.9	40.1	39.4	40.4
Grand mean	38.3				

The interaction was not significant (p=0.765).

Effects of Urea and TSP treatments on leaf (F17) nutrient concentrations

Urea had significant effects on leaflet N and Cl, and rachis N and P contents. TSP significantly increased N in leaflet N and rachis ash, N and P contents. There was a significant interaction of Urea x TSP on rachis P and K however still not clear yet. Nutrient concentrations for leaflets and rachis of all the plots were above their respective critical levels (Table 58 & Table 59).

Table 58. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2012.

Source	Leaflet nutrient contents (% DM)								Rachis nutrient contents (% DM)			
	Ash	N	P	K	Mg	B	Ca	Cl	Ash	N	P	K
Urea	0.957	**<0.001**	0.394	0.439	0.986	0.090	0.539	**<0.001**	0.401	**0.010**	**<0.001**	0.859
TSP	0.670	**0.010**	1.000	0.920	0.309	0.554	0.578	0.174	**0.034**	**0.023**	**0.002**	0.240
Urea.TSP	0.342	0.974	0.216	0.080	0.328	0.641	0.247	0.120	0.536	0.832	**<0.001**	**0.009**
CV%	*4.1*	*3.3*	*3.0*	*5.3*	*10.2*	*12.0*	*7.3*	*6.4*	*8.8*	*7.3*	*10.4*	*9.7*

p values <0.05 are indicated in bold.

Table 59. Main effects of treatments on F17 nutrient concentrations in 2012, in units of % dry matter, except B (mg/kg) (Trial 334).

Treatments	Leaflet nutrient contents (% DM)								Rachis nutrient contents (% DM)			
	Ash	N	P	K	Mg	B ppm)	Ca	Cl	Ash	N	P	K
Urea-1	14.7	**2.39**	0.148	0.71	0.21	15.6	0.779	0.425	4.8	**0.287**	**0.15**	1.52
Urea-2	14.8	**2.46**	0.148	0.72	0.21	14.9	0.772	0.448	4.8	**0.303**	**0.13**	1.55
Urea-3	14.7	**2.51**	0.150	0.73	0.21	14.2	0.757	0.489	5.0	**0.313**	**0.11**	1.54
l.s.d$_{0.05}$											*0.010*	
TSP-1	14.7	**2.41**	0.148	0.72	0.20	14.9	0.776	0.450	**4.8**	**0.279**	**0.12**	1.56
TSP-2	14.9	**2.53**	0.149	0.73	0.23	15.2	0.748	0.464	**4.8**	**0.302**	**0.13**	1.55
TSP-3	14.7	**2.47**	0.149	0.71	0.22	15.4	0.790	0.434	**5.1**	**0.309**	**0.13**	1.58
TSP-4	14.5	**2.39**	0.149	0.72	0.22	14.1	0.760	0.457	**4.5**	**0.300**	**0.13**	1.43
TSP-5	14.8	**2.47**	0.149	0.71	0.21	14.9	0.773	0.466	**5.0**	**0.313**	**0.15**	1.57
l.s.d$_{0.05}$												
GM	14.7	2.45	0.149	0.72	0.21	14.9	0.769	0.454	4.8	0.301	0.133	1.54
SE	0.603	0.080	0.004	0.038	0.022	1.790	0.056	0.029	0.428	0.022	0.014	0.149
CV %	4.1	3.3	3.0	5.3	10.2	12.0	7.3	6.4	8.8	7.3	10.4	9.7

Effects with p<0.05are shown in bold.

Effects fertiliser treatments on vegetative parameters

There was no Urea, TSP treatments and Urea x TSP interaction effects on physiological growth parameters (Table 60 & Table 61).

Table 60. Effects (p values) of treatments on F#17 nutrient concentrations 2012.

Source				Radiation interception			Dry matter production				
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Urea	0.630	0.543	0.348	0.368	0.280	0.318	0.083	0.062	**0.049**	0.070	0.147
TSP	0.609	0.731	**0.041**	0.721	0.635	0.657	0.447	0.323	0.330	0.422	0.483
Urea x TSP	0.090	0.999	0.946	0.275	0.384	0.387	0.669	0.802	0.754	0.677	0.752
CV %	*2.1*	*15.1*	*6.9*	*6.0*	*4.8*	*6.5*	*8.1*	*10.0*	*7.7*	*7.7*	*4.6*

p values <0.05 are indicated in bold.

Table 61. Main effects of treatments on vegetative growth parameters in 2012.

Treatments				Radiation interception			Dry matter production (t/ha/yr)				BI
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	
Urea-1	656.3	100.5	45.2	23.3	14.5	6.34	15.1	19.2	**38.2**	19.0	0.50
Urea-2	658.2	102.5	45.9	23.5	14.1	6.23	15.5	21.0	**40.5**	19.5	0.52
Urea-3	653.4	106.8	46.9	24.0	14.1	6.46	16.2	20.6	**40.9**	20.3	0.50
lsd $_{0.05}$									*2.285*		
TSP-1	656.1	104.2	**46.9**	23.4	14.4	6.34	15.7	20.0	39.7	19.7	0.50
TSP-2	651.0	102.1	**44.3**	23.7	14.4	6.50	15.1	19.6	38.6	18.9	0.51
TSP-3	655.0	105.8	**45.5**	23.9	14.1	6.39	15.6	19.5	39.0	19.5	0.50
TSP-4	656.7	97.4	**44.7**	24.0	14.3	6.27	15.4	21.1	40.6	19.5	0.52
TSP-5	661.5	106.8	**48.7**	23.2	14.0	6.22	16.2	20.9	41.3	20.3	0.51
lsd $_{0.05}$											
Grand mean	656.1	103.3	46.0	23.6	14.2	6.34	15.6	20.2	39.8	19.6	0.51
SE	13.7	15.62	3.183	1.408	0.679	0.414	1.271	2.032	3.055	1.507	0.023
CV %	2.1	15.1	*6.9*	*6.0*	*4.8*	*6.5*	*8.1*	*10.0*	*7.7*	*7.7*	*4.6*

Significant effects (p<0.05) are shown in bold.
FL = frond length (cm), FLI = Frond length increment (cm), PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production; BDM = Bunch Dry Matter production; TDM = Total Dry Matter production; VDM = Vegetative Dry Matter production; BI = Bunch Index (calculated as BDM/TDM).

Conclusion

Urea had an effect on FFB yield, single bunch weigh, leaflet N, rachis N & P. TSP had an effect on leaflet N, rachis Ash, N and P. Urea x TSP had an interactional effect on P & K in rachis. No significant treatment effects on physiological and vegetative growth parameters. It was still early to report any true responses to fertiliser treatments.

Trial 335. Nitrogen x TSP Trial (Immature Phase) on Outwash Plains Soils, Ambogo Estate (RSPO 4.2, 4.3, 4.6, 8.1)

Summary
This trial tested 3 rates of urea and 5 rates TSP in a factorial combination, resulting in 15 treatments. The design of the trial is a Randomised Complete Block Design (RCBD). The 15 treatments were randomly allocated and replicated 4 times, resulting in 60 plots. The purpose of the trial was to determine the optimum P and N supply rate and to determine critical P (or N/P ratio) deficiency level in leaflets and rachis of palms of different age and with differing N status. In 2012, Urea had a significant effect on FFB yield, single bunch weight, physiological and vegetative parameters in dry matter concentrations. Yield increased from 27.6t/ha to 36.0t/ha in response to a statistically significant increase in single bunch weight. A TSP and Urea interaction had no significant effect on FFB yield and its components, physiological, vegetative parameters and leaf nutrient concentrations.

Introduction
There has been little response to P fertiliser in previous trials in Higaturu. However leaf P-levels have been falling over the last few years in Sangara Estate (0.154 in 2000; 0.143 in 2004) whilst the critical level has been increasing (0.158 in 2000; 0.164 in 2004) as a result of improved N nutrition. The critical leaf level for P also changes with palm age. Thus it was decided to start a new trial with a wide range of P supply rates and palms of different ages. In addition, N supply can affect the movement of P from rachis to leaflet; such that at low N supply, increasing P supply only results in increase P accumulation in the rachis and not improved P nutrition of leaflets. Thus this trial also contained a range of rates of N to provide a better understanding of the relation between N and P nutrition – especially with respect to leaf and rachis nutrient levels.

Table 62. Trial 335 background information.

Trial number	335	Company	Kula Oil Palms
Estate	Ambogo	Block No.	Ambogo AA0220
Planting Density	135 palms/ha	Soil Type	Volcanic outwash plains
Pattern	Triangular	Drainage	Good
Date planted	Oct/Nov 2007	Topography	Flat
Age after planting	3	Altitude	54.75m asl
Recording Started	2008	Previous Land-use	Oil palm replant
Planting material	Dami D x P	Area under trial soil type (ha)	24.56
Progeny	4 known Progenies	.Agronomist in charge	Winston Eremu

Methods
The Urea TSP trial was set up as a 3 x 5 factorial arrangement, resulting in 15 treatments. The design of the trial was a Randomised Complete Block Design (RCBD). The 15 treatments were replicated 4 times, resulting in 60 plots. Each plot consisted of 36 palms, with the inner 16 being the target palms and the outer 20 being "guard palms". Recordings and measurements were taken on the central 16 palms in each plot. Planned fertiliser treatment applications are as scheduled (Table 63 & Table 64). Soil sampling, initial leaf tissues and vegetative measurements were made in 2008 and yield recording commenced in 2009. Palm height measurements commenced in 2012. The number of bunches and bunch weights were recorded in 10 day intervals on an individual palm basis and totalled for each plot, then totalled for each harvest and expressed as number of bunches per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Analysis of variance of the main effects of fertiliser and their interactions are carried out for each of the variables using the GenStat statistical program.

Table 63. Phosphorus fertiliser schedule (g TSP/palm).

Year	Age	P rate (kg/palm/year				
		0.0	2.0	4.0	6.0	10.0
		g TSP /palm/year				
Planting	hole	200	200	200	200	200
1st	6	0	300	600	900	1500
	12	0	300	600	900	1500
	Year 1 Total	0	600	1200	1800	3000
2nd	18	0	450	900	1350	2250
	24	0	450	900	1350	2250
	Year 2 Total	0	900	1800	2700	4500
3rd	30	0	500	1000	1500	2500
	36	0	500	1000	1500	2500
	Year 3 Total	0	1000	2000	3000	5000
4th	42	0	750	1500	2250	3750
	48	0	750	1500	2250	3750
	Year 4 Total					
5th	Split 1	0	1000	2000	3000	5000
	Split 2	0	1000	2000	3000	5000
	Year 5 and onwards total	0	2000	4000	6000	10000

Table 64. Nitrogen fertiliser schedule (g Urea/palm)

Year	Age	N Rate (kg Urea/palm/yr)		
		1	2	5
		---------------- *g Urea/palm*		------------
Planting	Hole	0	0	0
1st	1m	20	40	100
	3m	40	80	200
	6m	40	80	200
	9m	40	80	200
	12m	60	120	300
	Year 1 total	***200***	***400***	***1,000***
2nd	16m	120	240	600
	20m	120	240	600
	24m	160	320	800
	Year 2 total	***400***	***800***	***2,000***
3rd	28m	160	320	800
	32m	200	400	1,000
	36m	240	480	1,200
	Year 3 total	***600***	***1,200***	***3,000***
4th	40m	240	480	1,200
	44m	280	560	1,400
	48m	280	560	1,400
	Year 4 total	***800***	***1,600***	***4,000***
5th onwards	Split 1	320	640	1,600
	Split 2	320	640	1,600
	Split 3	360	720	1,800
	Year 5 and onwards total	***1,000***	***2,000***	***5,000***

Results and Discussion

Yield and yield components

The effects of fertiliser on oil palm yield and its components are presented in Table 65 and Table 66. Urea had significant effect on FFB yield $p<0.001$ and single bunch weigh (SBW) in 2012 and 2010-2012 period. The mean FFB yield was 36.0t/ha, an increase from 27.6t/ha in 2011. TSP increased the number of bunches, but this did not affect the yield.

Table 65. Effects (p values) of treatments on FFB yield and its components in 2012.

	2012			2010-2012		
Source	**FFB yield (t/ha)**	**BNO/ha**	**SBW kg/ha**	**FFB yield (t/ha)**	**BNO/ha**	**SBW kg/ha**
Urea	**<0.001**	0.107	**0.002**	**<0.001**	0.187	**<0.001**
TSP	0.378	**0.044**	0.700	0.473	0.156	0.433
Urea.x TSP	0.065	0.108	0.431	0.290	0.343	0.245
CV %	*6.3*	*5.2*	*5.4*	*5.5*	*6.0*	*4.5*

Table 66. Main effects of treatments on FFB yield (t/ha) in 2012

	2012			2010-2012		
Treatments	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
Urea-1	**34.6**	3643	**9.48**	**26.8**	3597	**7.47**
Urea-2	**35.7**	3607	**9.90**	**27.8**	3526	**7.92**
Urea-3	**37.6**	3735	**10.10**	**29.1**	3652	**8.03**
l.s.d$_{0.05}$	*1.442*		*0.336*			
TSP-1	35.2	3524	10.00	27.4	3471	7.96
TSP-2	36.5	3703	9.85	27.7	3568	7.81
TSP-3	36.0	3670	9.82	27.8	3595	7.80
TSP-4	35.4	3640	9.70	27.9	3637	7.69
TSP-5	36.8	3770	9.76	28.6	3689	7.77
Grand Mean	36.0	3661	9.83	27.9	3592	7.81
SE	2.259	191.8	0.527	1.537	213.8	0.348
CV %	*6.3*	*5.2*	*5.4*	*5.5*	*6.0*	*4.5*

Effects of interaction between treatments on FFB yiel

There was no significant interaction effect of Urea x TSP however the highest yield of 36.0 t/ha was obtained at Urea-3 and TSP-2 (Table 67).

Table 67. Effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2012.

	TSP-1	**TSP-2**	**TSP-3**	**TSP-4**	**TSP-5**
Urea-1	33.2	35.9	36.7	32.3	34.7
Urea-2	35.3	34.1	35.4	36.6	36.9
Urea-3	37.1	39.4	35.8	37.1	38.7
Grand mean	36.0		sed =1.598		

In the last three year period (2010-2012) monthly yields increased to more than 4.0t/ha (Figure 12). The number of bunches fluctuated but was between 300 and 350 bunches/ha (Figure 13). Average single bunch weight increased from 9.0kg to about 12.0Kg in 2012 (Figure 14).

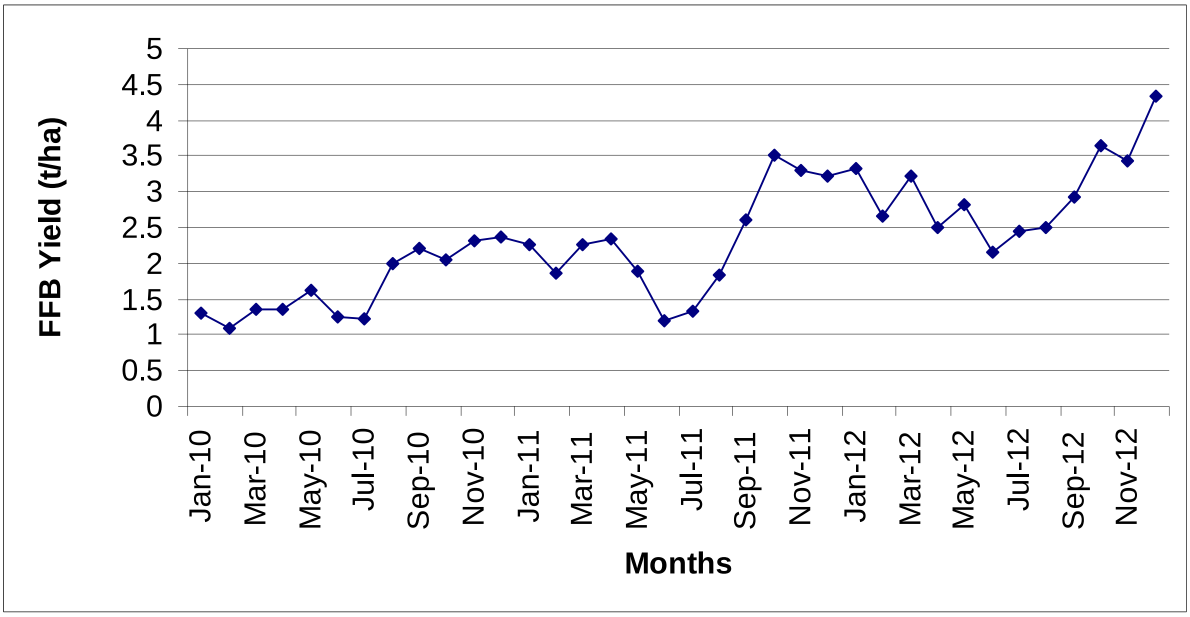


Figure 12. Monthly mean FFB yield t/ha over the last three year period (Jan 2010 - Dec 2012).

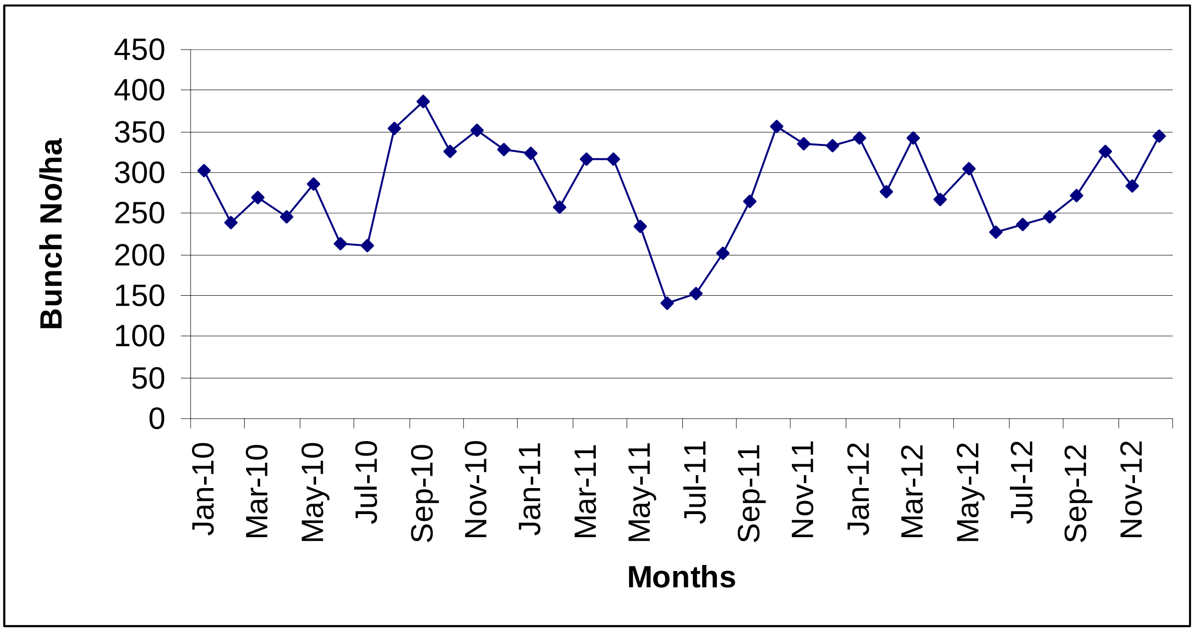


Figure 13. Monthly mean number of bunches per ha over the last three year period (2010 -2012).

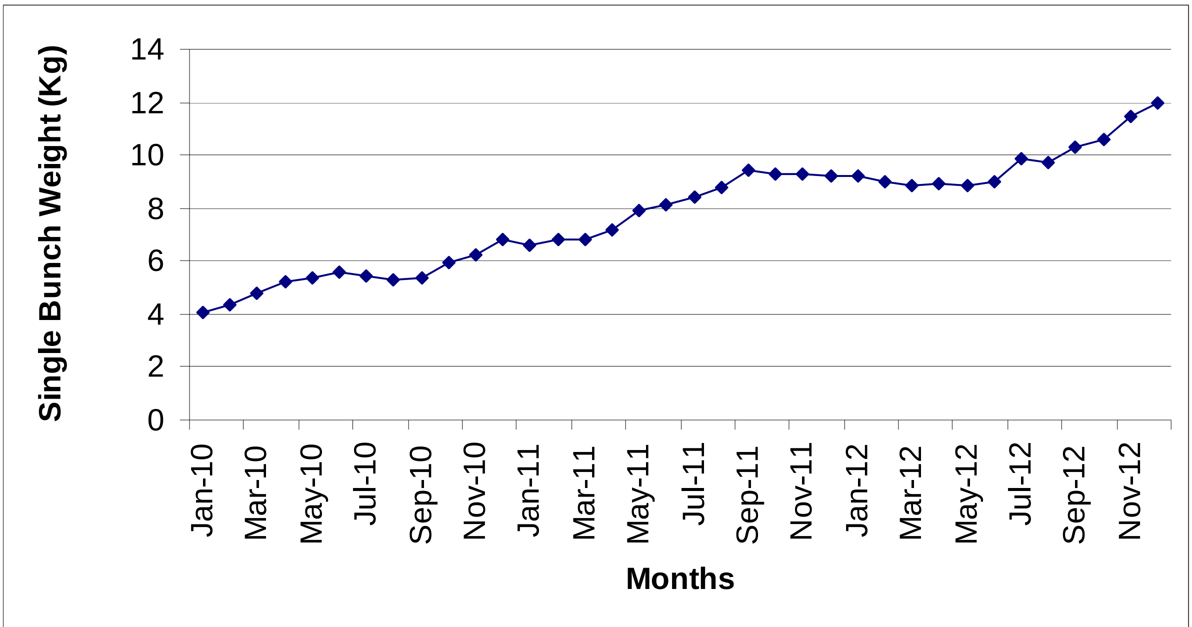


Figure 14. Monthly mean of single bunch weight per kg over the last three year period (2010- 2012).

Effects of Urea and TSP treatments on leaf (F17) nutrient concentrations
Urea increased leaflet Mg, Cl and rachis P, while TSP had no effect on the nutrient contents (Table 68 & Table 69). Increase in Urea rate resulted in fall in leaflet and rachis P contents.

Table 68. Effects (p values) of treatments on frond 17 nutrient concentrations 2012.

Source	**Leaflets**								**Rachis**			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ca**	**Cl**	**Ash**	**N**	**P**	**K**
Urea	0.314	0.449	0.510	0.711	**0.041**	0.613	0.306	**0.043**	0.880	0.890	**<0.001**	0.976
TSP	0.112	0.502	0.878	0.507	0.478	0.948	0.898	0.393	0.827	0.106	0.078	0.690
Urea.TSP	0.510	0.168	0.419	0.106	0.769	0.304	0.051	0.221	0.354	0.913	0.445	0.473
CV%	*7*	*3.5*	*2.4*	*4.6*	*9.6*	*10.0*	*4.9*	*9.1*	*9.3*	*8.2*	*16.9*	*10.5*

(p values <0.05 are indicated in bold).

Table 69. Main effects of treatments on F17 nutrient concentrations in 2011, in units of % dry matter, except for B (mg/kg).

Treatments	Leaflet nutrient contents								Rachis nutrient contents			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ca**	**Cl**	**Ash**	**N**	**P**	**K**
Urea-1	14.7	2.51	0.154	0.843	**0.278**	16.3	0.923	**0.337**	5.88	0.286	**0.252**	1.64
Urea-2	14.6	2.54	0.155	0.838	**0.288**	16.8	0.921	**0.329**	5.84	0.284	**0.196**	1.65
Urea-3	15.1	2.51	0.154	0.833	**0.266**	16.8	0.903	**0.313**	5.79	0.288	**0.221**	1.66
l.s.d$_{0.05}$										0.015	0.031	
TSP-1	14.2	2.54	0.155	0.852	0.286	16.5	0.910	0.338	5.94	0.284	0.199	1.69
TSP-2	14.7	2.51	0.154	0.833	0.278	16.4	0.914	0.322	5.69	0.272	0.219	1.60
TSP-3	14.8	2.48	0.154	0.827	0.278	16.8	0.910	0.324	5.82	0.290	0.221	1.62
TSP-4	15.2	2.54	0.155	0.845	0.279	16.6	0.918	0.332	5.89	0.298	0.239	1.65
TSP-5	15.3	2.52	0.155	0.833	0.266	16.9	0.926	0.316	5.85	0.286	0.238	1.67
l.s.d$_{0.05}$												
GM	14.8	2.52	0.155	0.838	0.278	16.6	0.916	0.326	5.84	0.286	0.223	1.65
SE	1.044	0.089	0.004	0.038	0.027	1.659	0.045	0.030	0.541	0.024	0.038	0.174
CV %	7	3.5	2.4	4.6	9.6	10.0	4.9	9.1	9.3	8.2	16.9	10.5

Effects with $p<0.05$are shown in bold

Effects fertiliser treatments on vegetative parameters

Urea significantly increased FL, HI, PCS, and dry matter production. TSP had no significant effect on any physiological parameters. Urea x TSP also showed no significant interactions (Table 70 & Table 71).

Table 70. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2012.

Source				Radiation interception			Dry matter production				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Urea	**0.016**	**<0.001**	**0.006**	0.119	0.368	0.473	**0.009**	**<0.001**	**<0.001**	**0.003**	0.412
TSP	0.307	0.282	0.327	0.525	0.218	0.257	0.486	0.367	0.335	0.432	0.846
Urea x TSP	0.221	0.235	0.700	0.245	0.409	0.299	0.373	0.061	0.107	0.303	0.222
CV %	*2.4*	*6.9*	*6.3*	*2.9*	*6.6*	*6.1*	*6.9*	*6.3*	*5.8*	*6.4*	*2.1*

p values <0.05 are indicated in bold.

Table 71. Trial 335, main effects of treatments on vegetative growth parameters in 2012.

Treatments				**Radiation interception**			**Dry matter production (t/ha/yr)**				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Urea-1	**514.1**	**100.2**	**22.2**	28.0	8.0	4.43	**9.4**	**18.4**	**30.8**	**12.4**	0.60
Urea-2	**510.7**	**108.4**	**22.8**	28.6	8.0	4.50	**9.8**	**19.0**	**31.9**	**13.0**	0.59
Urea-3	**522.4**	**109.8**	**23.7**	28.3	8.2	4.53	**10.1**	**20.0**	**33.4**	**13.4**	0.60
lsd $_{0.05}$	*8.02*			*0..527*		*0.175*	*0.430*	*0.765*	*1.193*	*0.532*	
TSP-1	515.4	106.3	22.9	28.0	7.9	4.41	9.6	18.7	31.5	12.8	0.59
TSP-2	510.2	106.6	22.7	28.6	7.9	4.45	9.7	19.4	32.3	13.0	0.60
TSP-3	514.4	108.2	23.3	28.2	8.2	4.54	9.8	19.1	32.2	13.1	0.59
TSP-4	517.2	102.0	22.3	28.3	8.0	4.13	9.5	18.8	31.4	12.6	0.60
TSP-5	521.3	107.4	23.4	28.4	8.3	4.63	10.0	19.5	32.8	13.2	0.60
lsd $_{0.05}$											
Grand mean	515.7	106.1	22.9	28.3	8.1	4.49	9.7	19.1	32.0	12.9	0.60
SE	112.6	7.286	1.436	0.826	0.532	0.274	0.674	1.198	1.869	0.833	0.012
CV %	*2.4*	*6.9*	*6.3*	*2.9*	*6.6*	*6.1*	*6.9*	*6.3*	*5.8*	*6.4*	*2.1*

Significant effects ($p<0.05$) are shown in bold.
FL = frond length (cm), FLI = Frond length increment (cm), PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production; BDM = Bunch Dry Matter production; TDM = Total Dry Matter production; VDM = Vegetative Dry Matter production; BI = Bunch Index (calculated as BDM/TDM).

Conclusion

Urea had a significant effect on yield, single bunch weigh, physiological parameters (FL, HI, PCS) and dry matter production, while TSP showed no effects in yield or its components, leaf nutrient concentrations and vegetative growth parameters.

SMALL HOLDER RESEARCH

Trial 218: Smallholder oil palm/food crop intercropping demo block, Kabaiya LSS (AIGS funded)

(RSPO 4.2, 4.3, 5.1, 6.1, 8.1)

Background

Food security exists when populations have access on an ongoing basis to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The trial was proposed to address food security problems in relation to land shortage in smallholder blocks (LSS) in the Bialla project area. Fundamental to addressing the increasing population and land pressures on the LSSs is the need to explore innovative ways of cultivating cash crops to free up land for food production. It is also important that food gardens provide a buffer against falling oil palm prices and provide income security for the smallholder growers and their families.

This is the third food security demonstration block in the oil palm sector carried out by OPRA and the first in the Bialla Project Area (OPIC) and funded by AIGS.

Table 72. Trial 218 background information.

Trial number	**218**	Company	OPIC – Bialla Project, OPRA, HOPL
Division	Meramera	Block No.	Kabaiya,1896 LSS (Paul Kausa)
Planting Density	65 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Freely draining
Date planted	Dec 2011	Topography	Flat
Age after planting	14 months	Altitude	19 m asl
Recording Started	first harvest	Previous Land-use	Old garden left to fallow
Progeny	Unknown*	Area under trial soil type (ha)	0.6ha
	Dami D x P	Assistant Agronomist in charge	Susan Tomda

Purpose

- To plant food crops in between palms in various spacing so eventually becomes a food security demonstration block.
- To build up some data base on intercropping, eventually become useful information to help equip small holder growers to improve their farming methods.
- help develop effective policies for enhancing food and livelihood security amongst smallholder oil palm growers b
- increase food production for domestic consumption and sale at local markets
- diversify and increase incomes, especially beneficial to women and blocks with large resident populations

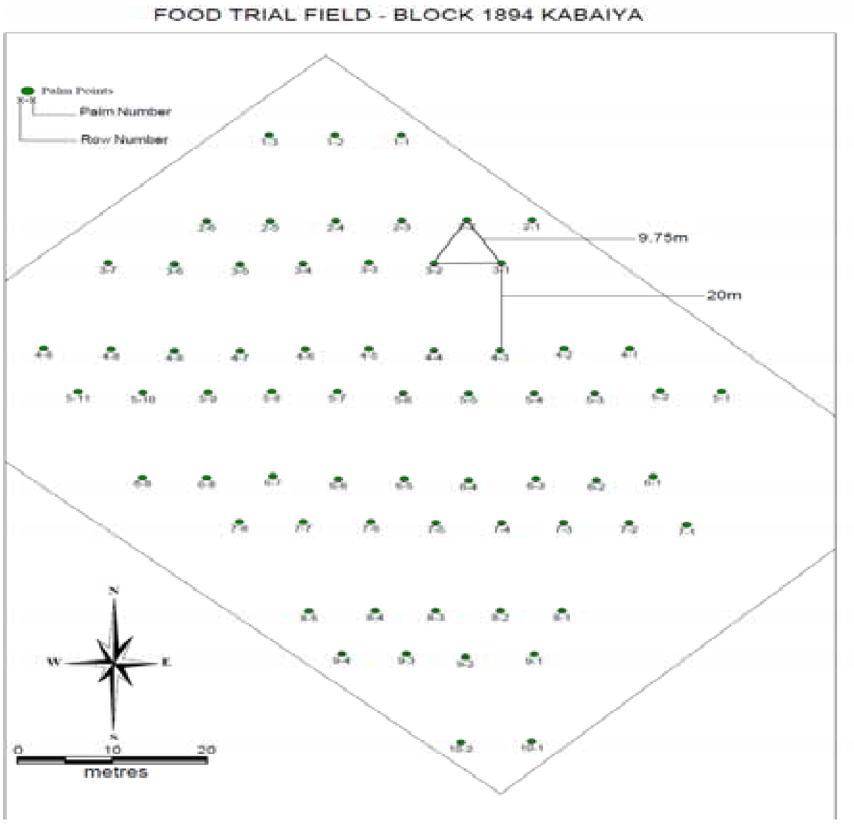


Figure 15. A diagram of how the trial is set out

Method

Intercropping Oil palm and Food crop

The trial site was a 0.6 hectare block as selected and agreed by the grower for demonstration purposes at Kabaiya LSS, Meramera Division. The site was mapped out by GPS team from OPIC assisted by OPRA/OPIC in the beginning of 2011. The block had a 20m x 20m wider avenue rows for oil palm planting. The block was divided into plots of 10m x 10m for (a) food crops and (b) legume cover crops (peanuts and beans). Two plots were planted with the same food crop and was rotated with legume cover crops within the wide avenue rows. The oil palms in both the normal and altered planting arrangements received fertilisers at the smallholder recommended rates.

This was the first demonstration block in the Bialla project area and will soon be rolled out if growers are interested in the idea. Market survey is also done per food crop harvested to see the economic value of the food crop.

Food crop measurements

<u>Above Ground –veins and leaves</u>

- ✓ Combine vines and leaves
- ✓ Weigh combine fresh weight (FW)
- ✓ Weigh separate FW for vines
- ✓ Weigh separate FW for leaves
- ✓ Mix thoroughly and sub sample vines and leaves
- ✓ Weigh sub sample FW for vines and leaves separately
- ✓ Divide sub sample into original (O) and duplicates (D)
- ✓ Oven dry at 75 degrees for 48 hours
- ✓ Weigh dry weight (DW) for vines and leaves separately

Below Ground – tubes and roots

- ✓ Combine tubes and roots
- ✓ Weigh combine fresh weight (FW)
- ✓ Weigh separate FW for tubers
- ✓ Weigh separate FW for roots
- ✓ Mix thoroughly and sub sample tubes and roots
- ✓ Weigh sub sample FW for tubers and roots separately
- ✓ Divide sub sample into original(O)and duplicate (D)
- ✓ Oven dry at 75 degrees for 48 hours
- ✓ Weigh dry weight for tubers and roots separately

Design and analysis

There was no strict statistical design used for setting up and analysing data from this experiment. Due to land shortage, only food crop land was allocated for the trial with no normal equal spacing arrangements. Plant tissue samples including yield and vegetative tissues were to be collected and dry matter production determined. The measurements will be done to determine nutrient movement in and out of the smallholder blocks. The food crop tissues were recorded per harvest.

Work progress 2011

- ✓ Site selected
- ✓ Area mapped out (OPIC-Bialla) including food crop
- ✓ Awareness made through the OPIC
- ✓ Slashing of bush/grass and Maintenance of trial
- ✓ Palm census done on a quarterly basis

Work progress 2012

- ✓ 65 oil palm seedlings planted
- ✓ Food crops planted (Kaukau, taro, yam, tapioca, rice, banana, peanuts, beans)
- ✓ Pre-treatment soils collected using an Auger from 0-60cm depth (0-20cm, 20-40cm, 40-60cm) in the Harvest path (HP) in February 2012. Soil will be tested for pH, Available P, Total P, Organic C, Total N
- ✓ 250g of AN applied per palm
- ✓ Food crops harvested and samples taken
- ✓ Market survey conducted

Results and discussion

Table 73. Summary of basic results of food crops data collected per harvest.

Field Data				**Market Data**			
Food Crop	**Quantity**	**Wts(kg) sub samples**	**Harvest Per Yr**	**Quantity**	**Wts(kg)**	**Unit Price/kilo**	**Unit Price/Qty**
Kaukau	135(...4)	45	2	11	11	K1/11kg	K1/11kaukau tubers
Yam(Africa)	50(...2)	62	1				
Tapioka	64(...2)	46	2	9	18.27	K0.70/18.27kg	K1/9tapioka tubers
Peanut	334(...5)	24	4	28	1.35	K0.50/1.35kg	K0.50/28pods
Taro/Singapore							Seeds collected
Banana/Rice							seeds collected

(...number *of mounds/stands per plot, average 10x10m)*

Summary
Food crops like kaukau, yam, and tapioca and legumes (peanut) performed very well in terms of yield. An average of 2 harvest was observed with kaukau, four harvest with peanut and one harvest with African yam. Banana, Singapore taro, rice and taro did not perform well. About 30% of food crops were stolen and 50% eaten by birds especially beans, peanuts, Singapore taro and taro.

On the other hand, oil palm seedlings are growing well after the transplanting. Second planting and monitoring will continue in 2013.

Trial 219: i) Smallholder Leaf Sampling, (RSPO 4.2, 4.3, 8.1)

Background

The Bialla smallholder oil palm project (LSS and VOP) was established in mid 1970's. It is made up of (3) three Divisions, -Cenaka (Divison-1), Maututu (Division-2) and Meramera (Division-3), extending from Haila river in the West to the border of East and West New Britain provinces on the East, covering about 13-15,000ha. Ammonium nitrate (AN), was supplied to LSS and VOP blocks by OPIC and applied either by the block owners or contractors. An application rate of 2.0kg AN/palm/year was first applied in 2011. The first leaf sampling was done in 2003 and then in 2004 but with no available data.

Leaf sampling commenced in 2009 and was carried out in selected representative blocks of the three Divisions. Leaf tissues were collected from frond 17 from 71 smallholder blocks (36 LSS and 35 VOPs) and sent to AAR Laboratory in Malaysia for nutrient analysis. Standard block assessment was also carried out in 2011-2012.

Purpose

To determine nutrient status of smallholder oil palms blocks from leaf tissue concentrations.

Smallholder block selection and sampling

In June/July 2012, a total of 71 blocks from LSS and VOP were randomly selected, 20-24 blocks were chosen from the 3 divisions in the project area. The selected blocks from the 3 divisions were further grouped into 11 classes according to topographical features as presented in Table 72. The leaf samples were then collected from palms 5-10 years old, which were marked for future reference and sampling. Leaf and rachis samples were collected from frond 17 on 4-7 palms per block.

In 2012, additional vegetative parameters (frond mark and count, palm census) and full standard leaf sampling procedures were carried out. The collected leaf tissue samples were sent to AAR for analysis.

Table 74. The table shows the topographical groupings

Division	*Group & Block location*	*Topography/Features*	*No blocks*
1	1- Lalopo, Uasilau,Sale	Flood plains/swamp	6
1	2-Kaiamo, Sulu, Malasi, Kiawa	Rock/ stones/sandy	6
1	3- Tiauru, Mataururu	Flat/foothills	7
2	4- Mataliliu, Ewase, Apupul, Baikekea	Flat/foothills	5
2	5- Bubu, Welolo	Sloppy/flat/swamp	7
2	6- Barema, Pakesi, Gigipuna	Flood plains/rocky/hills	7
3	7- Soi	Flood plains/ foot hills	7
3	8- Kabaya	Flat/ foot hills	7
3	9- Tianepou, Mauba, Galelolo	Flat/rocky, Kunai	7
3	10- Noau, Gamupa	Flat /gradual slope	6
3	11- Noua/Nantabu	Steep hills	5
			71

Results

The nutrient contents of the analysed leaf tissues are presented in Table 73 and Table 74. Leaflet N and P contents were below the adequate levels of 2.45 – 2.50 % DM and 0.148 % DM respectively. Leaflet K, Mg and B concentrations were reasonable; however, rachis K content was low. The palms were nutritionally deficient especially for N and P across all the 3 divisions since tissues were collected in 2009. The only obvious increase in the nutrient contents was in rachis N from 0.24%DM to 0.30%DM

Table 75. Leaf tissue nutrient concentrations of the 71 blocks in the 11 groups within the 3 divisions 2012

Division	*Group*	***Leaflet nutrient concentration (% DM)***					***Rachis nutrient concentration (%DM)***		
		N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
1	1	2.12	0.131	0.664	0.24	11.5	0.30	0.05	1.02
1	2	2.06	0.126	0.605	0.27	14.7	0.28	0.042	1.00
. 1	3	2.08	0.124	0.684	0.20	14.3	0.30	0.038	1.25
Division 1 mean		***2.09***	***0.13***	***0.65***	***0.24***	***13.52***	***0.29***	***0.04***	***1.09***
2	4	2.13	0.131	0.762	0.20	17.9	0.33	0.056	1.46
2	5	2.12	0.124	0.713	0.21	14.6	0.31	0.049	1.43
2	6	2.18	0.124	0.707	0.20	15.7	0.30	0.039	1.30
Division 2 mean		***2.14***	***0.13***	***0.73***	***0.20***	***16.06***	***0.31***	***0.05***	***1.40***
2	7	2.22	0.130	0.767	0.23	15.3	0.31	0.045	1.27
2	8	1.99	0.119	0.693	0.22	20.9	0.34	0.041	1.42
3	9	2.05	0.127	0.694	0.28	18.0	0.32	0.048	1.34
3	10	2.03	0.128	0.714	0.27	16.6	0.30	0.058	1.32
3	11	2.10	0.129	0.770	0.25	14.2	0.32	0.057	1.61
Division 3 mean		***2.08***	***0.13***	***0.73***	***0.25***	***16.98***	***0.32***	***0.05***	***1.39***
Grand Mean		2.10	0.127	0.702	0.23	15.5	0.31	0.047	1.29
Critical Value		*2.45*	*0.145*	*0.65*	*0.2*	*15*	*0.32*	*0.08*	*1.3*

Table 76. Tissue nutrient concentration for leaflets and rachis summarized in divisions for the 71 blocks in 2012

Division	**Leaflet (% DM, except B ppm)**					**Rachis (% DM)**		
	N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
1 – Ceneka (20)	2.09	0.13	0.65	0.24	13.52	0.29	0.04	1.09
2 – Maututu (20)	2.14	0.13	0.73	0.20	16.06	0.31	0.05	1.40
3 – Meramera (31)	2.08	0.13	0.73	0.25	16.98	0.32	0.05	1.39
Mean	**2.10**	**0.13**	**0.70**	**0.23**	**15.50**	**0.31**	**0.05**	**1.29**
Critical value	*2.45*	*0.145*	*0.65*	*0.20*	*15.0*	*0.32*	*0.08*	*1.30*

(...) number of blocks

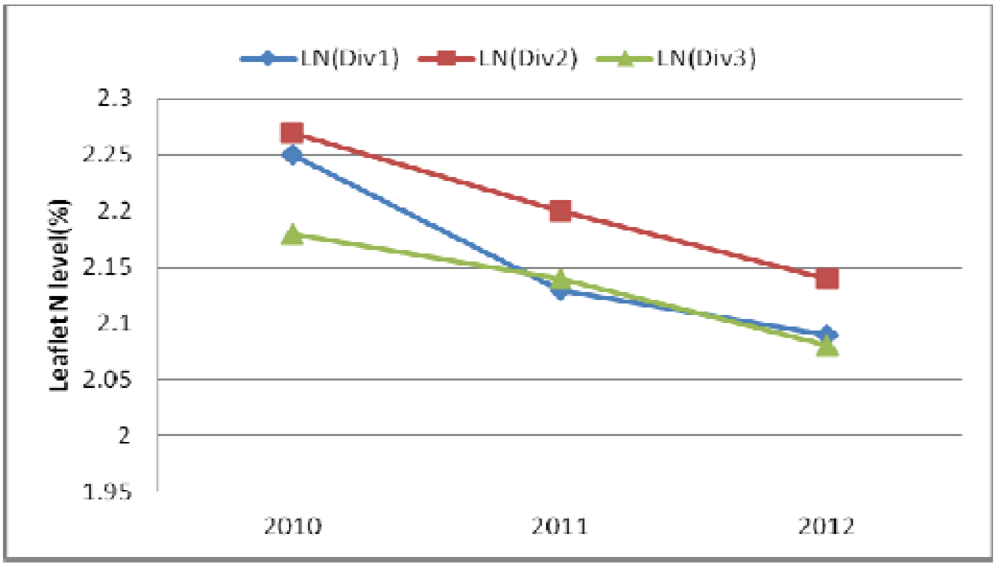


Figure 16. Leaflet N contents from 2010-2012

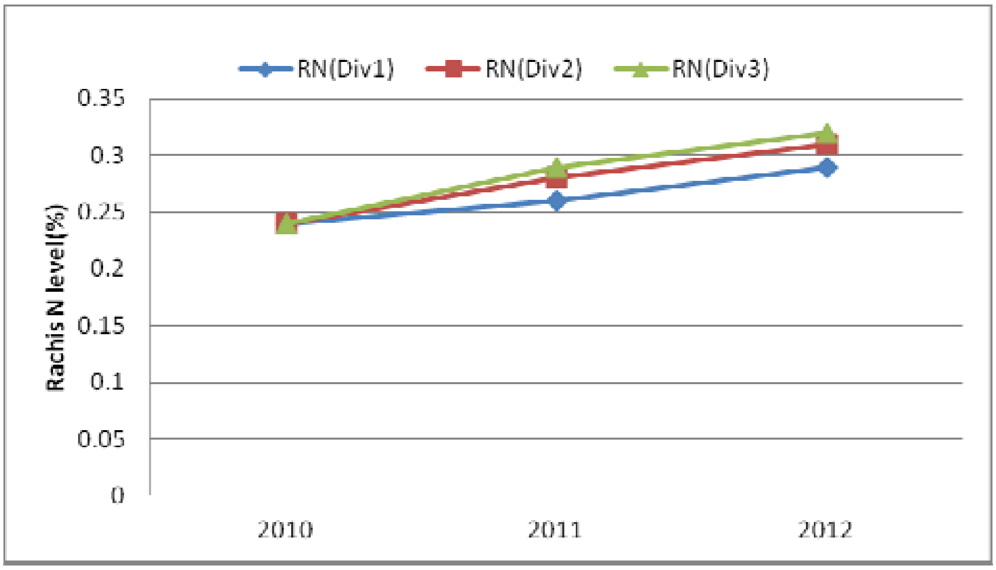


Figure 17. Rachis N contents from 2010-2012

Discussion and conclusion

There was not much difference in the nutrient concentration over since 2009 except rachis N, which is adequate in all 3 divisions (0.3 %DM). Nitrogen and P in leaflet and rachis P tissues are low (below adequate levels) except leaflet K. Rachis N shows an increase with time since 2009 (adequate level in 2012). The K content in both leaflet and rachis is above adequate level. There could be a lot of reasons for low N contents, which included non-application of fertilisers, rejected or disputed blocks, differences in palm age, poor upkeep, old blocks due for planting and palms planted on steep terrain. Sanitation was an issue in all blocks across all divisions.

Field days and radio broadcast

Common questions raised during the field days include:

- Can company supply EFB as alternative fertiliser source?
- Why growers applying only Ammonium Chloride (AC) or Ammonium Nitrate (AN)- N-sources and not others as the HOPL plantations do?
- What is the difference between the N sources of fertilisers (AC & AN)?

- When is the appropriate time for fertiliser applications?
- How many rounds of fertiliser application per year?
- What are the effects on the yield if the fertiliser delivery is delayed?
- Comparison of the two planting materials from Dami in terms of yield.
- Awareness of Food security and fertiliser demonstration blocks

Radio broadcasts were also a means of disseminating the technical information to the growers. However, PNGOPRA Bialla had 5/31 broadcast sessions in 2012. Topics covered in field days and radio talks were:

- What is PNGOPRA and its functions.
- The main effects of fertiliser (N) applications, in relation to yield, rates to apply and when is appropriate time to apply.
- Emphasis on the importance of fertiliser applications backed by trial results.
- Gains and losses on fertiliser applications against yield productions.
- Sanitation - to increase yield, isolate blocks from pest and disease infestation.
- Awareness to report in advance when blocks are infested with sexava and ganoderma, on its symptoms and dangers.
- Report on annual report of how well the smallholders were doing in yield productions per year, against trial and plantations results.
- Budgeting income from the block and how to improve on their spending.
- Food security trial establishment and its importance

Field visit

There were field visits to smallholder blocks for various activities;

- Socio-economic follow up on mobile card
- Agronomy leaf sampling at 72 blocks and
- Food security field day Kabaiya
- Visit of Best Management Practise (BMP) blocks

Field Days and radio broadcasts II

There were 2 different extension methods used during the year with OPIC. The field days and radio broad casts were organized by OPIC and PNGOPRA attended to these presentations (Table 77).

Table 77. Number of field days and radio broadcasts in 2012 for Bialla

Extension mode	Section		Total
	Agronomy and others	Agronomy alone	
Field days (...19)	0	7	7
Radio broadcasts(...31)	0	5	5

(....total number of field days and radio broadcast in Bialla Project area)

T219: ii) Smallholder Block Assessments
(RSPO 4.1-6, 4.8, 5.1, 8.1)

As part of the leaf sampling, block assessment was also done in 2012. While taking leaf tissue samples for nutrient analysis, visible nutrient deficiency from the surrounding 6 palms and legume cover crops were also assessed. Additional, physiological parameters (frond production, leaflet length, were also taken in 2012. The upkeep standards and pest and disease were also assessed and given a score out of three (refer to Figure 18 and Figure 19 for criteria used for assessment). The summarized scores are presented in Table 78.

Table 78. Smallholder block assessment scores in 2012

Criteria used for scoring block assessment	**Divisions**			**Average Score**
	Ceneka(19)	Maututu(19)	Meramera(33)	
Nutrient Deficiency – OP	1.4	1.2	1.3	1.3
Nutrient Deficiency – Cover	2.1	1.4	1.5	1.7
Block standard	1.9	1.7	2.2	1.9
Harvest- fruit on ground	1.9	1.5	2.2	1.9
Weeded circle	1.5	1.3	1.8	1.5
LCP	3.0	2.8	2.9	2.9
Weed ground cover	1.1	1.2	1.7	1.3
Frond stacks	2.7	2.3	2.0	2.3
Harvest paths	2.2	2.1	2.7	2.3
Woody trunk weeds	1.9	2.0	2.3	2.1
Trunk weeds – ferns	1.2	1.0	1.9	1.4
Pruning<7 years	1.8	1.7	2.4	2.0
Pruning>7years	1.5	1.3	1.3	1.4
Insect damage	2.0	2.0	2.2	2.1
Ganoderma	2.9	3.0	3.0	3.0
Rat Damage	2.9	2.8	3.0	2.9

(...) = number of blocks (VOP and LSS blocks included)

The mean nutrient deficiency score was 1.3 suggesting 3-4 (70-80 %) palms of the surrounding six palms showed nutrient deficiency symptoms. Nutrient deficiency was common across all blocks in all the 3 divisions (Table 78) and this was also reflected in the tissue analysis, especially nitrogen. General block upkeep (weeded circles, harvest paths and general weeds) were low in all the divisions, averaging at between 1.5 and 2.3. Average pruning standards were 2.0 for palms < 7 years and 1.4 for palms >7. The lower average at palms >7 years implied palms were probably too tall for pruning or only palms with bunches were being pruned. Harvesting standards were average with an average score of 1.9 for all the divisions. Insects pests, diseases and rat damage were high (2.1-3.0), with high frequency of rat damage at Ceneka and Maututu respectively. The assessments indicate that there were average scores in agronomic upkeep standards and pests and disease free blocks, however there were low scores in nutrient deficiency across all the divisions.

Block Assessment Form

Small holder block – hygiene and block management assessment

Block: **Division:**	**Date:**	**Inspected by:**

No	Insect/Nutrient deficiency	Score	Insect/Nutrient deficiency	Score
1	**Insect type:** **(i) % defoliation** 1. more than 25% 2. 1 to 25% 3. none		**Insect type:** **(ii) spears or fronds damaged** 1. 3 or more 2. 1 to 2 3. none	
2	**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none		**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none	
3	**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants		**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants	

Small holder block – hygiene and block management assessment

Block: **Division:**	**Date:**	**Inspected by:**

No	Insect/Nutrient deficiency	Score	Insect/Nutrient deficiency	Score
1	**Insect type:** **(i) % defoliation** 1. more than 25% 2. 1 to 25% 3. none		**Insect type:** **(ii) spears or fronds damaged** 1. 3 or more 2. 1 to 2 3. none	
2	**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none		**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none	
3	**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants		**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants	

No	Criteria or Standard	Score	No	Criteria or Standard	Score
4	**Harvest - Fruit on the ground:** 1. more than 30 fruit on ground 2. 5 to 30 3. less than 5		10	**Trunk weeds, woody or vines:** 1. more than 20% trunk covered 2. 1 to 20% 3. none	
5	**Weeded Circle:** 1. more than 50% ground cover 2. 10 to 50% 3. less than 10%		11	**Trunk weeds ferns:** 1. more than 80% (crown hidden) 2. 50 to 80% 3. less than 50%	
6	**Legume cover plants (LCP):** 1. less than 10% 2. 10 to 50%		12	**Pruning – less than 7 years old:** 1. 4 or more below lowest bunch 2. three to four	

Figure 18. Inspection form for smallholder blocks.

Procedures for under taking assessment:

- Select 6 palms randomly in block (each of these are called a palm site)
- At each palm site make the observations for the six surrounding palms (not including the palm you have selected to make your observations from)
- At each palm site record each of the criteria/standards listed and on the recording sheet fill in the average of the six palm sites

Details for each criteria/standard

No	Criteria or Standard
1	**Insects** • Record type of insect and extent of defoliation or frond damage
2	**Nutrient deficient palms** • Write in which nutrient is deficient and record no of palms (out of six) with the visual deficiency
3	**Ground cover deficiency** • Write in nutrient deficiency and record % of plants with the visual deficiency
4	**Harvest fruit on ground** • Assess number of loose fruit (total of fresh, old and rotten)
5	**Weeded circle** • Assess % of ground covered in the weeded circle with vegetation
6	**Legume cover plants** • Between the palms, assess % of ground covered with legume cover plants
7	**Weed ground cover (woody or grass weeds: Momordica, Kunai, Mimosa, Chromolaena, Weldaka)** • Between the palms, assess % of ground covered with these weeds
8	**Fronds stacks** • Record the placement of pruned fronds
9	**Harvest paths** • Record status of harvest paths
10	**Trunk weeds (woody or vines)** • Record % of trunk covered with woody weeds or vines
11	**Trunk weeds (ferns)** • Record % of trunk covered with ferns (at level 1 you cannot see bunches in the crown)
12	**Pruning (depending on palm age)** • Record the number of fronds below the most mature bunch
13	**Ganoderma** • How many of the six palms in each location have Ganoderma brackets
14	**Rat damage** • On either harvested bunches or bunches still on palms plus male flowers record the number of bunches plus male flowers with rat damage

Figure 19. **Procedures for filling in smallholder block inspection forms**

Smallholder Research Report in 2012, Oro Oil Palm Project
Murom Banabas and Merolyn Koia

Introduction
Smallholder sector within the oil palm industry comprises about half the oil palm planted area however contributes only 30-40 % of the total crop production in a year. The low proportion of total crop production is due to a variety of reasons ranging from socio-cultural-economic to agronomic to infrastructure related issues. Studies into socio-economic and cultural constraints to production are carried out by the Socio-economic Section and the reports are presented separately. This section deals specifically with addressing agronomic issues. The formal fertiliser trials have demonstrated especially in Popondetta and Milne Bay that fertilisers significantly increase annual yields however smallholder yields are generally low at 10-15 t/ha while in some plantations yields are at 30-35 t/ha. The agronomic involvement in smallholder studies include leaf tissue sampling and block assessments in selected blocks in Bialla and Popondetta, fertiliser trials in Hoskins, and fertiliser demonstration blocks in Poliamba and Milne Bay BMP blocks.

Smallholders are also not only involved in oil palm production but are involved in a number of other activities to sustain their livelihoods. A very important income source identified by Socio-economic studies within smallholder blocks is the sale of food crops in the local markets. PNGOPRA has set up a number of smallholder food security demonstrations in smallholder blocks. This is a joint project between Agronomy and Socio-economics Sections within PNGOPRA.

Smallholder activities are ongoing in all oil palm project areas around the country. This report highlights the four main areas of work for the smallholder sector in the Oro Oil Palm Project in 2012.

Main thrust of smallholder work:
1. Smallholder Leaf Sampling
2. Field Inspections (Visits)
3. Field Days
4. Radio Program for Oil Palm Growers in Oro Province.

Trial 336: SMALL holder Leaf Sampling

(RSPO 4.2, 4.3, 8.1)

Leaf sampling was carried out in selected representative blocks of the five Oil Palm Project Divisions; Sorovi, Igora, Saiho, Aeka and Ilimo Divisions. Leaf tissues were collected from frond 17 from 47 smallholder blocks and sent to AAR Laboratory in Malaysia for nutrient analysis. The results for each division are presented in Table 79. The mean nutrient contents of all the major nutrient elements were well below the critical levels. Nitrogen, the most important nutrient is required in all blocks in the 5 divisions as suggested by the low N contents in the sampled blocks. The K contents in the rachis were also low but N status has to be improved first. However, there were some blocks that had nutrient contents that were above the critical levels as indicated by the range of values. On the whole the average nutrient content of Sorovi Division was greater than the other four divisions, and N contents were lowest in Aeka while rachis K contents were lowest at Ilimo divisions. There were a range of reasons or possible combinations of reasons for the large range of values and they included; lack of fertiliser application, differences in palm age, negligence of block upkeep and very old palms due for replanting. In essence, the palms were very low in nutrients and needed inorganic fertiliser inputs especially nitrogen and potassium fertilisers.

Table 79. Mean nutrient contents of 47 smallholder blocks in 2012

Division		**Leaflet (% DM)**								**Rachis (% DM)**			
		Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**		**Ash**	**N**	**P**	**K**
Aeka (5)		13.5	1.87	0.125	0.63	0.26	0.70	0.31		3.26	0.21	0.098	0.92
Igora (13)		14.5	2.10	0.133	0.60	0.23	0.80	0.39		3.67	0.22	0.065	0.96
Ilimo (2)		15.2	2.15	0.133	0.43	0.17	0.96	0.43		3.19	0.28	0.040	0.30
Saiho (7)		14.1	2.17	0.136	0.55	0.24	0.85	0.41		3.20	0.24	0.054	0.67
Sorovi (20)		13.3	2.25	0.142	0.65	0.25	0.78	0.42		4.16	0.25	0.123	1.29
Mean		13.9	2.16	0.137	0.60	0.24	0.80	0.40		3.73	0.24	0.089	1.00
Min		10.25	1.60	0.106	0.40	0.13	0.58	0.2		2.38	0.17	0.031	0.2
Max		18.05	2.74	0.157	0.89	0.40	1.10	0.59		5.54	0.38	0.200	2.1
Critical value			*2.45*	*0.145*	*0.65*	*0.20*					*0.32*	*0.08*	*1.30*

(..) = number of blocks

Smallholder Block Assessments
(RSPO 4.1-6, 4.8, 5.1, 8.1)
While taking leaf tissue samples for nutrient analysis, visible nutrient deficiency from the surrounding 6 palms and legume cover crops were assessed. The upkeep standards and pest and disease were also assessed and given a score out of three (refer to Figure 20 and Figure 21for criteria used for assessment). The summarised scores are presented in Table 80.

The mean nutrient deficiency score was 2.1 suggesting 1-2 (10-30 %) palms of the surrounding six palms showed nutrient deficiency symptoms. Nutrient deficiency was common across all blocks in all the 5 divisions and this is also reflected in the tissue analysis results in Table 80. General block upkeep (weeded circles (1.6) and general weeds (1.6)) were low in all the divisions. The low to average score in nutrient deficiency scoring correlates well with the low nutrient concentrations in the leaflets discussed earlier. Average pruning standards were 2.0 for palms < 7 years and 2.4 for palms >7 suggest regular harvests which is indicated with high harvesting standards of 2.8. Insects pests, diseases and rat damage scored very high (3.0) implying no major problems with pests and diseases in the blocks. The assessments indicate that there is average and above average scores in agronomic upkeep standards and pests and disease free blocks, however there are low scores in nutrient deficiency across all the divisions. Harvesting at various frequencies is most likely leading to more nutrients leaving the blocks than going in and this could affect the long term sustainability of smallholder oil palm productivity.

Small holder block – hygiene and block management assessment

Block: **Division:**	**Date:**	**Inspected by:**

No	Insect/Nutrient deficiency	Score	Insect/Nutrient deficiency	Score
1	**Insect type:** **(i) % defoliation** 1. more than 25% 2. 1 to 25% 3. none		**Insect type:** **(ii) spears or fronds damaged** 1. 3 or more 2. 1 to 2 3. none	
2	**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none		**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none	
3	**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants		**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants	

Small holder block – hygiene and block management assessment

Block: **Division:**	**Date:**	**Inspected by:**

No	Insect/Nutrient deficiency	Score	Insect/Nutrient deficiency	Score
1	**Insect type:** **(i) % defoliation** 1. more than 25% 2. 1 to 25% 3. none		**Insect type:** **(ii) spears or fronds damaged** 1. 3 or more 2. 1 to 2 3. none	
2	**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none		**Palm Nutrient deficiency:** 1. 3 palms or more 2. 1 to 2 3. none	
3	**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants		**Ground cover nutrient def:** 1. more than 25% of plants 2. 5 to 25% of plants 3. less than 5% of plants	

No	Criteria or Standard	Score	No	Criteria or Standard	Score
4	**Harvest - Fruit on the ground:** 1. more than 30 fruit on ground 2. 5 to 30 3. less than 5		10	**Trunk weeds, woody or vines:** 1. more than 20% trunk covered 2. 1 to 20% 3. none	
5	**Weeded Circle:** 1. more than 50% ground cover 2. 10 to 50% 3. less than 10%		11	**Trunk weeds ferns:** 1. more than 80% (crown hidden) 2. 50 to 80% 3. less than 50%	
6	**Legume cover plants (LCP):** 1. less than 10% 2. 10 to 50%		12	**Pruning – less than 7 years old:** 1. 4 or more below lowest bunch 2. three to four	

Figure 20. Inspection form for smallholder blocks.

Procedures for under taking assessment:

- Select 6 palms randomly in block (each of these are called a palm site)
- At each palm site make the observations for the six surrounding palms (not including the palm you have selected to make your observations from)
- At each palm site record each of the criteria/standards listed and on the recording sheet fill in the average of the six palm sites

Details for each criteria/standard

No	Criteria or Standard
1	**Insects** • Record type of insect and extent of defoliation or frond damage
2	**Nutrient deficient palms** • Write in which nutrient is deficient and record no of palms (out of six) with the visual deficiency
3	**Ground cover deficiency** • Write in nutrient deficiency and record % of plants with the visual deficiency
4	**Harvest fruit on ground** • Assess number of loose fruit (total of fresh, old and rotten)
5	**Weeded circle** • Assess % of ground covered in the weeded circle with vegetation
6	**Legume cover plants** • Between the palms, assess % of ground covered with legume cover plants
7	**Weed ground cover (woody or grass weeds: Momordica, Kunai, Mimosa, Chromolaena, Weldaka)** • Between the palms, assess % of ground covered with these weeds
8	**Fronds stacks** • Record the placement of pruned fronds
9	**Harvest paths** • Record status of harvest paths
10	**Trunk weeds (woody or vines)** • Record % of trunk covered with woody weeds or vines
11	**Trunk weeds (ferns)** • Record % of trunk covered with ferns (at level 1 you cannot see bunches in the crown)
12	**Pruning (depending on palm age)** • Record the number of fronds below the most mature bunch
13	**Ganoderma** • How many of the six palms in each location have Ganoderma brackets
14	**Rat damage** • On either harvested bunches or bunches still on palms plus male flowers record the number of bunches plus male flowers with rat damage

Figure 21. **Procedures for filling in smallholder block inspection forms**

Table 80. Smallholder block assessments scores in 2012

Criteria used for scoring block assessment	**Divisions**					**Average Score**
	Aeka (5)	Igora (13)	Ilimo (2)	Saiho (7)	Sorovi (20)	
Palm Nutrient Deficiency	1.4	1.9	2.5	2.1	2.3	2.1
Block Standard	3.0	3.0	3.0	3.0	2.8	2.9
Frond stack	2.6	2.7	3.0	2.9	2.6	2.7
Ganoderma	3.0	3.0	3.0	3.0	3.0	3.0
Ground cover-deficiency	3.0	3.0	3.0	3.0	3.0	3.0
Harvest standard	3.0	3.0	3.0	3.0	2.6	2.8
Harvest paths	2.0	2.5	1.5	2.1	2.1	2.2
Insect Damage	3.0	3.0	2.0	3.0	3.0	3.0
LPC	2.4	2.3	3.0	2.9	2.5	2.5
Pruning <7years		2.0			2.0	2.0
Pruning >7years	2.4	2.3	3.0	2.4	2.3	2.4
Rat Damage	3.0	3.0	3.0	3.0	3.0	3.0
Trunk weeds/ferns	3.0	3.0	3.0	3.0	2.8	2.9
Trunk weeds/woods/vines	2.2	2.1	2.0	2.1	2.2	2.2
Weeded circle	1.0	1.8	1.0	1.4	1.7	1.6
Weed-ground cover	1.6	1.8	1.0	1.0	1.8	1.6

(..) = number of blocks

Field Visits
There were field visits to smallholder blocks for various activities; Socio-economic surveys at 100 blocks, while agronomy leaf sampling was done in 47 blocks.

Field Days and radio broadcasts
There were 3 different extension methods used during the year with OPIC. The first involved large number of growers (100-150) from a division and referred to as major field days. The second involved smaller number of growers (7-10) coming to PNGOPRA fertiliser trials and shown around the trial plots and third was radio broadcasts.

The field days and radio broad casts were organized by OPIC and PNGOPRA attended to these presentations (Table 81). There was only 1 major and 1 minor field day held in 2012.

Table 81. Number of field days and radio broadcasts in 2012

Extension mode	Section		Total
	Agronomy and others	Agronomy alone	
Field days (Major)	1		1
Field days (Minor)		1	1
Radio broadcasts	Nil	Nil	nil

Common questions asked by the growers were in earlier field days:
- What is the difference between the 1st and 2nd planting materials?
- Why does the company apply MOP (red *marasin*) & SOA (white *marasin*) while the growers are only provided with SOA?
- Can the fertiliser application be divided into smaller portions?
- What are the orange spots/colour on the palm leaves?
- When and why is the company not giving fertilisers on time as per the calendar schedule?

The main topics presented to growers during field days were:
- Explaining what PNGOPRA is and what are its functions
- Explaining the importance of fertiliser, the main type of fertiliser (SOA), main role of SOA in oil palm production, application rates for immature and mature palms.
- Fertiliser application calendar
- Block sanitation- to slow down the pest population (especially Sexavae and Stick insects in all the small holder blocks).
- Budgeting and savings of earnings from oil palm
- Biological control measures to control pest and weeds at the growers' level.
- Ganoderma awareness –"*Tok save*" to all block holders to check all the palms in their block for symptoms of Ganoderma and also the brackets and report any findings to their Area Extension Officers.
- Environment and sustainability project
- Food security and OPRA-OPIC food security project
- Impacts of HIV-AIDS on oil palm production

Trial 337: Smallholder oil palm/food crop intercropping demo block, Sangara and Biru in Oro Province (AIGS funded)
(RSPO 4.2, 4.3, 5.1, 6.1, 8.1)

Summary
Planting of food crops at both Sangara and Biru are ongoing. Data collected suggested varying dry matter production however mostly in the vegetative tissues parts.

Background
Food gardening is a primary livelihood activity of smallholders. All smallholder households grow sufficient food to meet their food requirements, and the sale of garden foods at local markets provides women with an important source of income. Smallholders spend considerably more time in gardening than they do in oil palm related work. In 2000, women allocated almost 2.5 times as much of their labour to gardening than to oil palm, whereas, for men, gardening and oil palm were of about equal importance in terms of the time allocated to each activity (Koczberski *et al*. 2001). The same study also demonstrated the importance of food gardens for maintaining food security: dietary recall surveys during a period of low oil palm prices revealed that almost 80% of meal ingredients were from household food gardens. Food gardens provide a buffer against falling oil palm prices and provide income security for the smallholder growers and their families.

Fundamental to addressing the increasing population and land pressures on the LSS blocks is the need to explore innovative ways of cultivating cash crops to free up land for food production. One potential strategy emerged from a six year trial (since 2002) to assess different planting densities and spacing of oil palm in the plantation sector for use of machines for infield collection of harvested fruit. Yield data for the past 6 years have shown no yield penalty from shortened inter-palm distance with wider avenue plots. Broader avenues meant more light was able to penetrate to ground level with a consequent increase in vegetation cover thus reducing soil compaction from the use of machines. However, these findings for the plantation sector are of great significance to the smallholder sector because alternative planting patterns with wider avenues can enable intercropping of oil palm with food crops and fuel wood species while maintaining per ha oil palm yields. There have been no agronomy trials in oil palm smallholder blocks in PNG to address food security, and this trial will be very important for current and future smallholdings, and the technology developed here has the potential to be transferred to other tree crop industries like cocoa and coffee.

The trial was set up to:

- help develop effective policies for enhancing food and livelihood security amongst smallholder oil palm growers
- development strategies for intercropping oil palm with food and fuel wood crops which will have relevance for other export cash crops
- increase food production for domestic consumption and sale at local markets
- diversify and increase incomes, especially beneficial to women and blocks with large resident populations
- produce fuel wood and food on-block thereby reducing pressure on environmentally sensitive areas such as creeks and river banks and on steep slopes.

To provide a greater understanding of how commodity crops can be intercropped with food crops and fuel wood species is vital for developing sustainable farming systems in PNG.

Method

Intercropping trials.
Two blocks were chosen in Popondetta for the studies, Blocks 050136 (Sangara) and 888888 (Biru). Depending on block sizes, the experimental areas varied from 2 to 4 hectares each. The experimental

areas in each block were divided into two: the first half was planted with oil palm at the normal equilateral spacing of 128 palms per ha, while the second half of the block was planted at the same density of 128 but with shorter planting distances between the palms and wider avenue widths between every second row of palms, though may be at reduced density in some cases. In the first half of the block (normal equilateral planting distance), legume cover crop were established with no food crop. However at Biru, food crops have been planted in the normal planting density to see crop production before canopy closes. In the second half of the block, the wide avenue rows were divided into plots. The plots were planted with (a) food crops (b) legume cover crops and (c) tree crops (fuel wood **spp**). The food crops were meant to rotate with legume cover crops within the wide avenue rows. The oil palms in both the normal and altered planting arrangements will receive fertilisers at the smallholder recommended rates.

Design and analysis
There was no strict statistical design used for this experiment. The blocks were divided into two but not necessary equal halves depending on the farmers' wishes. One half of the block was planted at normal equal spacing arrangements while the other half with altered spacing arrangement. Soils and plant tissue samples were collected randomly and replicated in odd numbers for analysis. Block information for Sangara and Biru are shown in Table 82 and Table 83while the sketch maps in Figure 22and Figure 23 respectively.

Table 82. Trial 337, Block information - Sangara

Trial number	**337**	Soil Type	Volcanic ash plain
Block owner	Mr. R. Safitoa	Drainage	Good
Block No.	050136	Topography	Flat
Location	Sangara	Altitude	m asl
Division	Sorovi	Previous Land-use	Oil Palm
Planting Density	128		
	128	Supervisor in charge	Merolyn Koia
Pattern	Triangular		
Date planted	2008		
	2010		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2010 (Food crops)		

Table 83. Trial 337, Block information - Biru

Trial number	**337**	Soil Type	Volcanic outwash plain
Block owner	Biru CIS	Drainage	Good
Block No.	888888	Topography	Flat
Location	Biru – Sorovi	Altitude	m asl
Division	Sorovi	Previous Land-use	Oil Palm
Planting Density	128		
		Supervisor in charge	Merolyn Koia
Pattern	Triangular		
Date planted	2012		
	2012		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2012 (Food crops)		

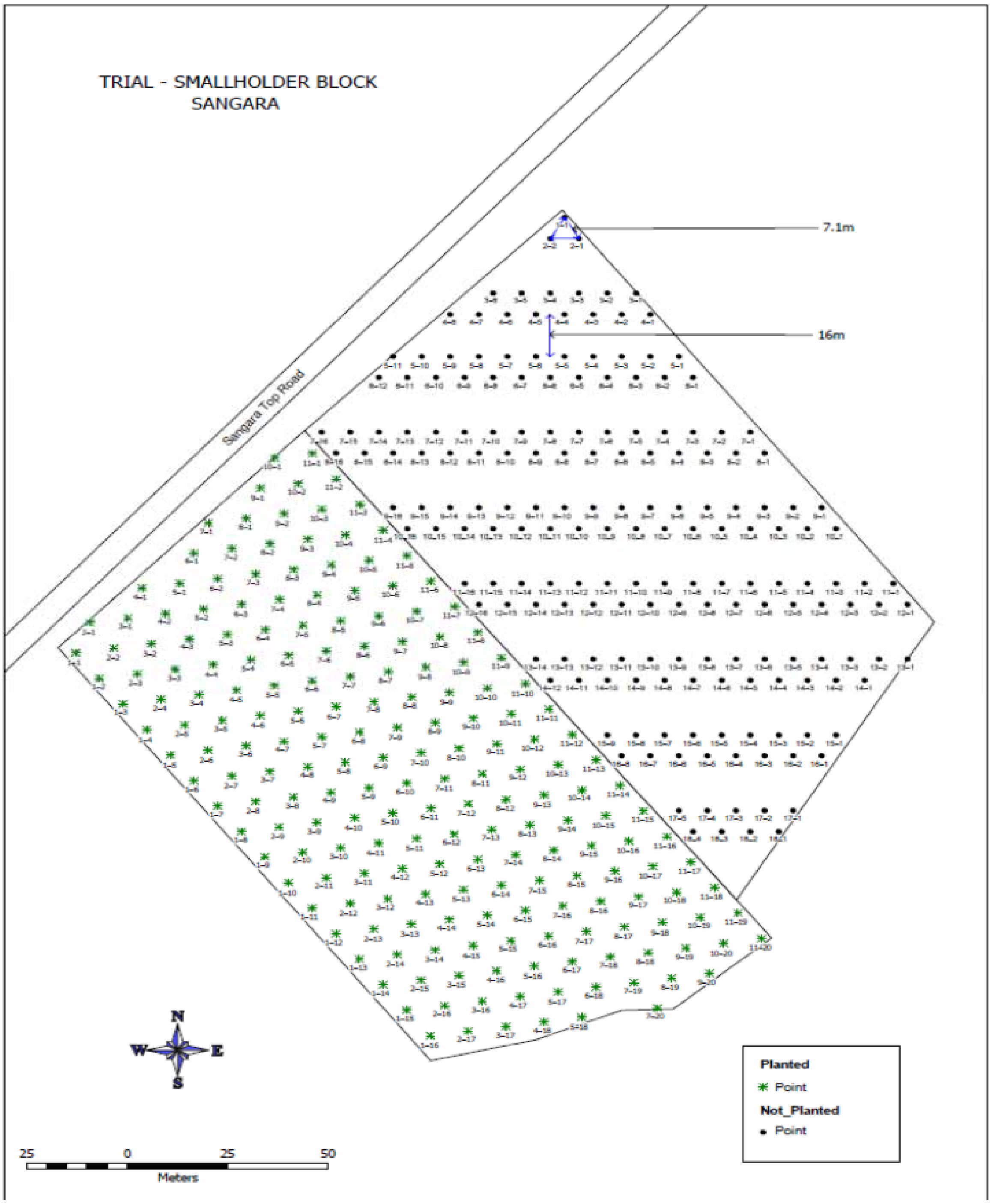


Figure 22. Sketch of small holder block in Sangara

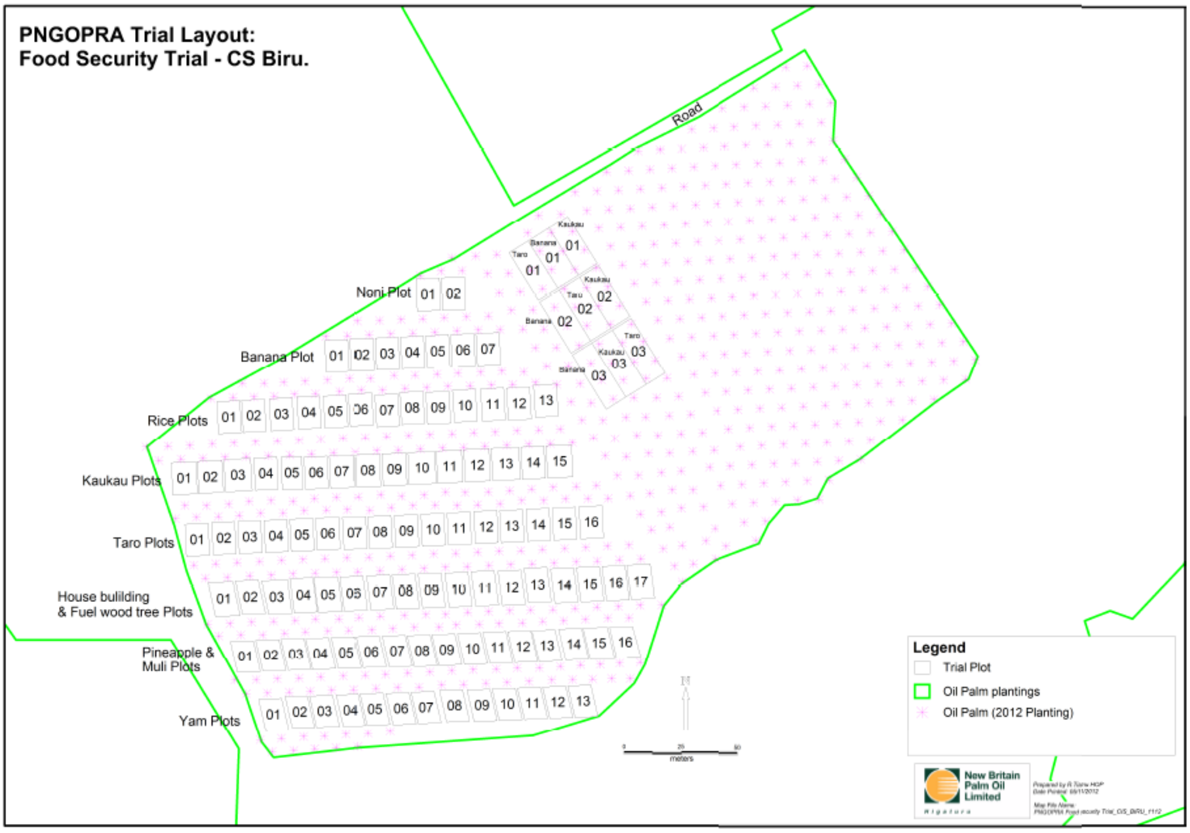


Figure 23. Sketch of small holder bloc in Biru

Data collection

Plant tissue samples including yield and vegetative tissues were collected and dry matter production determined from the food crops. The measurements were done to determine nutrient movement in and out of the smallholder blocks. Oil palm vegetative measurements and yield data were also collected from the two blocks. A summary of major crops planted to date is presented on Table 84and Table 85. Other crops not included are mandarin, *noni*, fuel wood, wood for house roof, pineapples, bananas and cassava. The duration of cropping is 4-6 months for the major crops.

Table 84. Major food crops and date of planting in Block 050136 at Sangara

Crop	Total plots	Rounds	Date planted	Date Harvested	Months	Planted plots	Plot size
Kaukau	8	1	17-Jun-10	27-Oct-10	4	3	10m x 10m
		2	16-Dec-10	17-Jun-11	6	4	10m x 10m
		3	22-Jun-11	25-Oct-11	4	4	10m x 10m
		4	27-Oct-11	Stolen		4	10m x 10m
Taro	6	1	21-Jan-10	6-Jul-10	6	3	10m x 10m
		2	9-Jul-10	18-Dec-10	6	3	10m x 10m
		3	28-Jan-11	1-Aug-11	6	3	10m x 10m
		4	10-Aug-11	Pig eaten		3	10m x 10m
Rice	4	1	5-Jan-10	27-May-10	5	2	10m x 10m
		2	7-Jun-10	16-Nov-10	5	2	10m x 10m
		3	5-Jan-11	4-Jul-11	6	2	10m x 10m
		4	11-Aug-11	5-Jan-12	5	2	10m x 10m
Yam	6	1	16-Apr-10	8-Nov-10	7	3	10m x 10m
		2		26-Oct-11	6	3	10m x 10m
		3	Pigs damaged			3	

Table 85. Major food crops and date of planting in Block 88888 at Biru - CIS

(a) Normal oil palm spacing

Crop	Total plots	Rounds	Date planted	Date Harvested	Months	Planted plots	Plot size (m)
Kaukau	3	1	22-May-12	5-Sep-12	4	3	10 x 24.5
	3	2	10-Sep-12	26-Feb-13	4	3	10 x 24.5
	3	3	04-Feb-13			3	10 x 24.5
Taro	3	1	25-May-12	29-Oct-12	5	3	10 x 24.5
	3	2	6-Nov-12			3	10 x24.5
Banana	3	1	22-May-12	6-Mar-13		3	10 x 24.5

(b) Wide avenue oil palm spacing

Crop	Total plots	Rounds	Date planted	Date Harvested	Months	Planted plots	Plot size (m)
Kaukau	15	1	18-Jun-12	6-Nov-12	5	4	10 x 14
	15	2	9-Nov-12	26-Mar-13	5	4	10 x 14
	15	3	9-Apr-13			4	10 x 14
Taro	16	1	8-Nov-12			3	10 x 14
Rice	13	1	5-Jun-12	02-Oct-12	4	4	10 x 14
	13	2	2-Jan-13			4	10 x 14
Yam	13	1	15-Jan-13			5	10 x 14

Results and discussion

Results of dry matter production and nutrient contents of main staple food crops and crop parts from Sangara Block are presented in Table 86 and Table 87 respectively. The results are presented on per ha basis and for a single crop cycle. The total nutrient for each of the crop represents the nutrient demand for the crop during that cropping cycle while the nutrient content of the part that is harvested for cooking or for market represents the amount of nutrient that is exported from the system. The data for taro is presented in two parts, with and without EFB compost.

Most of the food crop DM produced are in the vegetative unharvested parts of the crop except for yam with 87% of the total dry matter at the time of harvest were from the tubers. In the “No EFB compost” taro plots, the corm DM was 25 %, however after addition of compost, the corm DM increased to 46 % of the total DM. Addition of EFB compost increased taro corm DM weight by about seven times, and this shows clearly the importance of use of EFB compost for food crop farming especially taro production in the replanted oil palm blocks.

Table 86. Food crops dry matter production in 2010-2011 at Sangara

Crop	Crop part	DM kg/ha/crop	% of Total DM
Kaukau	Leaf	663.1	16.7
	Vines	2124.5	53.5
	Roots	151.6	3.8
	Tubers	1030.7	26.0
	Total	**3969.92**	
Taro		No Compost	
	Corm	498.7	25.6
	Stick	775.9	39.8
	Suckers	674.8	34.6
		1949.45	
		With compost	
	Corm	3646.4	45.7
	Stick	1333.7	16.7
	Suckers	2999.7	37.6
		7979.79	
Yam	Leaves	73.0	5.5
	Roots	1.8	0.1
	Tubers	1162.3	86.9
	Vines	100.4	7.5
		1337.57	
Rice	Good rice grains	8.99	0.1
	Bad rice grains	8.03	0.1
	Rice stalk	6696.33	99.7
		6713.35	

Of the three main staple crops (kaukau, yam and taro with no EFB), kaukau appeared to have the highest nutrient demand. This is a very crude comparison because of the different timing of cropping and not all the crops were producing at their potential yield. Kaukau demanded 51kg of N per cropping cycle however removed 6kg N /ha. In the no EFB compost plots, taro demanded 29kg of N and removed 3.5kg of N while yam demanded 16kg N and removed 14kg N. Rice appeared to demand more N than the other food crops however because of the very low yields; N removed cannot be really calculated. Addition of EFB greatly increased DM production of taro corms and the other components and also increased the nutrient demand. Nutrient removed with the corms was greater than from the other crops.

The harvested crop implies nutrient removed from the system for domestic use and or marketing. Taro corms in EFB added plots and yam tubers appeared to remove most nutrients from the system. The nutrient removal from the system was probably highest with taro because the sticks and suckers were normally removed as well for gardening in other newly cleared areas.

Table 87. Nutrient contents of food crops at Sangara in 2010 and 2011.

				Nutrient content (kg/ha/crop)						
Crop	**Crop part**	**Dry matter**		**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**Fe**
		(kg/ha/crop)								
Kaukau	Leaf	663.1		20.28	1.93	24.73	2.52	6.39	2.45	0.53
	Vines	2124.5		23.54	7.86	106.22	7.99	21.07	21.41	0.41
	Roots	151.6		1.40	0.29	2.65	0.31	2.33	0.45	0.21
	Tubers	1030.7		5.96	1.94	14.04	0.80	1.55	1.76	0.21
	Total			**51.09**	12.03	147.65	11.62	31.34	26.08	1.36
Taro		No EFB compost								
	Corm	498.7		3.57	0.88	6.49	0.54	1.91	0.28	0.14
	Stick	775.9		13.23	3.41	37.16	1.59	11.72	2.41	0.42
	Suckers	674.8		12.59	3.72	35.06	1.60	8.38	1.60	0.50
	Total			**29.38**	8.00	78.71	3.73	22.01	4.29	1.05
		With EFB compost								
	Corm	3646.4		36.83	10.05	53.72	4.01	8.14	1.64	0.22
	Stick	1333.7		39.61	8.94	72.68	3.73	12.54	1.87	0.19
	Suckers	2999.7		85.49	20.40	145.19	8.70	33.00	3.60	1.31
	Total			**161.93**	39.39	271.59	16.44	53.68	7.11	1.72
Yam										
	Leaves	73.0		1.37	0.10	0.35	0.49	2.84	0.12	0.00
	Roots	1.8		0.01	0.00	0.00	0.00	0.01	0.00	0.00
	Tubers	1162.3		13.85	1.59	13.70	2.03	8.32	1.24	0.00
	Vines	100.4		0.58	0.06	0.42	0.25	1.74	0.05	0.00
	Total			**15.81**	1.75	14.47	2.76	12.90	1.41	0.00
Rice	Good rice grains	8.99		0.14	0.02	0.02	0.01	0.00		0.00
	Bad rice grains	8.03		0.10	0.01	0.02	0.01	0.01		0.00
	Rice stalk	6696.33		89.62	9.40	137.27	9.71	13.06		2.55
	Total			**89.87**	9.43	137.32	9.73	13.07	0.00	2.55

Conclusion

More than 50% of the dry matter produced was in non consumable/marketable products except for yam. EFB addition greatly increased the production of taro. *Kaukau* (potato) appeared to have the highest nutrient demand. Major staple crops can be produced twice a year.

Trial 520: Milne Bay Smallholder fertiliser/BMP demonstration blocks
(RSPO 4.2, 4.3, 4.5, 4.6, 4.8, 8.1)

Work is in progress

Trial 256: New Ireland Smallholder fertiliser/BMP demonstration blocks
(RSPO 4.2, 4.3, 4.5, 4.6, 4.8, 8.1)
Murom Banabas and Paul Simin

Background
In February 2008, OPIC, CTP Poliamba LTD, and PNGOPRA agreed to set up two fertiliser demonstration blocks (in different locations) within the smallholder blocks in New Ireland. Many smallholder blocks were very low yielding and the demonstration plots were to show best management practices to smallholder oil palm growers in New Ireland.

Trial setup
The demonstration trials started in 2008 and some of the information about the blocks is presented in (Table 88). Each of the 2 blocks has a different number of palms with nil fertilised and fertilised plots. At Lakurumau, Block 5655 has 40 palms not receiving any fertiliser while the rest of the block received fertiliser. Yield recording was done on the 40 nil fertilised palms and from 80 of the palms given fertiliser. The palms with fertiliser in both blocks received 6kg SOA and 2kg MOP per palm per year in 2008 but SOA was reduced to 3kg and while MOP remained at 2kg/palm/year in 2009 and thereafter. A new block (Block 1618) was established in 2010 to replace the previous block at Kafkaf because the grower at Kafkaf was having problems in organising FFB harvesting.

Table 88. Trial 256 demonstration blocks information

Trial number	**256**	Soil Type	On raised coral
Block owner	Siri	Drainage	Good
Block No.	2655	Topography	Flat
Location	Lakurumau	Altitude	m asl
Division		Previous Land-use	Food gardens
Planting Density	(a)		
	(b)	Supervisor in charge	Paul Simin
Pattern	Triangular		
Date planted	(a)		
	(b)		
Trial started	March 2008		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2010 (Food crops)		

Methods
Yield data was collected on a fortnightly basis from the nil fertilised and selected fertilised palms while petiole cross section is measured twice in a year. Leaf tissues were collected once a year for nutrient analysis.

Results and discussion
Yield data and petiole cross section data are presented in Table 89 and Table 90. Data collection began in June 2009. The palms given fertiliser yielded more bunches and had higher single bunch weights than nil fertilised palms. This resulted in higher FFB yields from the fertilised palms than from the nil fertilised palms. In 2012, fertilised palms yielded 27.1t/ha compared to 17.5t/ha from the nil fertilised palms, a difference of 9.6 tonnes. A similar trend was seen in the second block (Block 1618) (Table 89). Yield response to fertilisers was rapid after a year (Figure 24). The increase in

yield in nil fertilised plots was probably due to the palms accessing fertilisers from neighbouring fertilised palms.

Petiole cross section (PCS) in fertilised plots was greater than in nil fertilised plots.

Table 89. Trial 256, Yield, yield components results – Block 2655

Year	Treatment	FFB yield (t/ha)	BN (Bunches/ha)	SBW (kg)	PCS-1	PCS-2	FL
2009	- Fert	7.7	573	13.4	20.0	20.8	
	+ Fert	9.1	590	15.4	23.4	27.8	
2010	- Fert	7.6	477	15.9	26.9	28.3	
	+ Fert	24.9	1272	19.6	34.0	37.1	
2011	- Fert	17.4	1059	16.4	23.5		497.6
	+ Fert	25.1	1256	20.0	32.7		523.5
2012	- Fert	17.5	1024	17.1	24.5		
	+ Fert	27.1	1235	22.0	34.7		

PCS = petiole cross section (cm^2) measured in April (PCS-1) and October (PCS-2)

Table 90. Trial 256, Yield and yield components in 2011 for Block 1618

Year	Treatment	FFB yield (t/ha)	BN (Bunches/ha)	SBW (kg)	PCS-1	FL (cm)
2011	- Fert	11.3	1315	8.6	20.7	533.3
	+ Fert	25.3	2582	9.8	21.5	531.3
2012	- Fert	15.2	1469	10.3	23.9	
	+ Fert	19.5	1486	13.1	25.3	

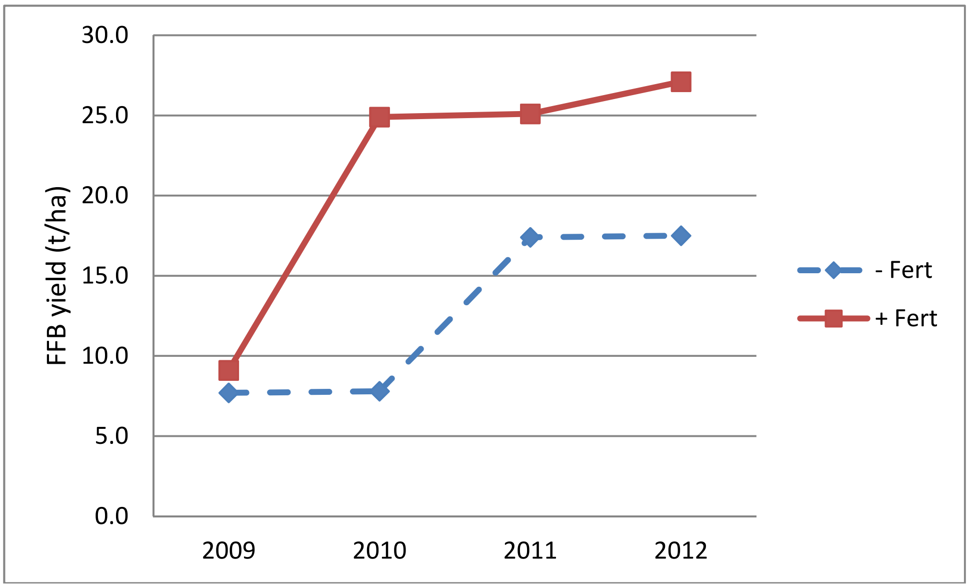


Figure 24. Fresh fruit bunch yield from Block 2655 in fertilised and nil fertilised plots from 2009 to 2012

Analysed leaf tissue results are presented in Table 91 and Table 92for the two demonstration blocks. At both blocks, leaflet N and K, and rachis K in the fertilised palms were greater than those in the nil fertilised palm. Leaflet N contents increased to above adequate levels (2.50 % DM) however leaflet and rachis K contents were still very low. The increase in rachis K from 0.20 % DM to 0.87 % at Lakurumau in 2012 corresponded with a yield increase of 9 t/ha, during the same period. There were increases in rachis K contents in 2012; however the contents are still lower than the critical levels of 1.35% DM. On the other hand, the rachis K contents are still increasing with time (Figure 25).

Table 91. Trial 256, Leaf tissue nutrient contents (% DM except B in ppm) from 2009 to 2012 in Block 2655 at Lakurumau.

Year	Treatment	Leaflet										Rachis			
		Ash	N	P	K	Mg	Ca	Cl	B	S		Ash	N	P	K
2009	- Fert	7.62	2.10	0.150	0.42	0.49	1.61		21.8			3.47	0.26	0.156	0.24
	+ Fert	7.67	2.27	0.152	0.44	0.49	1.44		14.5			3.60	0.29	0.145	0.30
2010	- Fert	6.68	2.33	0.152	0.42	0.36	1.38		17.0	0.18		3.45	0.27	0.114	0.20
	+ Fert	6.11	2.59	0.157	0.61	0.27	1.17		12.3	0.20		3.43	0.37	0.118	0.69
2011	- Fert	6.71	2.25	0.148	0.4	0.39	1.46		10.6	0.19		3.69	0.57	0.088	0.20
	+ Fert	6.13	2.48	0.151	0.61	0.28	1.28		9.6	0.2		3.34	0.32	0.094	0.67
2012	- Fert	7.38	2.29	0.161	0.42	0.4	1.56	0.47	16.3	0.18		3.23	0.31	0.116	0.2
	+ Fert	6.74	2.46	0.165	0.61	0.26	1.5	0.67	10.9	0.2		3.8	0.51	0.134	0.87

Table 92. Trial 256, Leaf tissue nutrient contents (% DM except B in ppm) in 2011 and 2012 at Block 1618.

Year	Treatment	Leaflet										Rachis			
		Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**S**		**Ash**	**N**	**P**	**K**
2011	- Fert	7.73	2.18	0.143	0.4	0.57	1.35		16.7	0.18		2.9	0.38	0.086	0.20
	+ Fert	8.26	2.25	0.144	0.4	0.66	1.34		16.5	0.19		3.4	0.38	0.082	0.24
2012	- Fert	8.43	2.53	0.165	0.44	0.54	1.48	0.67	17.8	0.2		3.11	0.3	0.093	0.24
	+ Fert	7.6	2.80	0.171	0.58	0.44	1.3	0.67	16.1	0.22		3.46	0.43	0.102	0.54

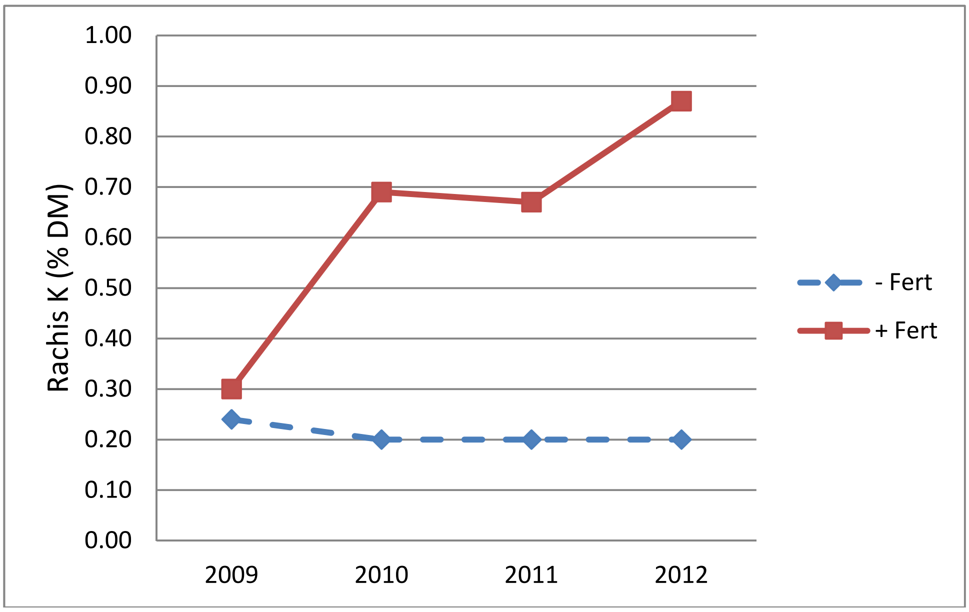


Figure 25. Rachis K contents Block 2655 in fertilised and nil fertilised plots from 2009 to 2012

Conclusion

The addition of AC and MOP greatly improved yield and yield components, fronds petiole cross sections and leaf tissue N and K contents. Fertiliser addition increased yields by 6-10t/ha in 2012.

Trial 257: New Ireland Oil palm smallholder food security demonstration blocks
(RSPO 4.2, 4.8, 5.1, 6.1, 8.1)

Summary
Work is in progress

Background
Refer to Trial 337

BLOCK DETAILS AND **TRIAL SET UP**
The set up of the food security demonstration site in New Ireland was different to that from Popondetta. The food security plot was set up outside the block and fenced with bamboos to prevent pigs spoiling the food crops inside. Small plots were setup inside the fenced area and planted with food crop. Empty fruit bunch from the mill was added to the plots before food crops were planted especially for the banana plots. Block information is shown in Table 93.

Table 93. Trial 257, Block information.

Trial number	**257**	Soil Type	On raised coral
Block owner	Siri	Drainage	Good
Block No.	2655	Topography	Flat
Location	Lakurumau	Altitude	m asl
Division		Previous Land-use	Food gardens
Planting Density	(a)		
	(b)	Supervisor in charge	Paul Simin
Pattern	Triangular		
Date planted	(a)		
	(b)		
Trial started	March 2008		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2010 (Food crops)		

Measurements in 2010 and 2011
The harvested food crops from the plots were weighed and sub-samples were taken to determine the dry weights and to be sent for analysis. Soil samples were also taken from the plots and will be sent for analysis.

Summary
Work is in progress and data collection continued into 2012.

Trial 150: Smallholder fertiliser application/BMP demonstration blocks (WNBP)
(RSPO 4.2, 4.3, 4.5, 4.6, 4.8, 8.1)
Steven Nake and Murom Banabas

Summary
The FFB yields (t/ha), bunches per hectare (BHA) and single bunch weights (SBW) showed no significant response to the fertiliser treatments in 2012. Similarly, there was no significant effect on the leaflet and rachis nutrient concentration. The BDM, TDM and VDM however responded positively to the fertiliser treatments. All three dry matter production parameters were increased at the highest level of fertiliser application (3kg AN + 1kg MOP). Irrespective of the treatments, the average yield was 19.8t/ha which is 1.5 tonnes more than the 2011 yield. The N levels were still low (below the adequate mark) after 3-4 years of treatment application, while K levels both in the leaflets and rachis were above the adequate mark.

Background
The smallholder sector in PNG makes up about 42% of the total area under production and produces 32% of the total crop. PNGOPRA field trials in plantations across the country prove yields of 30 – 35t/ha are achievable. The benefits of increased yields from the smallholder blocks can be substantial and are very important for the oil palm industry. The smallholder sector holds the key to a substantial untapped potential in production. Setting up of demonstration plots and experiments in smallholder blocks are one important way of contributing to increasing yields in the smallholder blocks through training, however trial and demonstration work with smallholders is never straight forward. The reasons behind the low production and productivity are complex. Smallholder Trials-Demonstration blocks in Hoskins Project were started in 2008 with the following aims:

- Demonstrate best management practices with smallholders (extension);
- Develop robust criteria for fertiliser decisions with smallholders (research).

The main issues which are taken into account when undertaking trial/demonstration work with smallholders are:

- Uneven block management (to the extent that uneven production is achieved across the block due to poor management of weeds, harvest and pruning standards, fertiliser application etc).
- Uneven harvest across the site (because of a lack of labour).
- Time demands on smallholders are such that at times there may be no or very little work carried out in the blocks at all.
- Interest by the smallholder in participating in such trials and demonstration decline with time.
- The trial treatments have to be meaningful (i.e. visual) but simple (we cannot afford to run complicated, replicated trials on smallholder blocks).

Materials and methods

Site Details

Trial 150 consisted of 19 (initially 26) smallholder blocks from the Hoskins Project Site. Within the project area, the distribution of the trial blocks under each division are shown in Table 94.

The blocks initially were low producing with poor block sanitation (management) and obvious N deficiency on the oil palm (i.e. pale leaflet colour, small frond area, smaller PCS, erected fronds (with less small and less number of bunches). The blocks were proposed by OPIC and confirmed by PNGOPRA upon site inspection.

Table 94. Block data information on Trial 150

	Block No.	LSS/VOP	Division	Year Planted	Year trial started	Year treatment commenced	Comments
1	138	Waisisi, CRP	Siki	1999	2009	June, 2009	Current
2	1	Porapora VOP	Siki	2000	2009	Nov, 2009	Closed 2010
3	750	Banaule VOP	Kavui	1999	2009	Oct, 2009	Current
4	1681	Kavui Sect 5	Kavui	1997	2009	Oct, 2009	Closed 2011
5	1719	Kavui Sect 7	Kavui	1998	2009	Oct, 2009	Current
6	1186	Buvusi Sect 6	Buvusi	1997	2009	Nov, 2009	Current
8	354	Kapore Sect 7	Kavui	2002	2009	Not applied	Closed 2009
7	510	Tamba, Sect 5	Nahavio	1991	2009	Nov, 2009	Closed 2011
8	114	Ubae VOP	Salelubu	2000	2009	May, 2009	Current
9	16	Kukula VOP	Salelubu	1998	2009	May, 2009	Current
10	906	Mamota, Sect 8B	Salelubu	1999	2009	May, 2009	Closed 2011
11	921	Mamota, Sect 8B	Salelubu	1991	2009	May, 2009	Current
12	26	Marapu VOP	Salelubu	2001	2009	May, 2009	Current
13	980	Sarakolok Sect 6	Nahavio	1998	2009	May, 2009	Current
14	984	Sarakolok Sect 6	Nahavio	1994	2009	Nov, 2009	Closed 2010
15	2247	Siki LSS	Siki	1991	2010	April, 2010	Current
16	1093	Kavui Sect 11	Kavui	1999	2009	Feb, 2010	Closed 2010
17	1169	Buvusi Sect 5	Buvusi	1997	2010	Feb, 2010	Current
18	1312	Buvusi Sect 9	Buvusi	1996	2009	Feb, 2010	Closed 2011
19	1532	Galai 1, Sect 14	Buvusi	2000	2009	Feb, 2010	Current
20	1637	Kavui Sect 11	Kavui	1983	2011	2011	Current
21	92	Koimumu	Siki	1994	2011	2011	Current
22	209	Tabairikau	Siki	1999	2011	2011	Current
23	165	Buluma	Kavui	2000	2011	2011	Current
24	126	Mai	Kavui	1998	2011	2011	Current
25	8	Gaongo	Kavui	1985	2011	2011	Current
26	458	Silanga	Salelubu	2004	2011	2011	Current

Experimental Design and Treatments

The trial layout is shown in Figure 26. The trial block consisted of 4 rows of each treatment, a total of 12 rows. Only 10 palms in the two central rows in each treatment were used for data collection. Each individual treatment consisted of two rows of 10 palms (20 palms/treatment). Fertiliser treatments were applied to both the 20 recorded palms and the guard row palms. Other palms not included in the plots (outside the treatments) but still within the trial block were also fertilised with the standard rate (2kg AN/palm/year).

Fertiliser treatments are:

- Treatment 1 **-** (current block fertiliser practice)
- Treatment 2 - OPIC recommended rate (2kg AN/palm)
- Treatment 3 - Recommended plus (3kg AN/palm + 1kg MOP)

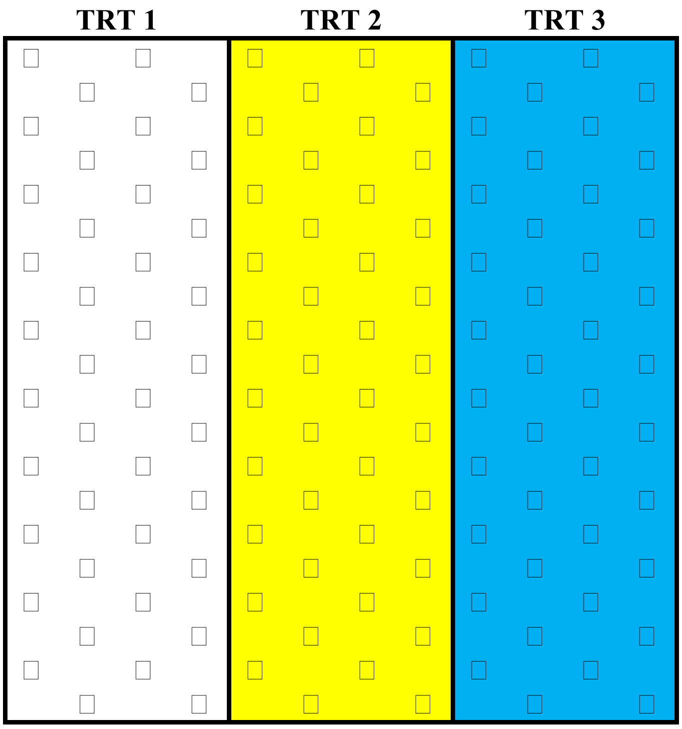


Figure 26. Treatment layout on a 1ha block

Research Activities

- Fortnightly yield recording (bunch count and weights). Some trials setup in 2009, did not produce any yield data (t/ha) because only bunch count was undertaken.
- Leaf sampling for nutrient analysis – once a year
- Leaf measurements also done during leaf sampling
- Frond marking and production counts – every 6 months
- Monthly field assessment (reported separately below)
- Normal upkeep work – as and when required

Data analysis

Data from the trials was analysed using GenStat 15th Edition to determine treatment effects on yield and growth parameters with leaf tissue nutrient concentration.

Reporting

Data will be presented for each individual blocks as well as looking at the overall effect of the treatments (fertiliser) from the data combined from all the trial blocks.

Block standard assessment

At the end of each month, block assessments are compiled for every individual trial blocks. The scores are then averaged for the month and year for reporting. Table 95 shows the average scores for the current 19 trial blocks in 2012. Generally the block standards have improved significantly over the last 3 years. The average score for 2012 was 2.8.

Table 95. Block assessments scores (average) from 2009 to 2012

Criteria used for scoring block assessment	2009 (before setup)	2009 (after setup)	2011	2012
Palm Nutrient Deficiency	1.0	1.0	2.4	2.6
Block Standard	3.0	3.0	3.0	3.0
Frond stack	1.5	3.0	2.5	2.9
Ganoderma	3.0	3.0	3.0	3.0
Ground cover-deficiency	2.0	2.0	2.6	2.7
Harvest standard	2.7	2.5	2.8	2.9
Harvest paths	1.0	2.9	3.0	3.0
Insect Damage	2.3	2.3	2.9	2.9
LCP	2.9	2.9	2.9	2.9
Pruning <7years	1.0	2.8	2.8	N/A
Pruning >7years	1.0	2.9	2.9	2.4
Rat Damage	3.0	3.0	3.0	3.0
Trunk weeds/ferns	2.1	2.1	2.1	2.8
Trunk weeds/woods/vines	2.2	2.2	2.2	2.8
Weeded circle	1.0	2.5	3.0	2.9
Weed-ground cover	1.2	2.8	2.7	2.7
Average	1.9	2.6	2.7	2.8

Results

Treatment effect on yield and its components on individual blocks in 2012

The FFB yield in 4 trial blocks were significantly ($p<0.05$) affected by the fertiliser treatments in 2012 (Table 96). In all these 4 trial blocks (Blocks 92, 209, 165 and 1637), the yields from treatment 3 (3kg AN + 1kg MOP) were higher than the other two fertiliser treatments (treatments 1 & 2) (Figure 27). Contrary to the yield response, bunches per hectare (BHA) and single bunch weights (SBW) in the same 4 blocks did not show any response to the treatments in 2012. The yield, BHA and SBW for all the other 15 trial blocks did not respond to the treatments applied in 2012.

Table 96. P values for yield, BHA and SBW for individual blocks in 2012

Trial Block	Division	Yield (t/ha)	BHA	SBW
92	SIKI	**S (p<0.001)**	NS	NS
209	SIKI	**S (p=0.033)**	NS	NS
138	SIKI	NS	NS	NS
2247	SIKI	NS	NS	NS
750	KAVUI	NS	NS	NS
165	KAVUI	**S (p=0.039)**	NS	NS
126	KAVUI	NS	NS	NS
08	KAVUI	NS	NS	NS
1637	KAVUI	**S (p=0.013)**	NS	NS
1719	KAVUI	NS	NS	NS
1169	BUVUSI	NS	NS	NS
1186	BUVUSI	NS	NS	NS
1532	BUVUSI	NS	NS	NS
980	NAHAVIO	NS	NS	NS
114	SALELUBU	NS	NS	NS
16	SALELUBU	NS	NS	NS
26	SALELUBU	NS	NS	NS
921	SALELUBU	NS	NS	NS
458	SALELUBU	NS	NS	NS

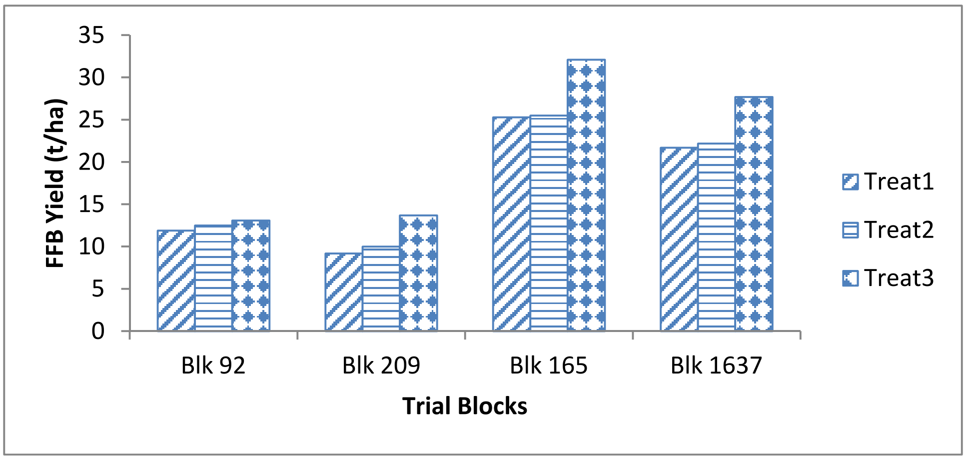


Figure 27. Fertiliser treatment effect on 4 smallholder trial blocks showing response in 2012

Treatment effect on combined yield and its components for the 19 blocks in 2012

Table 97 shows the treatments effect on the yield and its components in 2011 and 2012 regardless of the individual blocks. Each individual block was used as a replicate . The means and treatment effects were calculated from the combined data for all the 19 blocks put together for analysis. Unlike 2011, the treatments did not have any significant effect on the yield, BHA and SBW. Treatments 2 and 3 however continued to produce higher yields, BHA and SBW in 2012, though statistically not superior or different to Treatment 1.

Table 97. Effect of fertiliser on yield and its component in 2011 and 2012.

Fertiliser Treatments	2011			2012		
	Yield (t/ha)	BHA	SBW (kg)	Yield (t/ha)	BHA	SBW (kg)
1	**17.8*a***	**1021*a***	**17.8*b***	19.1	1019	19.3
2	**18.2*a***	**1025*a***	**18.6*ab***	20.1	1053	19.6
3	**18.9*a***	**1049*a***	**19.5*a***	20.1	1069	19.6
Mean	*18.3*	*1031*	*18.6*	*19.8*	*1047*	*19.5*
Significance (at 5 %)	P<0.001	P=0.022	P=0.028	NS	NS	NS
LSD	1.4	74	1.2	-	-	-
CV %	46.0	44.6	25.4	38.1	37.6	20.4

Values in bold are significant at p<0.05. ***Note****: Same letter denote means are not different even though the results are significant, while different letters indicate the means differ statistically.*

Overall block yield response

Regardless of the fertiliser treatments, the yields and its components (BHA and SBW) in 2011 and 2012 (Table 97). While the single bunch weights (SBW) continued to increase in 2012 in all the 19 blocks, the yields and bunches per hectare (BHA) experienced either an increase or a decrease in comparison to 2011. In 2012, 6 out of 19 trial blocks (Blocks 92, 2247, 750, 1719, 16 and 26) showed a yield decline of between 9.3-83.5%. Trial block 2247 had the highest percentage yield drop of 83.5 %, due to of inconsistent harvesting (*skip* harvesting).

According to the harvesting records, the block received only 10 harvests in 2012 reducing the block yield dramatically. It was also evident from Table 97 that all the blocks yielding over 20 t/ha in 2011 experienced slight to moderate decline in yields in 2012. For example, block 1719 which produced over 30t/ha in 2011, yielded 2t/ha less in 2012, but still maintained its status as the highest producing block with 28t/ha in 2012.

Despite the yield drop in the 6 blocks, the FFB yields from the other 13 trial blocks increased by 0.2 – 9.5t/ha (0.9 to over 39.7 %). The highest % increase of 39.7 % was from block 1637. Other trials with similar positive yield response included blocks 114, 138, 209, 921, 980, 1169, 1186 and 1532 (Figure 28). Since their inception, the yields from these trial blocks continued to increase steadily. A marked positive relationship (correl=0.92) was observed between yield and the BHA over the time. An increase in the BHA only triggers an increase in yield and *vise versa*. Despite the variances in the yield, BHA and SBW trend over the last two years for each individual trial blocks, the yields in general increased from 18.3t/ha in 2011 to 19.8t/ha in 2012. Similarly, the BHA also increased to 1047 bunches in 2012 while the SBW was raised from 18.6 kg/bunch in 2011 to 19.5kg/bunch in 2012.

Table 98. Overall block yield in 2011 and 2012 (regardless of fertiliser treatment)

Trial Block	Division	2011			2012			% Difference*		
		Yield (t/ha)	BHA	SBW	Yield (t/ha)	BHA	SBW	Yield	BHA	SBW
92	SIKI	14.2	948	15.5	12.4	716	17.4	-14.5	-32.4	10.9
209	SIKI	10.5	724	14.5	11.3	549	20.2	7.1	-31.9	28.2
138	SIKI	16.9	940	18.1	17.9	996	18.3	5.6	5.6	1.1
2247	SIKI	21.1	1058	20.1	11.5	570	20.5	-83.5	-85.6	2.0
750	KAVUI	22.5	1182	19.2	20.5	1052	19.3	-9.8	-12.4	0.5
**165	KAVUI				27.6	1504	19.0			
**126	KAVUI				25.4	1278	19.9			
**08	KAVUI				22.3	1024	21.9			
1637	KAVUI	14.4	940	15.5	23.9	1134	21.6	39.7	17.1	28.2
1719	KAVUI	30.7	1566	20.1	28.1	1400	20.8	-9.3	-11.9	3.4
1169	BUVUSI	13.6	718	19.6	16.8	776	21.9	19.0	7.5	10.5
1186	BUVUSI	15.7	647	24.9	17.3	710	25.0	9.2	8.9	0.4
1532	BUVUSI	15.0	928	16.8	18.1	912	20.5	17.1	-1.8	18.0
980	NAHAVIO	15.7	842	19.2	20.8	998	21.1	24.5	15.6	9.0
114	SALELUBU	22.9	1314	17.8	23.1	1290	18.2	0.9	-1.9	2.2
16	SALELUBU	21.6	1398	16.0	18.7	1124	16.8	-15.5	-24.4	4.8
26	SALELUBU	22.6	1260	17.7	16.5	970	18.3	-37.0	-29.9	3.3
921	SALELUBU	17.5	992	17.9	19.1	1070	18.1	8.4	7.3	1.1
**458	SALELUBU				22.3	1766	12.8			
Mean		18.3	1031	18.6	19.8	1047	19.5			

** A negative sign indicates percentage decrease; **Trials were set up in 2012 thus no 2011 data*

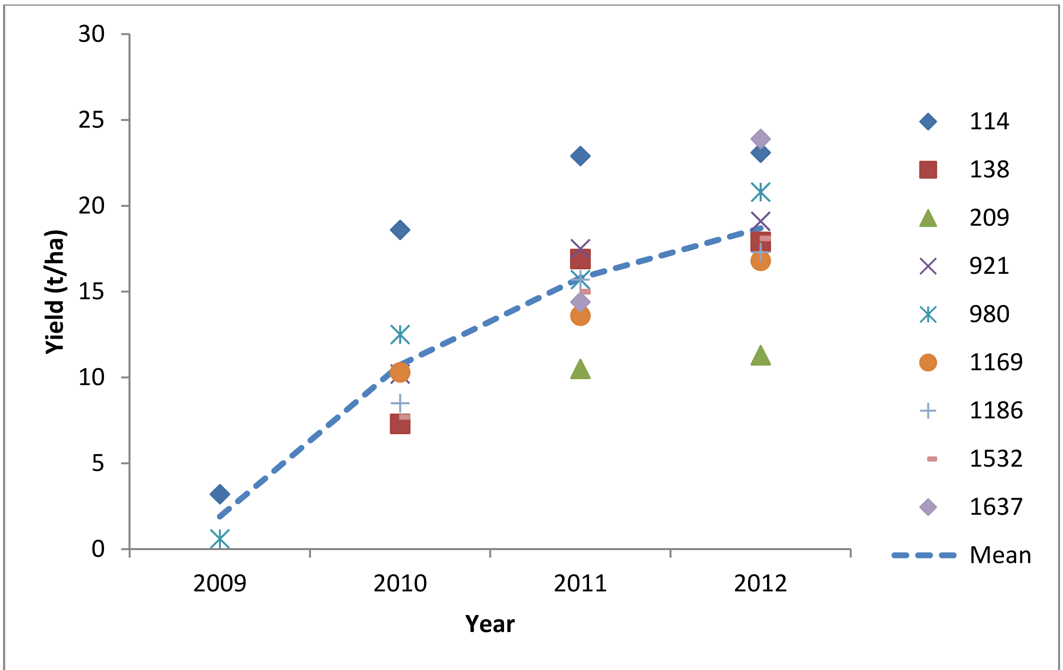


Figure 28. Yield (t/ha) response between 2009 to 2012 in the 9 selected trial blocks.

Treatment effects on Tissue nutrient concentration (% DM)

The effects of the three fertiliser treatments are presented in Table 99. The fertiliser treatments had no significant effects ($p>0.05$) on both leaflet and rachis nutrient concentration in 2012 unlike in 2010 and 2011. Leaf and rachis tissue concentrations in all three treatments were more or less the same. Irrespective to the treatments, leaflet N, P, Mg and rachis N levels were raised in 2012, while there

was a slight drop in leaflet K as well as rachis P and K levels. These changes in nutrient concentration in the leaflets were however not very distinct as seen in Figure 29.
Rachis K also fluctuated with time with no obvious response (Figure 30). The following nutrients were still below the adequate level in 2012: leaflet N, leaflet P, leaflet Mg and rachis P. Leaflet K, rachis N and K were within or above the adequate level (Table 99).

Table 99. Nutrient levels (% dm) in leaflet (L) and rachis (R) tissues in 2011 and 2012.

Fertiliser Treatments	2011							2012						
	LN	LP	LK	LMg	RN	RP	RK	LN	LP	LK	LMg	RN	RP	RK
1	***2.09a***	0.131	0.72	0.17	0.27	0.09	1.41	2.29	0.138	0.71	0.19	0.31	0.07	1.34
2	***2.12a***	0.133	0.73	0.17	0.29	0.12	1.50	2.25	0.136	0.69	0.18	0.32	0.07	1.34
3	***2.17a***	0.134	0.69	0.16	0.29	0.09	1.50	2.28	0.138	0.68	0.18	0.32	0.08	1.46
Mean	*2.13*	*0.134*	*0.71*	*0.16*	*0.28*	*0.10*	*1.45*	*2.27*	*0.137*	*0.70*	*0.18*	*0.32*	*0.08*	*1.38*
Adequate levels	2.45	0.145	0.65	0.20	0.32	0.10	1.2	2.45	0.145	0.65	0.20	0.32	0.10	1.2
LSD	*0.15*	*ns*	*ns*	*Ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
CV %	6.6	2.4	10.7	9.9	7.9	22.7	9.1	2.6	2.5	5.4	9.5	8.1	35.1	14.4

Values in bold are significant at p<0.05
Note: Same letter denote means are not different even though the results are significant, while different letters indicate the means differ statistically.

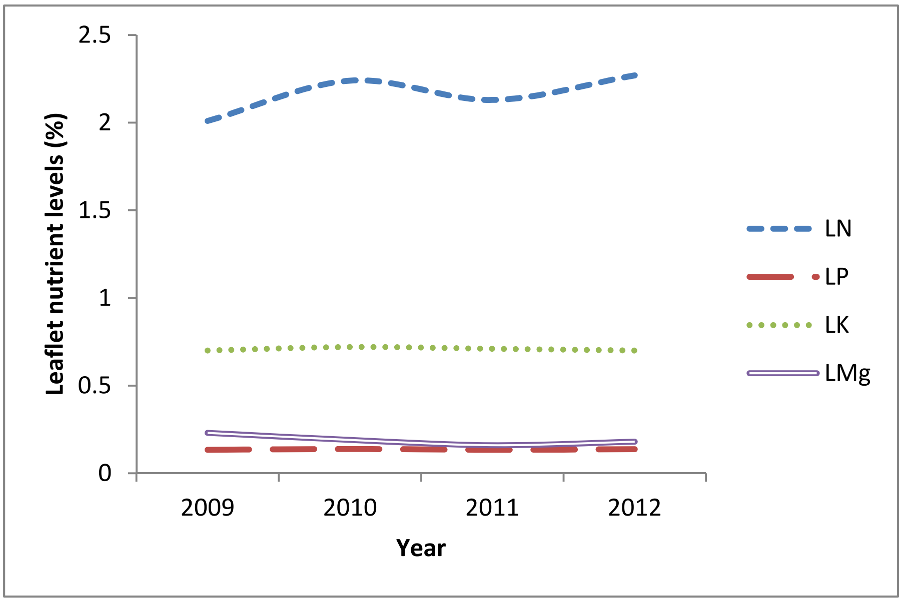


Figure 29. Leaflet nutrient concentration (% DM) over time (2009-2012).

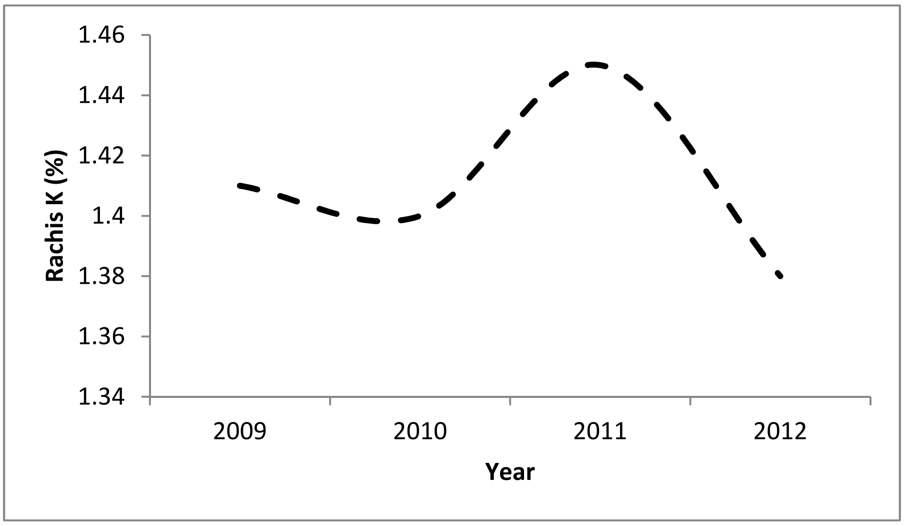


Figure 30. Rachis K concentration (% DM) over time (2009-2012).

Table 100 shows the leaflet and rachis nutrient levels for the individual blocks in 2011 and 2012. While leaflet N for most of the blocks were elevated in 2012, the rachis K in most blocks declined.

Table 100. Tissue nutrient concentration for individual trial blocks in 2011 and 2012

Trial Blocks	2011							2012						
	LN	LP	LK	LMg	RN	RP	RK	LN	LP	LK	LMg	RN	RP	RK
92	2.16	0.108	0.64	0.13	0.28	0.04	1.59	2.03	0.117	0.64	0.15	0.27	0.11	1.33
209	1.85	0.117	0.65	0.20	0.24	0.06	1.14	2.44	0.140	0.74	0.17	0.30	0.04	1.10
138	2.15	0.124	0.68	0.14	0.26	0.04	1.01	2.31	0.128	0.69	0.14	0.29	0.04	1.02
2247	2.19	0.125	0.52	0.16	0.34	0.04	1.02	2.18	0.125	0.56	0.16	0.32	0.04	0.96
750	2.06	0.133	0.63	0.15	0.31	0.09	1.83	2.18	0.137	0.68	0.19	0.31	0.07	1.80
*165								2.33	0.136	0.72	0.13	0.33	0.06	1.21
*126								2.27	0.141	0.64	0.18	0.32	0.06	1.61
*08								2.41	0.141	0.68	0.13	0.35	0.08	1.61
1637	1.79	0.117	0.76	0.18	0.27	0.14	1.40	2.40	0.145	0.80	0.17	0.35	0.10	1.37
1719	2.26	0.136	0.59	0.13	0.29	0.06	1.08	2.40	0.143	0.63	0.13	0.36	0.06	1.18
1169	2.15	0.127	0.56	0.19	0.30	0.04	0.90	2.23	0.133	0.58	0.16	0.29	0.05	1.23
1186	2.20	0.137	0.65	0.14	0.41	0.10	1.50	2.30	0.141	0.74	0.13	0.37	0.10	1.96
1532	2.20	0.134	0.58	0.18	0.29	0.06	0.98	2.13	0.136	0.60	0.22	0.30	0.05	1.12
980	2.02	0.131	0.70	0.17	0.29	0.07	1.57	2.22	0.132	0.62	0.19	0.33	0.05	1.33
114	2.16	0.137	0.76	0.17	0.28	0.15	1.49	2.27	0.142	0.68	0.18	0.31	0.10	1.49
16	2.16	0.138	0.90	0.23	0.27	0.19	1.77	2.30	0.149	0.75	0.32	0.30	0.14	1.56
26	2.23	0.133	0.86	0.13	0.26	0.17	1.63	2.23	0.141	0.90	0.21	0.27	0.11	1.33
921	2.07	0.131	0.82	0.18	0.26	0.17	1.49	2.21	0.142	0.82	0.24	0.28	0.19	1.65
*458								2.37	0.138	0.74	0.25	0.28	0.09	1.26

*Trials were set up in 2012 thus no 2011 data

Treatment effects on Physiological parameters

FP, BDM, TDM and VDM responded significantly ($P<0.05$) to the fertiliser treatments in 2012 (Table 101). BDM, TDM and VDM were maximised by treatment 3 application (3kg AN + 1kg MOP) while the number of fronds produced per year decreased with the treatments (Figure 1). Other vegetative parameters did not respond to the fertiliser treatments (Table 101). In 2012, the fronds grew to over

600cm in length with an average PCS of 37 cm^2. Number of green fronds was maintained at 36, a result of regular pruning.
An average of 23 new fronds was produced in 2012 (one in every 16 days). Generally the palms in all the trial blocks have improved in their vegetative growth compared the last two years.

Table 101. Effects of the fertiliser treatment on vegetative growth parameters in 2012

	Llen (cm)	PCS (cm^2)	Radiation interception				Dry matter production (t/ha)			
			FA	GF	FP	LAI	FDM	BDM	TDM	VDM
Means	613	37.0	18.9	36	**23.4**	5.2	11.2	**18.0**	**33.0**	**15.1**
Significance	ns	ns	ns	ns	**p=0.016**	ns	ns	**p=0.001**	**P<0.001**	**P<0.001**
lsd	-	-	-	-	**0.47**	-	-	**1.01**	**1.3**	**0.47**
CV%	37.6	17.3	17.5	12.2	13.4	22.8	11.2	38.1	26.7	21.0

Llen = Leaf length (cm); PCS = Petiole cross-section of the rachis (cm^2); FA = Frond Area (m^2); GF = number of green fronds (fronds per palm); FP = annual frond production (new fronds/year); LAI = Leaf Area Index; FDM = Frond Dry Matter production (t/ha/yr); BDM = Bunch Dry Matter production (t/ha/yr); TDM = Total Dry Matter production (t/ha/yr); VDM = Vegetative Dry Matter production (t/ha/yr).

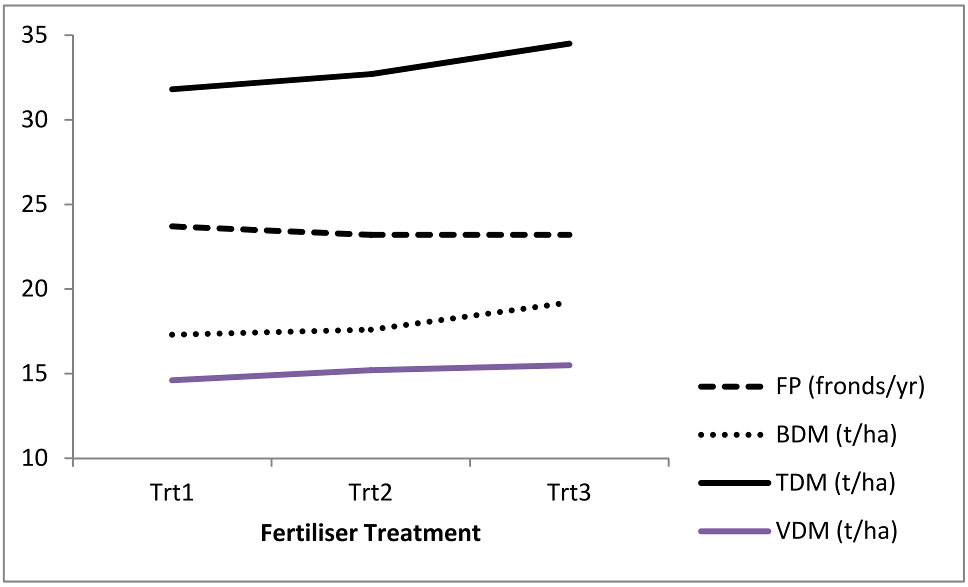


Figure 31. Treatment effect on FP, BDM, TDM and VDM in 2012

Discussion

When considering the individual trial data, 4 trial blocks had significant response out of the 19 blocks. This significant response may be due to best management practise and not the fertiliser treatment, because the overall response by the yield and its components (BHA and SBW) in 2012 was not significant. No response to fertiliser treatments especially N was also seen in PNGOPRA trials setup in NBPOL plantations in the past and it was not surprising to obtain similar results in the smallholder trials. Similarly, all leaflet and rachis nutrients were not significantly affected by the treatments. The nutrient concentration in both the leaflet and the rachis tissues were more or less the same regardless of the fertiliser treatments. In addition, the leaflet nutrient concentration barely changed with time (years), except N level which has been increasing slowly over the 3 years. This is quite surprising to note that leaf K was maintained around 0.70% to 0.72% DM from the first year of treatment application to 2012. Rachis K was raised from 1.40% in 2010 to over 1.45% DM in 2011, but plummeted to 1.38% in 2012 but still within the adequate range. The following nutrients were below the adequate level: leaflet N, P, Mg and rachis P.

Since the initiation of the trial blocks in 2009, the yield increment had been declining with time as shown in Figure 31. The rapid increase in yield in the first 1-2 years was caused by high crop recovery from pruning, regular harvesting and weeded circle maintenance which facilitated loose fruit collection. The block assessment reports have obviously shown steady increase in the average block scores since 2009, and indication of prudent block management practices. Individual block yields have increased beyond 20t/ha with the highest producing block on 28 t/ha. This may imply that yield potential in smallholder blocks can be realised through integration of all best management practices.

Conclusion

Unlike 2011, the fertiliser treatments had no significant effects on yield and its components (BHA and SBW) in 2012. Irrespective to the treatments, the average production in 2012 was 19.5t/ha which represented an increase in yield by 1.5t/ha. The block yields ranged from the 11.3t/ha to the 28.1t/ha. BHA and SBW were also elevated to an average of 1047 bunches per ha and 19.6 kg/bunch respectively. There was also no significant effect on both leaflet and rachis nutrient concentration. Leaflet N levels are still below the adequate mark, while leaflet and rachis K are above their critical levels. The palm dry matter production (BDM, TDM, VDM), however showed significant response to the treatments.

Trial 151: Smallholder oil palm/food crop intercropping demo block, Buvusi, Hoskins Project
(AIGS funded) (RSPO 4.2, 4.3, 5.1, 6.1, 8.1)
(Steven Nake and Murom Banabas)

Summary
A trial on intercropping oil palm with food crops was established in Buvusi, Hoskins Project to address food security issues within smallholder oil palm blocks. About 1.5ha was planted to full stand oil palms (196 palms) while 0.5ha was planted with food crops. Eight different food crops were planted in 8 plots replicated 2 times. The food crops included kaukau (potatoes), Singapore (taro), cassava, taro, yam, banana, peanut, bean and ginger. Unfortunately, the beans were eaten by birds and ginger did not perform well. All other food crops performed well and would have earned reasonably good cash if they were to be sold at the local markets. Losses from the crop yields were also experienced in the trial and were mainly attributed to pest and diseases attack and theft.

Background
Refer to Trial 337 at Sangara, Popondetta project.

The trial was set up to:

- help develop effective policies for enhancing food and livelihood security amongst smallholder oil palm growers
- development strategies for intercropping oil palm with food and fuel wood crops which will have relevance for other export cash crops
- increase food production for domestic consumption and sale at local markets
- diversify and increase incomes, especially beneficial to women and blocks with large resident populations
- produce fuel wood and food on-block thereby reducing pressure on environmentally sensitive areas such as creeks and river banks and on steep slopes.

Thus, greater understanding of how commodity crops can be intercropped with food crops and fuel wood species is vital for developing sustainable farming systems in PNG.

For the Hoskins Oil Palm Project, block 1358 at Buvusi Section 8 was identified and work commenced in July 2011 (Table 102). Up to 1.5ha of the total area (2ha) under replant was planted with oil palm at the spacing of 9.75 m x 9.75 m (120 palms/ha) (Figure 32). Only 0.5ha was reserved for the intercropping with food crops, which the oil palm grower sacrificed 44 palms. The food crops were planted in 2 replicates of 8 plots. Each plot is approximately 8m x 8m (16 m^2 or 0.0016ha). The list of planted food crops are shown in Table 103.

Table 102. Trial 151, Block information

Trial number	**151**	Soil Type	Volcanic ash plain
Block owner	Mr. S. Oiza	Drainage	Good
Block No.	1358	Topography	Gentle slope
Location	Section 8, Buvusi	Altitude	51 m asl
Division	Buvusi	Previous Land-use	Oil Palm
Planting Density	120 palms/ha	Agronomist in charge	Steven Nake/Graham Dikop
Pattern	Triangular		
Date planted	July 2011		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2011 (Food crops)		

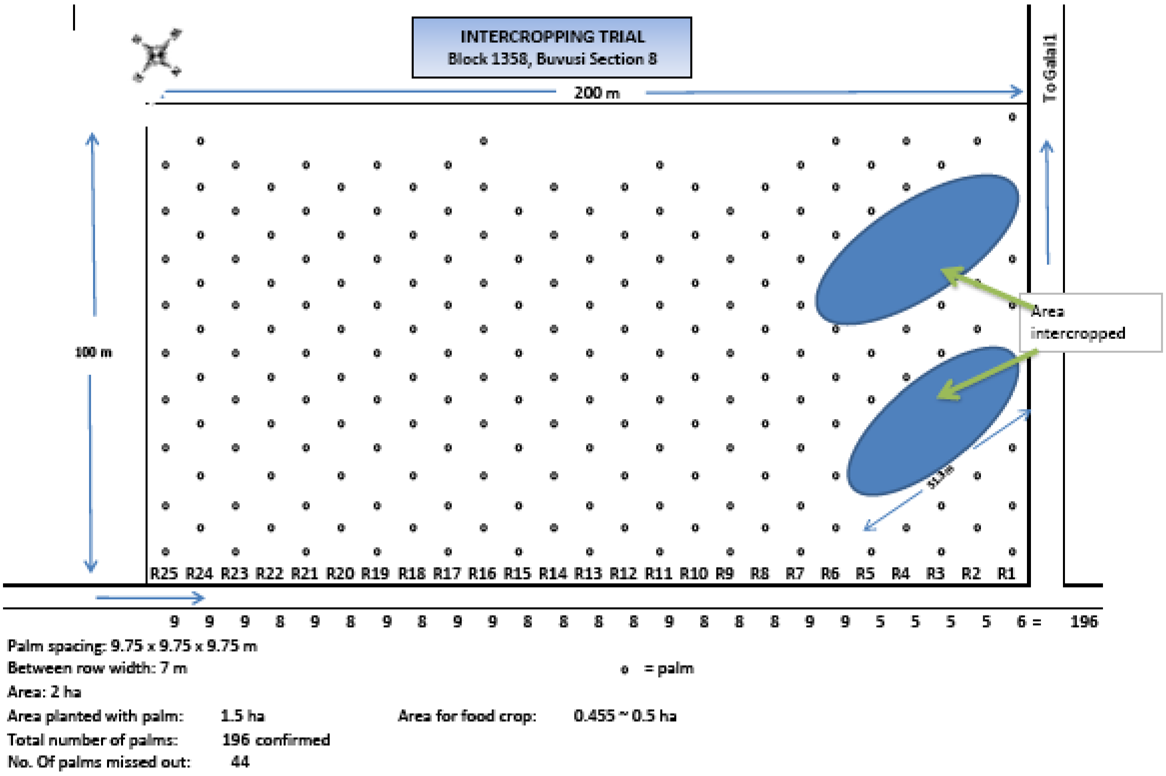


Figure 32. Trial Map of the Intercropping trial (Block 1358) at Buvusi section 8, Hoskins Project.

Materials and methods

Design and analysis
There will be no strict statistical design used for this experiment. The oil palm block is divided into 2 and not necessary equal parts, depending on the farmers wish. One portion will be planted with normal equal spacing arrangements while the other with altered spacing arrangement. Soils and plant tissue samples were collected randomly and replicated in odd numbers for analysis.

Data collection
Plant tissue samples including yield and vegetative tissues will be collected and dry matter production determined. The measurements will be done to determine nutrient movement in and out of the smallholder blocks. Soil samples were taken as well from the both farming systems (Full oil palm stand and intercropped area). Market surveys were also conducted to determine the selling price of the food crops at the time of harvest.

Trial maintenance
Fertiliser (Ammonium nitrate @200g/palm) was applied to all the young palms in October 2012. Slashing was also done around the young palms and circles were maintained both in the intercropped and full palm stand components.
The plots (food gardens) were maintained as and when required to suppress the weeds and encourage robust growth by the food crops.

Results

The total yield harvested from the crops planted in the 8 plots within the intercropping trial are shown in Table 2. In 2012, the intercropping trial recorded 15 harvests, of which one of these which was supposed to be for kaukau gave no data as the all the kaukau tubers in the entire plot were stolen before the data was taken. From the 14 harvests, reasonably higher yields were obtained even though the soils have been continuously utilised for oil palm for the last 20 years. Kaukau, taro, singapore, cassava and yam yielded reasonably well. The banana did not perform well for some reason and its yields were quite low. Mung beans were also planted but had no yield data because the birds ate them all before maturity and time for harvesting. Similarly, ginger plants started off very slow and were not yet ready for harvesting.

Market surveys were conducted at the main and roadside markets to determine the current selling price of particular food crops at the time of harvesting. The market survey data and yields for each crop at the time of harvest are shown in Table 104. The same table also shows the market value (Kina) for the crops if all were to be sold at the market. It is obvious from Table 103 and Table 104 that reasonably high crop yields obtained from the 0.5ha of land used for oil palm with food crops can also fetch good money from the local markets to sustain the livelihood of the oil palm grower over time. In 2012, over K1400 was estimated to be earned from the food crop if all (100%) of the harvested produce were to be sold at the local markets.

Unfortunately, 147kg of food crop with market value of K190 was estimated to have been lost. From the losses, 3.7 % was caused by taro beetle, 3.8 % from fungal infected on peanuts while 92.5 % was stolen before the crops were harvested (Table 105). In addition, a plot of mung bean was severely damaged (eaten) by birds but the amount of crop loss was not calculated.

Table 103. Total yield from crop harvested from the intercropping trial

Food crop	Total Quantity harvested in 2012 (kg)	Number of Harvests
Kaukau	138.7	2
Taro	381.2	3
Singapore	131.5	2
Cassava	283.1	2
Banana	21.6	1
Yam	131.1	2
Peanut	96.5	2
Mung Beans	All eaten up by birds before maturity and harvesting	
Ginger	Did not perform well in terms of growth. No harvests yet	

Table 104. Food crop data harvested from intercropped component of the block

Food crop	Date harvested	Quantity harvested (kg)	Average Selling price (K/kg)	Monetary value if all crop sold at the market (K)
Kaukau	20/01/12	96.2	K1.20/kg	K115.44
Kaukau	20/02/12	42.5	K1.20/kg	K51.00
Taro	15/03/12	139	K1.19/kg	K165.41
Taro	23/03/12	130.1	K1.20/kg	K156.12
Singapore	16/03/12	71.6	K0.45/kg	K32.22
Singapore	24/03/12	59.9	K0.45/kg	K27.00
Cassava	25/04/12	144.2	K0.35/kg	K50.47
Cassava	20/06/12	138.9	K0.30/kg	K41.67
Banana	21/06/12	21.6	K0.53/kg	K11.45
Yam	18/07/12	112.2	K1.50/kg	K168.30
Yam	20/07/12	18.9	K1.21/kg	K22.87
Taro	29/08/12	112.1	K1.25/kg	K140.13
Peanut	06/09/12	62.0	K4.50/kg	K279.00
Peanut	11/10/12	34.5	K4.40/kg	K151.80
Total cash (K) expected from 0.5 ha in 2012				**K1412.88**

Table 105. Estimated yield loss from the intercropping trial

Food crop	Date harvested	Crop loss	Estimated quantity loss	Crop loss estimated in monetary value
Taro	23/03/12	9 taro stolen	Average of 0.63 kg taro corm/plant ~5.7 kg stolen	K6.80
Taro	23/03/12	8 corms severely damaged by taro beetles	Average of 0.63 kg taro corm/plant ~5.4 kg stolen	K6.05
Singapore	16/03/12	5 plant dug and tubers stolen	Average of 2.86 kg of tubers/plant ~14.3 kg tubers	K6.44
Singapore	24/03/12	3 plant dug and tubers stolen	Average of 2.40 kg of tubers/plant ~7.2 kg tubers	K3.24
Cassava	25/04/12	9 cassava plants dug and tubers stolen	Average of 1.69 kg of tubers/plant ~15.2 kg	K5.32

			tubers	
Cassava	20/06/12	14 cassava plants dug and tubers stolen	Average of 0.38 kg of tubers/plant ~5.3 kg tubers	K1.59
Peanut	06/09/12	13 peanut plants stolen	200 g/plant ~2.6 kg of nuts	K11.70
Peanut	06/09/12	28 plants dried up due to some kind of fungal root infection	200 g/plant ~5.6 kg of nuts	K25.20
Peanut	11/10/12	32 peanut plants stolen	200 g/plant ~6.4 kg of nuts	K28.16
Kaukau	13/11/12	Entire plot (100 mounds) stolen	Average of 800 g of kaukau/mound ~ 80 kg	K96.00
Total loss (K) in 2012				**K190.50**

Discussion

Intercropping of food crops with oil palm has always been practiced by smallholder oil palm growers during the establishment (planting) phase of the oil palm. That is first few months into replant or when the oil palm canopy has not closed allowing sufficient sunlight between the palm rows. There are a lot of benefits for intercropping, it serves as an insurance against crop failure and improves both land use efficiency and the income earning capacity of the farmer/oil palm grower. This is an approach which oil palm growers can tap into to alleviate poverty and food security issues. The trial results show additional income can be made from sale of food crops planted between the young immature palms during the waiting period of 12 – 18 months before the oil palm starts producing crop. If only 0.5ha of the block can produce up to 1183kg (1.2 tonnes) of food crop from 14 harvests, there is huge potential in producing even high yields if more than 0.5ha or even half of the 2ha block is committed for intercropping with food crops. With the current declining trend in FFB price (Figure 33), such an initiative will go a long way to sustain the livelihood of the growers by ensuring that there is alternative way of earning cash rather than relying entirely on income from oil palm sales.

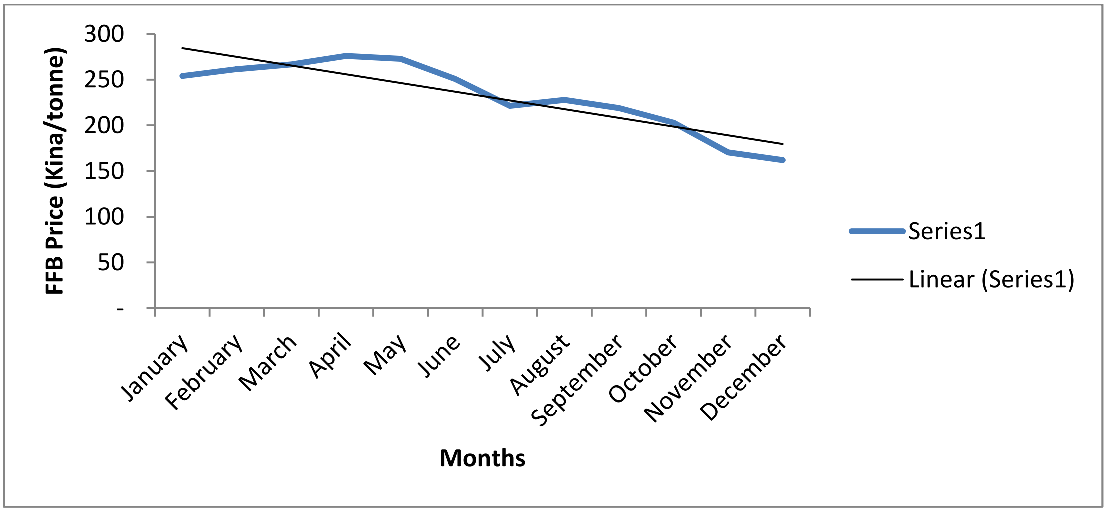


Figure 33. Oil Palm FFB price in 2012 for smallholder oil palm growers in the Hoskins Project

In the current planting arrangement, the 0.5ha of land within the existing block reserved for intercropping food crops is permanent for the entire production cycle of the palms (18-20 years) until the palms are replanted. This will mean that the block owner will have continuous supply of food crops to sustain his/her household. Unlike temporary arrangement for under planting during the initial development phase, food crops will continue to thrive well for the entire production cycle because of the 21m distance between the palm rows which allows adequate sunlight on the plots where the food crops are grown. In under planting system, the temporary gardens do not produce and thrive well as the canopy close due to limitation of sunlight.

The reasonable high food crop yields suggests that the soils under oil palm can still supply adequate nutrients (minerals) to sustain any food crop even after 18-20 years of oil palm farming. The inherent soil physical and chemical properties could have been maintained at the level conducive for growing food crops through nutrient recycling from oil palm fronds, rachis, roots, flowers.

The expected income as well as the selling price (Kina/kg of food crop) from the sales of food crops at the market from the market surveys in the results section showed that food crops can fetch good cash from the markets and also in high demand. Unfortunately, 100% of the harvested food crop is not always sold for cash. In most cases, all or most of the garden produce is retained for consumption and whatever little that is left is normally shared between relatives or sold at the markets for additional income. The decision on quantity for grower consumption and sales at the market for extra income really depends on the quantity of the particular food crop harvested, the demand and selling price of that particular food crop at the markets, oil palm grower’s current financial status and short term needs, whether it’s a non-pay week or pay week and the current FFB price. With the declining trend in the FFB price in 2012, more garden produce were expected to be sold at the markets to get extra income to buffer the drop in FFB price.

The level of infestation by pests and diseases on food crops also contributes to low edible and marketable produce. Farmers have experienced increased in attacks of their garden crops by birds (parrots), rodents and insects such as beetles, grasshoppers, caterpillars. Food crops like rice, peanuts, taro, banana and beans are vulnerable to pests and diseases. Furthermore, the incidence of food crops being stolen from the garden plots before harvesting has also increased, and the food security trial (intercropping trial) has also suffered immensely from theft. This obviously confirms that there are food security issues within the smallholder oil palm blocks and there is a need to address this problem through such initiatives.

Conclusion

Food crop data from the intercropping trial indicated that food crops can thrive and perform well in same soil being planted with oil palm for 18-20 years. High yields of food crops were harvested from the 0.5ha of land reserved for planting food crops. In addition, the prices of food crops at the local markets showed that reasonable amount of cash can be made from selling the food crops at the market. Food crops like peanut and taro can provide good income to sustain livelihood of oil palm growers during low crop or in periods when the FFB price is low.

PROJECT REPORT: 'SUSTAINABLE MANAGEMENT OF SOIL AND WATER RESOURCES UNDER OIL PALM IN PAPUA NEW GUINEA' ACIAR 2009-2013

Field Monitoring and experiment

Four large experiments are being carried out that contribute to Objectives 1, 2, 3 and 5 (soil health, nutrient and carbon balances, and crop modelling). They are the 'Allometrics', 'SCAN' (Silicon, carbon and nutrients), 'Replant' and FOPEC' (Forest to oil palm erosion and carbon) experiments. The way in which they relate to the oil palm cycle is shown in Figure 34, with the main question being: "*are stocks of C and nutrients going up or down during these periods*"?
The locations and methods used for those experiments, as well as the field work being carried out under Objective 4 (Aquatic ecosystem health) are summarised in Table 106.

During field work we developed methods for soil sampling that accounts for tree-scale variability. A paper on that work has been drafted for publication (Nelson *et al*. in prep).

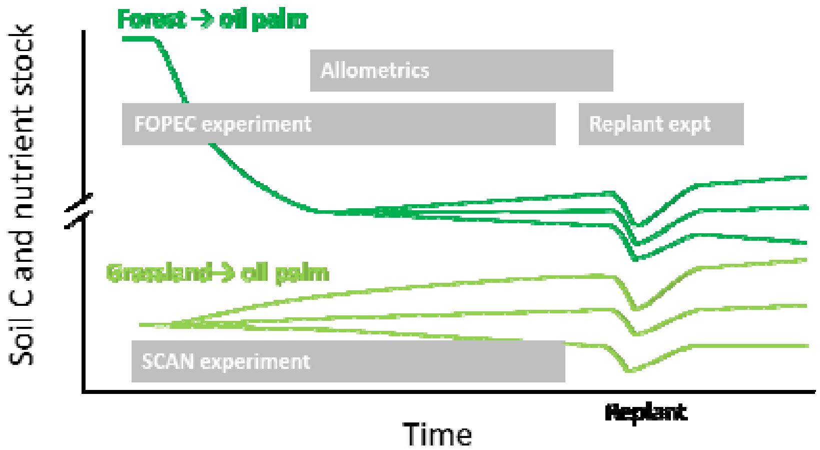


Figure 34. Hypothetical trajectories of carbon and nutrients stocks under various parts of the oil palm cycle, and the time period being covered by major field experiments.

Table 106. Location of field research sites.

Experiment	Location	Description	Sampling and analysis
Allometrics	Numundo, Haella, Bebere estates (West New Britain)	In each plantation (ages 6, 10 and 20 years), 4 palms sampled	All components of palms measured, sampled and analysed for C and nutrients
SCAN	Oro Province	16 smallholder blocks, each with adjacent grassland site and forest site	Soils sampled and analysed for bulk density, C and nutrients. Some plant analyses.
Replant	Waigani estate (Milne Bay Province)	Within one block, the stocks of nutrients and carbon will be followed over the felling-replant-immature part cycle,	Exhaustive sampling of palms, ground cover, litter and soil
FOPEC	Navarai, Karato estate (West New Britain)	4 groups of sites chosen, each group having 2 forest and two plantation sites, all having the same slope.	Soil sampled and analysed for bulk density, C and Pu
Aquatic studies	West New Britain	150 sites in 22 stream systems	Water quality parameters and fauna surveys

'SCAN' is 'Silicon, carbon and nutrients' experiment
'FOPEC' is 'Forest-to-oil palm erosion and carbon' experiment

Cross objectives activities: "allometrics"

Allometric relationships are being developed so that amounts of biomass and nutrients can be estimated from simple routine measurements. These will be used to estimate nutrient and carbon balances as well as providing information for the modelling component. See 'Objective 2' section for further information on activities carried out in 2012.

Cross objective activities : "scan" experiment

This experiment ('Silicon, carbon and nutrients' or 'SCAN') was designed to provide information on the effects of conversion of grassland or forest to oil palm development for Objective 1 (soil pH and microbiology), Objective 2 (soil nutrient stocks) and Objective 3 (soil C stocks). Previously, soil and plant samples were taken from 16 sites in Oro (smallholder oil palm blocks planted on grassland 1-25 years previously, and adjacent grassland) and two sites in Hoskins (smallholder oil palm blocks planted on ex-forest 13-22 years previously, and adjacent forest). Results have been presented at a soil science conference (Goodrick *et al*. 2012; Nelson *et al*. 2012), and are currently being written up for scientific publication. A summary of the soil carbon results and soil microbiology results was presented in the 2011 PNGOPRA Annual Report. Results of the soil fertility analyses are summarised below.

In the grassland-to-oil palm sites there were consistent but significant decreases in soil (0-15 cm depth) pH and increases in exchangeable Al following conversion to oil palm, but there were no significant effects on the other parameters measured (Table 107). In the forest-to-oil palm sites there were significant decreases in soil (0-15 cm depth) bulk density, cation exchange capacity and exchangeable calcium, magnesium and potassium and increases in exchangeable aluminium (Table 108). Soil pH decreased at 0-5 cm depth and increased at 10-15 cm depth. The soil acidification observed under oil palm might be arrested with changed management.

Table 107. The effect of vegetation (grassland versus 1-25 years of oil palm), depth (0-5 versus 10-15 cm) and their interaction on soil properties at 16 sites in Oro Province, from ANOVA.

	Bulk density	pH	Tot. C	Tot. N	Colwell P	ECEC	Exch. Al	Exch. Ca	Exch. K	Exch. Mg
	(kg/m^3)		(g/kg)		(mg/kg)		(cmol+/kg)			
					p value					
Vegetation	0.620	<u>0.002</u>	0.863	0.599	0.585	0.607	<u>0.030</u>	0.716	0.054	0.335
Depth	<u>0.011</u>	0.296	<u>0.014</u>	<u>0.002</u>	<u>0.000</u>	0.087	0.174	<u>0.044</u>	0.104	0.407
Veg. x Depth	0.853	0.841	0.806	0.710	0.212	0.565	0.929	0.670	0.451	0.346
					Mean values					
Grassland		6.16					0.3		0.4	2.6
Oil palm		5.90					0.4		0.2	2.2
0-5 cm	798		50.5	3.62	50.5	11.5		8.3		
10-15 cm	891		38.6	2.75	21.6	9.1		6.2		

ECEC is effective cation exchange capacity

(Oil palm values were calculated as the area-weighted mean of separate samples taken in the weeded circle, frond pile, and 'between zones' zones. Significant p values (<0.05) are underlined and means are given for effects with significant or lowest p values.)

Table 108. The effect of vegetation (remnant forest versus 13-22 years of oil palm), depth (0-5 versus 10-15 cm) and their interaction on soil properties at two sites in Hoskins, from ANOVA.

	Bulk density (kg/m^3)	pH	Colwell P (mg/kg)	ECEC	Exch. Al	Exch. Ca	Exch. K	Exch. Mg
						(cmol+/kg)		
				p value				
Vegetation	0.037	0.400	0.391	0.032	0.280	0.049	0.015	0.030
Depth	0.011	0.847	0.076	0.001	0.001	0.001	0.007	0.016
Veg. x Depth	0.725	0.069	0.546	0.182	1.000	0.177	0.489	0.261
				Mean values				
Forest	737	6.32		20.8		165.7	8.5	29.5
Oil palm	664	6.16		13.1		112.9	3.7	11.4
0-5 cm	647		35.3	26.0	3.5	214.2	9.1	31.5
10-15 cm	754		7.4	7.9	1.3	64.4	3.2	9.4

ECEC = effective cation exchange capacity
(Oil palm values were calculated as the area-weighted mean of separate samples taken in the weeded circle, frond pile, and 'between zones' zones. Significant p values (<0.05) are underlined and means are given for effects with significant or lowest p values).

Cross objective activities : 'replant' experiment

The replant experiment at Waigani Estate in Milne Bay was done in 4 phases:

a) Collecting frond tissue samples from palms just before poisoning and after poisoning.
b) Collecting oil palm samples, above ground cover crop samples, dead litter matter, soil samples before palms are poisoned and felled for replanting.
c) Collecting oil palm samples, cover crops and soil sample from replanted area every six months.
d) Collecting oil palm tissue samples and soil samples from fallen palm trunks in the windrows every six months.

Phases a) and b), the experiments were set up and samples were collected for the first 6 months. The second set of samples will be collected in May/June 2013.

Cross objective experiment activities: 'FOPEC' experiment
The primary aim of the 'FOPEC' (forest to oil palm erosion and carbon) experiment is to obtain quantitative data on erosion following conversion of forest to oil palm, but it will also permit the measurement of carbon losses. The concept and method were provided in the 2011 PNGOPRA Annual Report. Sampling was completed in 2012 (Table 109) and samples were sent for analysis.

Table 109. Location of FOPEC sampling sites.

Site	Vegetation	Plantation	Northing (UTM)	Easting (UTM)	Slope (˚)	Sampled
1	oil palm	Karato	9405110	169572	8	Nov-2011
2	oil palm	Karato	9405110	169575	9	Nov-2011
3	forest	Karato	9405060	169621	9	Nov-2011
4	forest	Karato	9405026	169629	9	Mar-2012
5	oil palm	Navarai	9405322	170264	23	Sep-2012
6	oil palm	Navarai	9405294	170244	21	Sep-2012
7	forest	Navarai	9405328	170300	21	Sep-2012
8	forest	Navarai	9405326	170309	24	Sep-2012
9	oil palm	Haella	9387440	174273	10	Jun-2012
10	oil palm	Haella	9387442	174191	8	Jun-2012
11	forest	Haella	9387474	174276	10	Jun-2012
12	forest	Haella	9387496	174274	8	Jun-2012
13	oil palm	Garu	9390812	168496	13	May-2012
14	oil palm	Garu	9390790	168526	11	May-2012
15	forest	Garu	9390782	168501	13	May-2012
16	forest	Garu	9390748	168492	11	May-2012

Objective 1: To determine by indicator soil health

Soil health may be decreased by erosion, loss of organic matter, acidification, compaction and accumulation of toxins. The conceptual basis of indicators for soil health was described in the 2012 PNGOPRA Annual Report. Data that will be used to develop indicators are being collected from the SCAN and FOPEC experiments (described above) and by measuring acidification in Trial 324, described here.

The extent and rate of soil acidification under different N fertiliser types and rates is being determined in Trial 324 (N source trial) in Oro Province. Composite soil samples were collected from all the plots in the trial at 5 depths down to 150cm. Soil samples were also collected two high rates AMC fertilised plots from predetermined points from the palm down to 150cm depth, this was done to see changes in pH with depth and distance from the palms. Soil pH was measured from all the samples on site. The only pending work is the determination of pH buffer capacity.

Objective 2: To develop indicators of nutrient balances

Using results of the measurements in the 'Allometric' work we are now able to estimate nutrient stocks in the palms over time.

Fronds

Nutrient contents were measured in some of the samples taken for allometric relationships. Using nutrient concentrations analysis, we can combine this with the allometric relations developed for biomass estimation. As an example, the biomass data given in Table 110, was derived from petiole cross section (PCS) measured for Frond 17 (a standard measurement); using equations presented in the 2011 Annual Report. These data can now be used to assess nutrient budgets and nutrient movement for a single palm or an area (Table 110). Not all material were yet analysed, and complete these calculations with actual nutrient measurements. Instead typical analytical data for frond 17 of a

10 year-old palm was used. However, as the data becomes available, values will be adjusted to better predict nutrient storage and nutrient movement.

Table 110. Biomass and nutrient contents of the palm crowns and pruned fronds for different aged palms.

Stored in Fronds (per palm)					Stored in Fronds (per ha)				
Age (y)	Biomass (kg)	N (kg)	K (kg)	C (kg)	Age (y)	Biomass (kg)	N (kg)	K (kg)	C (kg)
6	148	1.3	2.0	65	6	18,605	163	253	8,186
10	174	1.5	2.4	76	10	21,879	198	307	9,627
20	188	1.6	2.6	83	20	23,714	214	333	10,434
Returned in pruned fronds (per palm)					**Returned in pruned fronds (per ha)**				
Age (y)	Biomass (kg)	N (kg)	K (kg)	C (kg)	Age (y)	Biomass (kg)	N (kg)	K (kg)	C (kg)
6	117	1.0	1.6	52	6	14,764	128	199	6,496
10	138	1.2	1.9	61	10	17,362	156	242	7,639
20	149	1.3	2.0	66	20	18,819	169	262	8,280

(33 fronds per palm assumed, based on measurements made, with 26 fronds pruned per year. The planting densities of the palms measured were 126, 130, 130 palms per ha for 6-, 10-, and 20-year old palms respectively).

The results show that large amounts of nutrients are stored and returned to the soil each year and that this varies with palm age. There is 148 kg of biomass stored in just the fronds of a single 6-year old palm and this increases with palm age. This biomass contains several kg of N and K and 65 kg of C; all increasing with palm age.

The story on a 'per ha' basis is the same as the per palm basis as it is simply a multiple of the planting density. However, it is the magnitude of these values which is relevant. The amount of N and K either stored or recycled through pruning is similar to the annual rates of application of that nutrient in fertiliser. Thus the management of canopy and pruning is vital to reducing inputs. This only represents the fronds, as we have not yet analysed the nutrient in roots or trunks. It is expected that the oil palm trunk will be a major store of nutrients and provide a major input during replanting.

Roots

Nutrient contents of roots have not yet been analysed, however substantial biomass data collected in a grid pattern representing the planting pattern are available. There are now data for roots from palms of the three ages. This pattern is expressed both horizontally (Figure 35) and vertically (Figure 36). It is clear that root density and total biomass increases with age, especially around the trunk.

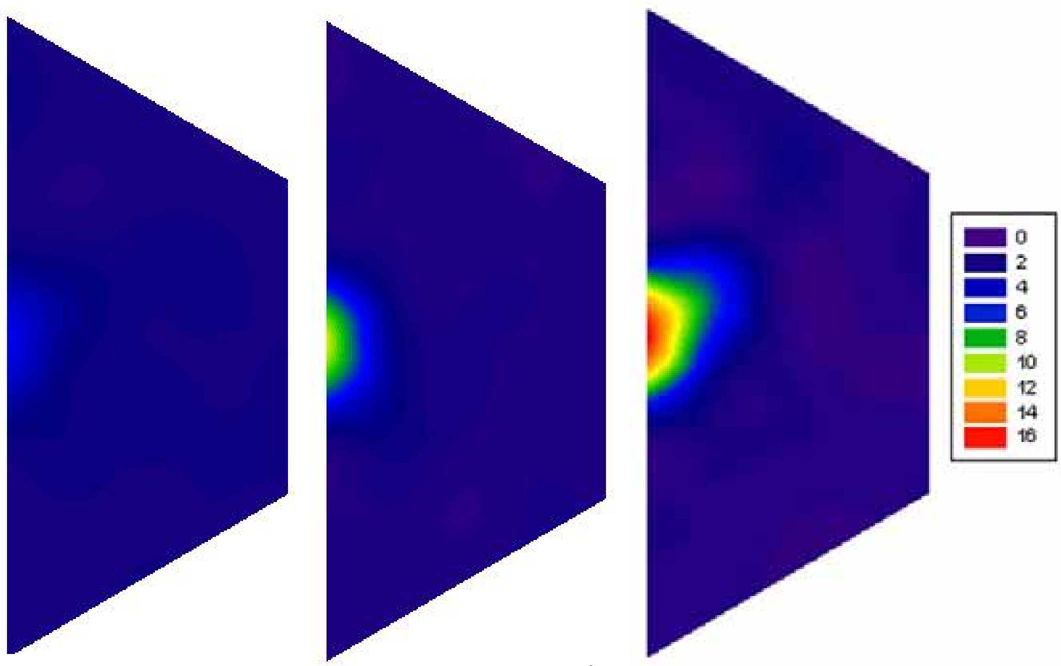


Figure 35. Horizontal distribution of roots (kg DM/m^2 to 2-m depth) around the trunk
(centre of left side) for (left to right) 6-year old palm (average 0.9 kg DM/m^2 (se, 0.1); 71 kg DM/palm; 9 t DM/ha); 10-year old palm (average 1.0 kg DM/m^2 (se, 0.1); 76 kg DM/palm; 10 t DM/ha); and 20-year old palm (average 1.8 kg DM/m^2 (se, 0.2); 137 kg DM/palm; 18 t DM/ha).Note that the same scale has been used for all ages to allow direct comparison.

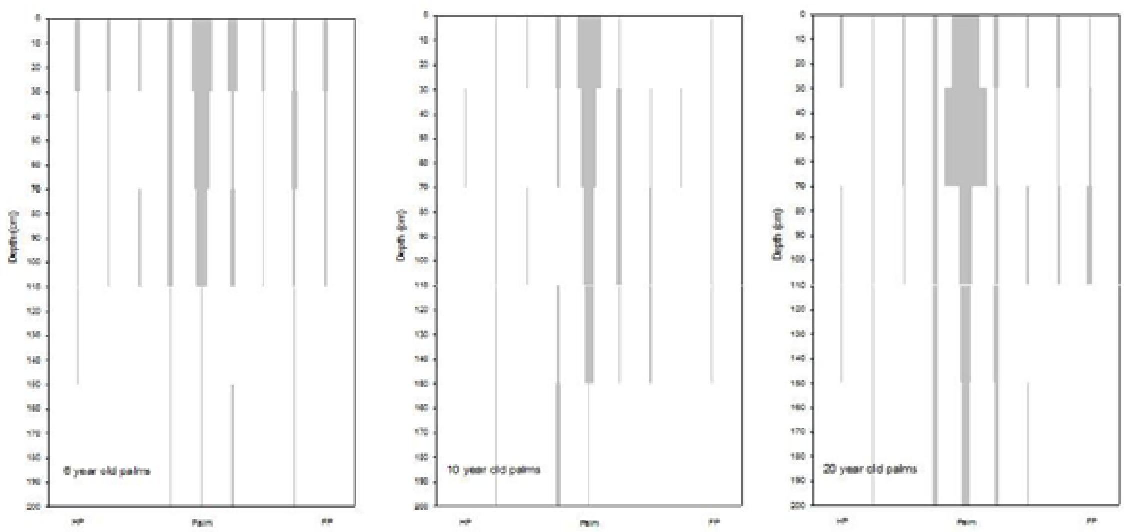


Figure 36. Distribution of roots from the harvest path to the frond pile (left to right in each profile) for 6-, 10-, and 20-year palms (left to right).
(The width of the bars shows the relative root density for that depth increment).

It is clear that root density is greatest and deepest under the trunk. As nutrient analysis becomes available this will allow us to locate zones where nutrients are concentrated in the roots and are likely to be released as roots senesce.

Once these additional analyses are completed and analysed, it will be a simple task of entering routinely collected data such as PCS, frond count, and nutrient analysis of frond 17 to gain an estimate of biomass and nutrient content of the canopy as well as nutrient cycling via pruning.

Biological nitrogen fixation

Ms Rachel Pipai completed and submitted for examination her MSc thesis (Pipai 2013). This was entitled: "**Biological Nitrogen Fixation By Cover Legumes Under Oil Palm Plantations In Papua New Guinea".**

Objective 3: To develop indicators of carbon sequestration

Since the start of the project there have been several developments in NBPOL and RSPO that are relevant to this objective. NBPOL published its first carbon footprint report (NBPOL 2012), basing their calculations on the model of Chase and Henson (2010). That model has been further developed by the RSPO into 'PalmGHG', which will probably become the industry standard to calculating greenhouse gas emissions. The research will provide inputs to the field component of the model. It will also provide below-ground data, which is currently not included in the model. C-cycling research is being carried out in the Allometrics, SCAN, Replant and FOPEC experiments.

Objective 4: To develop indicators of aquatic ecosystem health

The aim for work to this point was to (a) develop an improved understanding of the functional ecology of aquatic ecosystems of palm oil landscapes, (b) produce a base-line evaluation of the threats oil palm operations pose to these ecosystems, and (c) make a preliminary evaluation of the current status of aquatic ecosystem health at a model study area in West New Britain (WNB). To date we have identified issues, categorised ecosystem types, identified aquatic ecosystem function and structure, evaluated present ecosystem status and developed indicators and monitoring protocols for understanding the functional ecology of aquatic ecosystems. Potential impact levels were evaluated for over 200 sites in WNB between Walindi and Bialla, conducted detailed water quality assessments at 63 sites in 23 stream systems and examined the status of aquatic faunas from 41 sites in 22 stream systems.

Current status of water quality and environmental conditions

Detailed water quality analysis indicated stream-to-stream variability, and in some cases site-to-site scale variability in water quality parameters within a stream system. There were no clear relationships between water quality parameters and potential impact variables for streams that do not receive effluent from mill settling ponds.

<u>Streams not receiving mill effluent</u>: **The geomorpholocical characteristics of the non-effluent streams and their associated sites were responsible for most of the variability in water quality parameters. Among these streams water quality was generally at an acceptable standard although the oxidation-reduction potential (ORP) of stream water was consistently below standards set for drinking water by the World Health Organisation (WHO) (**

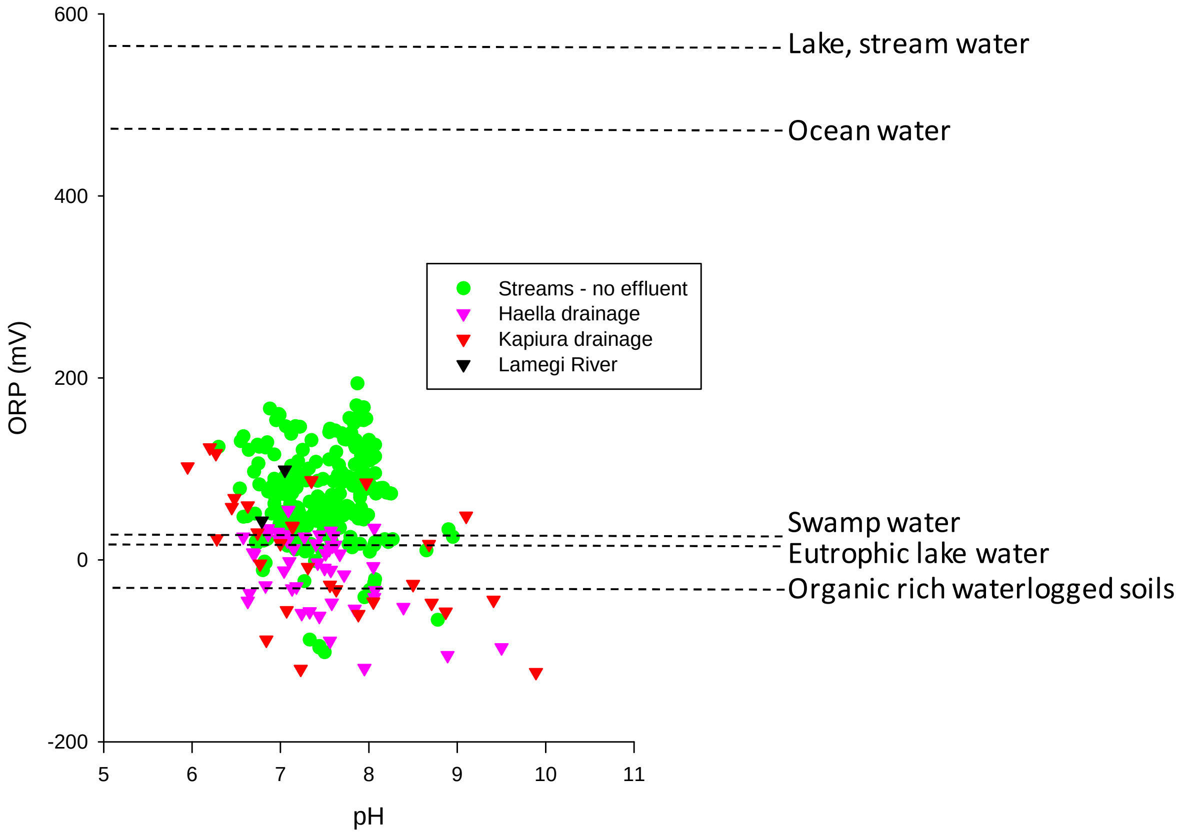


Figure 37). From a water quality perspective ORP provides a useful estimate of the likelihood of pathogen persistence (e.g. *E. coli*) in water. Pathogen survival is greatly reduced at high ORP levels (> 400 mV). ORP values in non-effluent streams rarely exceeded 150 mV suggesting a high potential for pathogen survival and transfer.

<u>Streams receiving mill effluent:</u> Water quality among streams that receive mill effluent from settling ponds was relatively poor. ORP values frequently suggested an oxygen reducing environment similar to those that might be expected from organic rich waterlogged soils or eutrophic waters (

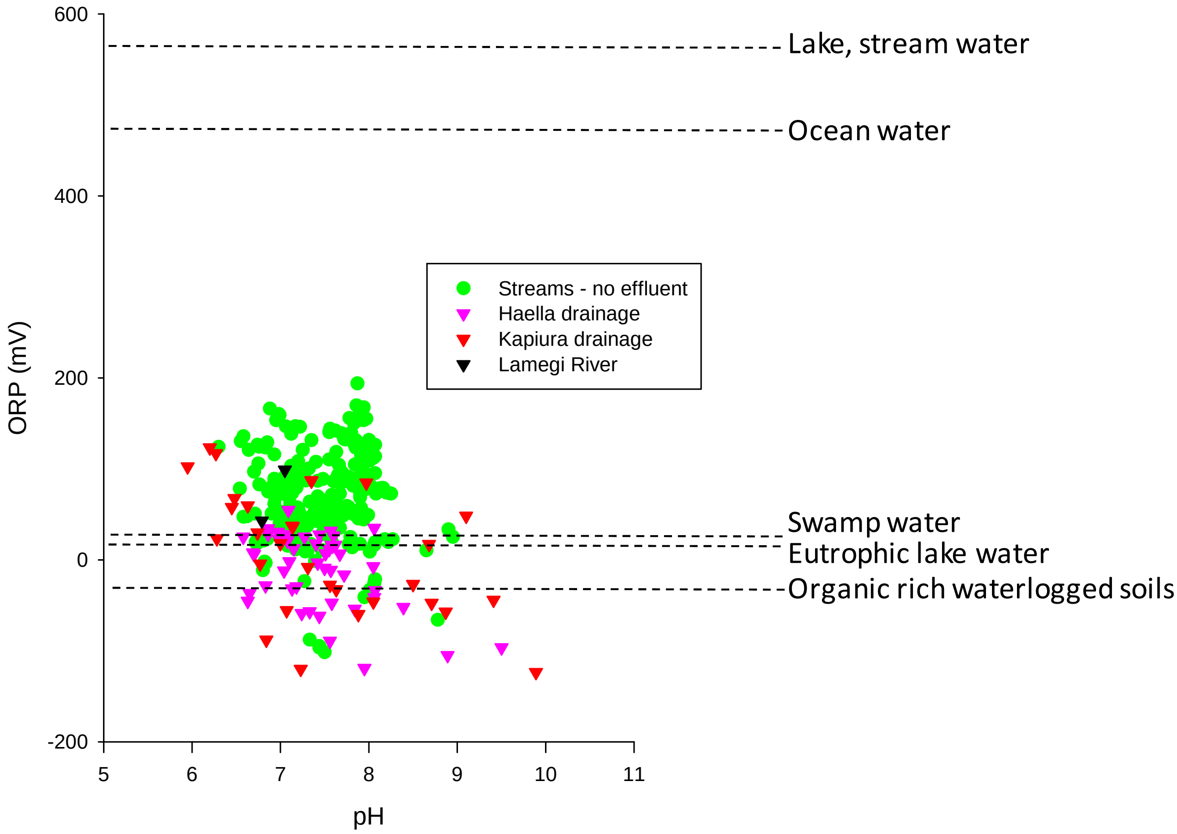


Figure 37). Moreover, dissolved oxygen (DO) saturations in streams receiving mill effluent were consistently low.

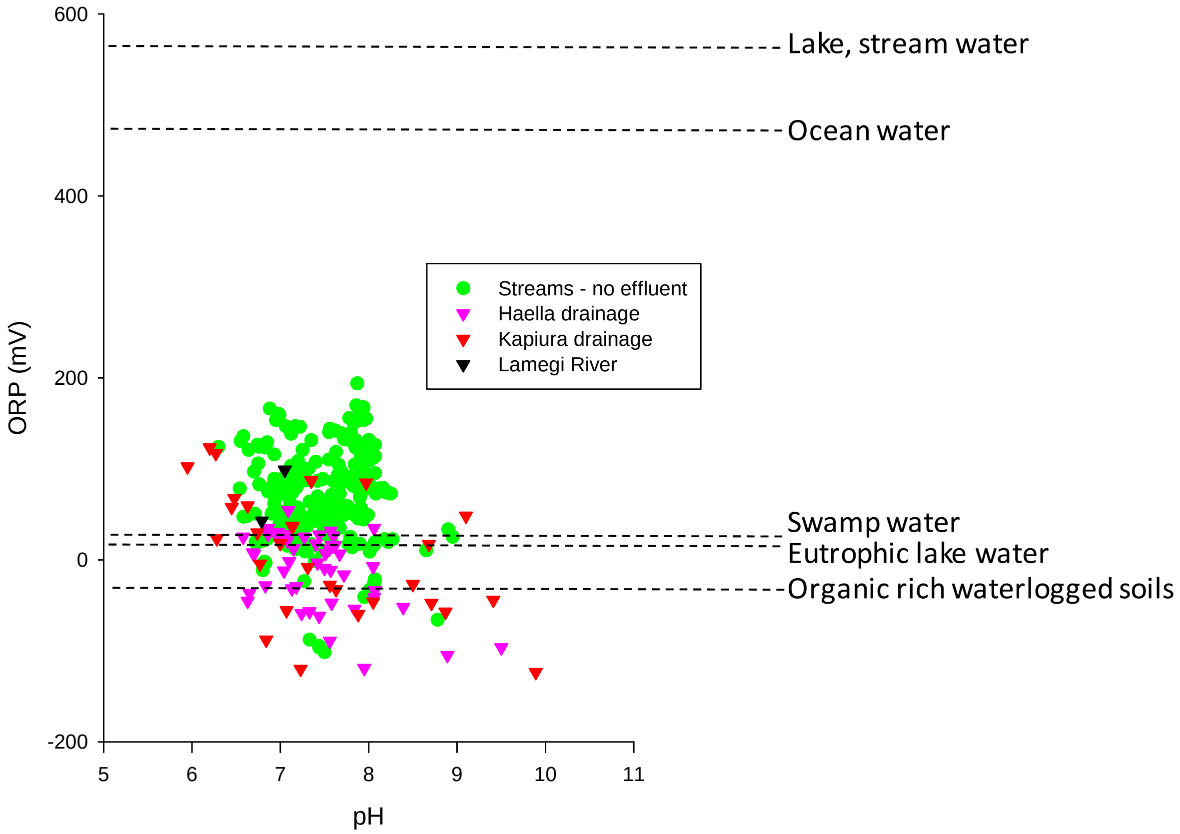


Figure 37. Oxidation-reduction potential (ORP)-pH relationship for West New Britain streams. Haella and Kapiura drainage systems and the Lamegi River receive effluent from mill settling ponds.

Turbidity levels were consistently high compared to non-effluent streams (Figure 38). DO reached critically low levels close to effluent outfall points and low DO levels persisted up to two km downstream from outfall points and downstream from "clean" tributary streams which introduce better oxygenated water to the system. However this represents a fairly localised impact suggesting DO is not a critical concern. Improvements could be achieved and those would also contribute to improved ORP levels for these systems.

Of much greater concern is the elevated turbidity in mill effluent streams. Mill effluent contributes substantially to turbidity levels through the discharge of fibrous material and dissolved organics. Both reduce light penetration, in turn negatively affecting water column and stream bed productivity with subsequent impacts on stream biota. Fibrous and dissolved materials were detected over 1km.

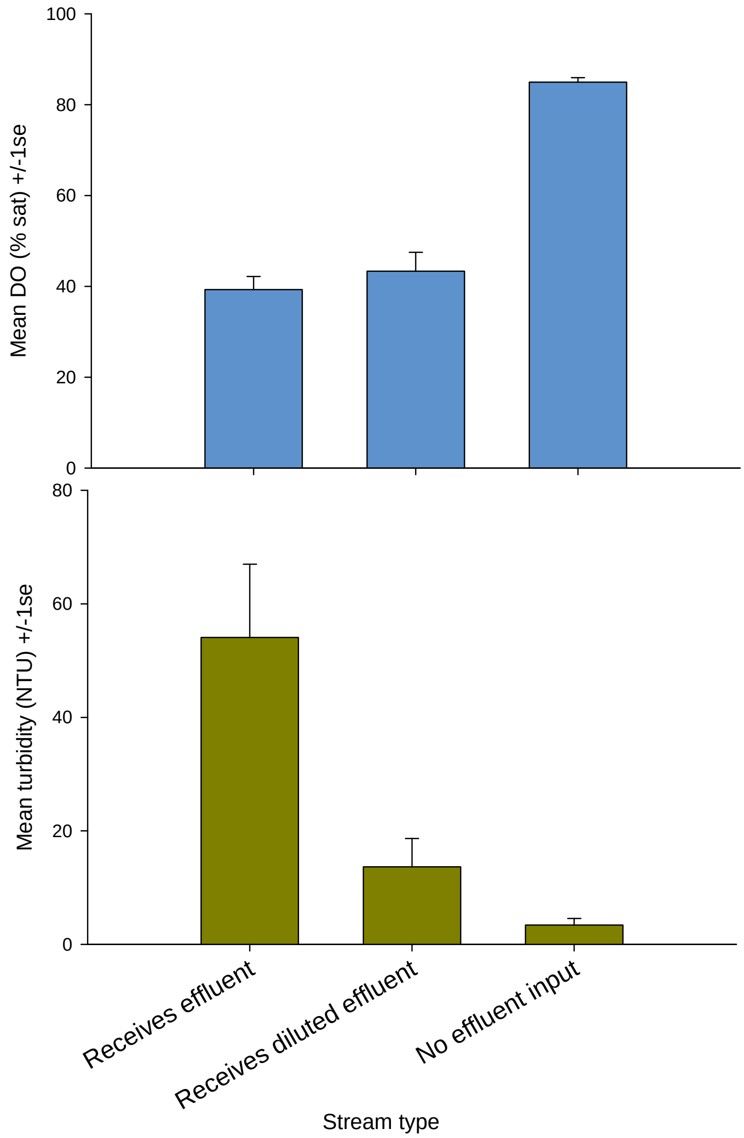


Figure 38. **Average dissolved oxygen saturations and turbidity levels for three WNB stream types** *(those that directly receive mill effluent, effluent stream downstream from junctions with "clean" tributary streams (i.e. after dilution), and streams that do not receive mill effluent downstream from outfalls even after dilution by tributary streams).*

Evidence of discharged material disperses relatively quickly once discharge ceases because fibrous and dissolved materials are flushed but the downstream fate of effluent is unknown and so problematic; it must end up somewhere else, probably in coastal ecosystems. In addition, settling pond overflows which potentially impact adjacent "clean" streams and the presence of lumps of waxy material that originated from ponds occurring well downstream from outfalls are also of concern. There is a need for investigation of the implications of the discharges relative to discharge chemistry.

Other sources of turbidity such as road crossings and gravel extraction operations are obvious. At the scale of individual sources these appear quite localised (water clarity improves rapidly with distance downstream) however, this is not necessarily the case because many aquatic species use different components of a river system for particular life-history functions, so require unimpeded connectivity along the stream. For species intolerant of turbidity even a small area of increased turbidity could lead to severe life-cycle dislocation. Additionally, at an entire stream scale cumulative impacts from the aggregation of many small sources are likely to have more pervasive, but difficult to detect, effects. This is particularly important because historic turbidity levels may have been even lower than the present relatively low levels of non-effluent streams. If that were the case then present levels may in fact be having a deleterious effect on stream health. A good example is systematic increases in turbidity greatly above historic levels in the Kaipura River which locals report is now always muddy despite being seasonally clear in the past. There is a clear need to determine and isolate major sources of turbidity and gain an in-depth understanding of the impact of turbidity on the unique PNG stream biota. The issue is complex because it is difficult to determine the extent to which oil palm contributes to turbidity as opposed to other sources such as logging or even gardens so there is a critical need for additional research into sources of turbidity and their potential impacts.

Potential anthropogenic chemical inputs**:** There was no evidence of systematic elevation of nitrate, phosphate or BOD in larger systems, e.g. Dagi River. However, water-borne nitrate and phosphate may be difficult to detect in well flushed systems. Some of the smaller, lower volume, slower flowing streams had elevated concentrations of nitrate and phosphate. Possible sources of nitrate and phosphate are fertiliser inputs, soaps and detergents or effluent from mill settling ponds.

Riparian condition: Riparian condition along freshwater streams was generally quite poor. Riparian in degraded and very degraded conditions was reported from 41.6% of sites near the upstream extents of oil palm cultivation and 87.5% of lowland sites. Natural (unmodified) riparian was only present in 33.3% of upstream sites, mostly upstream from plantation areas, and 2.5% of lowland sites. The extent to which this high level of riparian degradation has impacted of water quality and aquatic faunas cannot be determined because there are no baseline data. Without baseline data it is not possible to determine whether change has occurred. Although riparian condition did not account for much of the variability in water quality parameters it was clear from on-ground observation following rainfall that increased turbidity levels were often associated with areas where natural riparian vegetation had been cleared to establish gardens.

Current status of aquatic faunas

We recorded 65 species of fish, 47 of which were first records for WNB estuaries or freshwaters. This demonstrates how little is known about WNB fish faunas and the situation is no better for other aquatic animals. Fish and crustacean abundances were very low and dominated by small and juvenile individuals. Distributions of many species of fish were confined to particular reaches of streams, some to particular habitats within reaches suggesting sustainability of local populations is likely dependent on continued in-stream connectivity and continued availability of appropriate in-stream habitats. In addition, WNB streams are important nursery areas for many coastal species. Fish population structures in WNB streams are indicative of overfished systems and suggest there is a real problem for potential replenishment and sustainability of stocks in streams and coastal waters (Figure 39). This said, there is no reliable baseline data against which the present situation can be compared meaning that current status can be assessed but the present trajectory cannot be evaluated.

Indicators

Four key criteria were used for the development of indicators for the monitoring of stream health; the indicator should contribute to impact reduction, regular monitoring with the indicator should be achievable and reliable, the indicator should produce meaningful data, and finally the indicator should have a capacity to generate management actions.

Indicators developed during this project have been kept to simple robust approaches that do not rely on levels of technological expertise that are not available on-ground. Indicators for water quality and

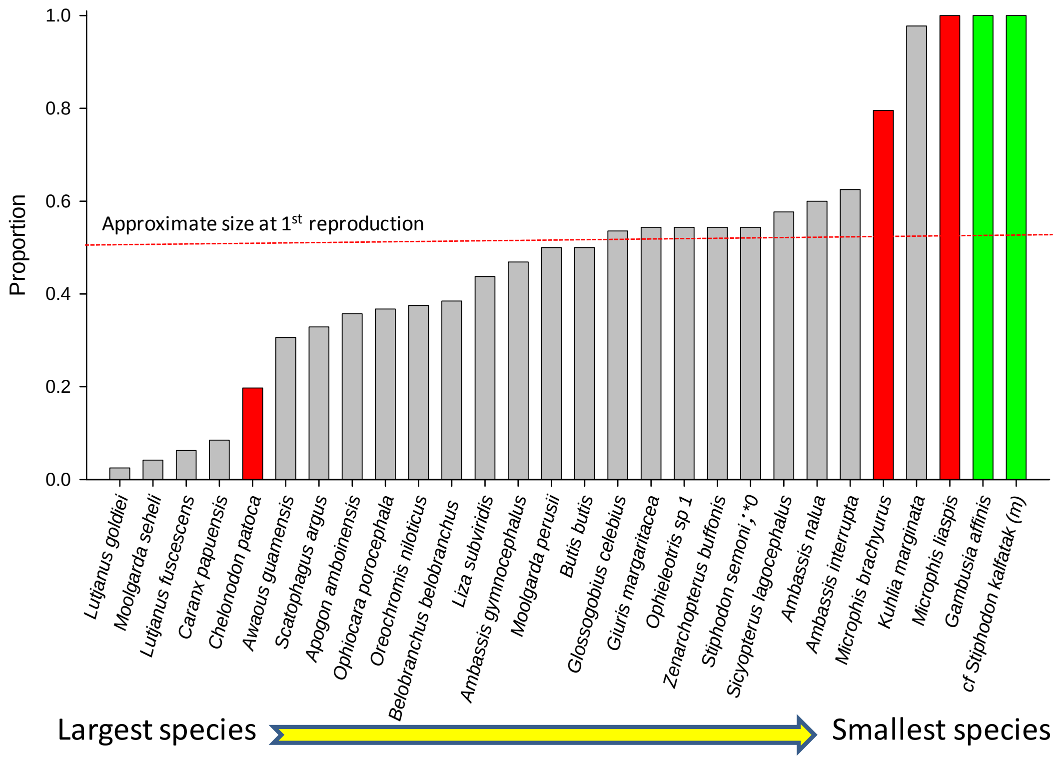


Figure 39. Maximum size of individual fish caught for a range of species, relative to the maximum size recorded for that species.
(Red bars indicate inedible species, green bars species that are normally considered too small for human consumption).

Biological state should be conducted monthly and include measures of turbidity, water temperature, sludge surveys (fibrous material from mill outfalls), extent of site coverage by aquatic plants and bank-side fish surveys. Riparian surveys should be conducted bi-annually. Riparian surveys should be undertaken twice per year however noticeable changes in riparian condition (e.g. removal of streamside oil palm) should be recorded during monthly physical/biological monitoring to establish time of disturbance where possible. Riparian surveys take the form of stream transects to detect reductions in oil palm on banks, increases in gardens/clearing in riparian and points where erosion is beginning. In addition a response survey to identify sources of turbidity should be undertaken during or immediately following rain events.

A monitoring plan and operation manual has been developed and implementation of monitoring will commence in June 2013. Trials of the indicators have been successfully conducted along with training of operators. Long-term success of the monitoring program will depend on continuing availability of trained on-ground operators, on-going support for capacity building and monitoring from companies, an on-going commitment from operators and companies and independent assessment of data collected from the monitoring.

Conclusion
Key issues going into the future are:
1) Maintenance and regeneration of existing and lost riparian vegetation.
   This is crucial because:
   - Many rainforest aquatic organisms are temperature sensitive and natural riparian is likely to be more effective at moderating water temperatures than oil palm.

- During natural processes of forest turn-over natural riparian vegetation contributes fallen timber to streams that provides complex habitat that many stream ORGANISMS? rely on for protection.
- Delivery of large woody debris to streams also fosters improved stream hydrodynamics that enhances biodiversity of in-stream habitat.

2) Maintenance of current levels of connectivity among and within stream systems. This is important because:
   - Connectivity facilitates re-population and utilisation of streams by aquatic faunas.
   - Disruptions to connectivity may reduce or remove in some cases, opportunities to rebuild fish stocks and this is likely a crucial link in food security going into the future.
   - Disruptions may prevent life history migrations of some species and lead to localised loss of species.
3) Improvements in settling pond management. This is important because:
   - Low DO water releases are potentially harmful to system productivity and aquatic faunas and floras.
   - High turbidity releases reduce system productivity and are potentially harmful to aquatic faunas and floras.
   - The ultimate fates and potential for environmental impact of discharge materials is unknown but potentially damaging for aquatic ecosystems.
4) Identification and mitigation of sources of turbidity. This is important because:
   - Elevated turbidities reduce system productivity and are potentially harmful to aquatic faunas and floras.
   - Sedimentation reduces in-stream habitat diversity, reduces stream flow and increases flooding magnitude.
   - Sediments are ultimately distributed across coastal habitats where they have adverse effects, particularly on coastal reef ecosystems.

Objective 5: to develop a crop system model

The prototype Oil Palm model has been extended to provide a more detailed model of bunch development, and to estimate the impact of legume cover crops on the carbon and nitrogen balance of oil palm systems. Testing of the model has been extended to four regions to provide a wide range of environmental conditions (Figure 40).

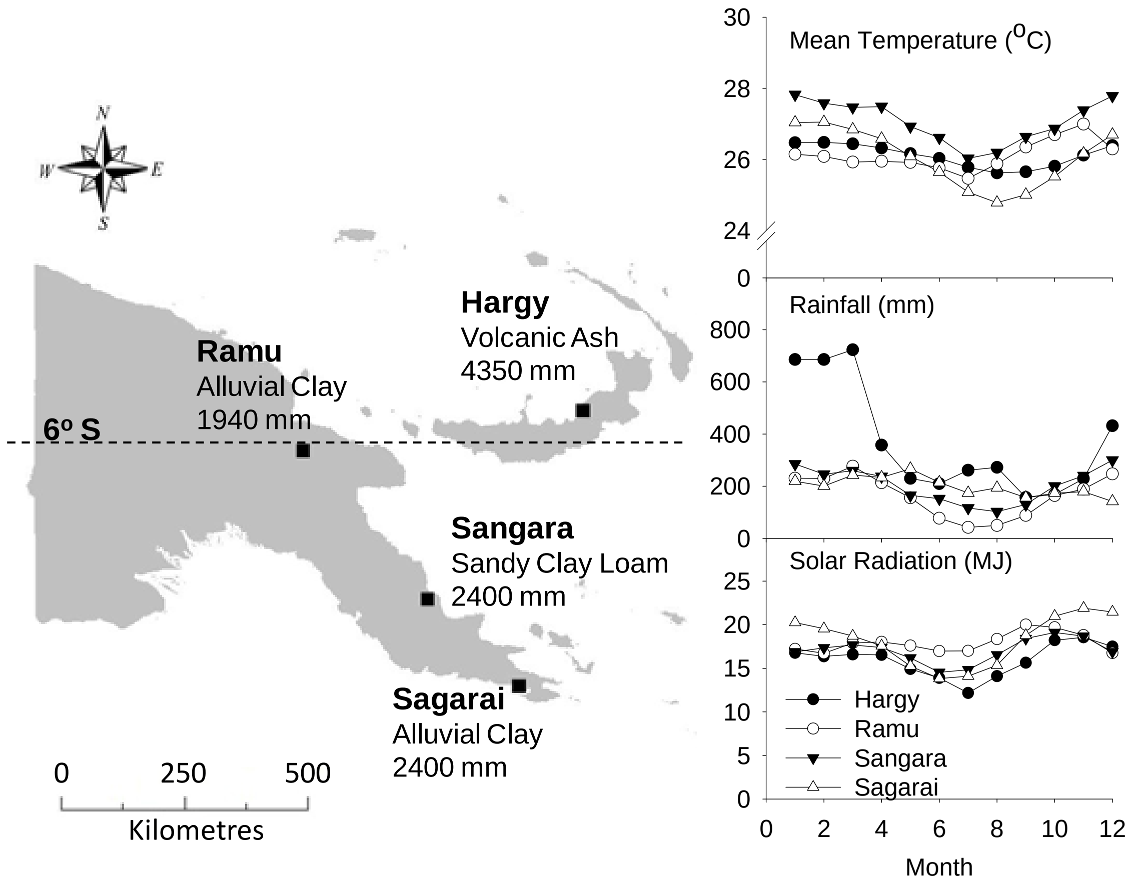


Figure 40. **Location of datasets used in the APSIM model development and testing. Sites were chosen to represent at range in soils and climatic conditions.**

Legume Cover Crop Model Development

Models for a wide range of grain and pasture legume species are available within APSIM (Robertson *et al.*, 2002). However, models do not exist for species commonly used in the understory of oil palm systems. Furthermore, these species are often grown as mixtures with other legume or grass species and the temporal dynamics of competition between overstory and understory are complex. A very simple model was developed for the legume understory to provide a basic level of functionality for simulating carbon and nitrogen inputs and water use by legumes within oil palm plantations. Data on understory canopy cover (Pipai, 2013) show that legume cover decreases from 40% soon after palm planting with the reduction related to cover provided by the palm overstory. Light interception by the legume understory was calculated, after accounting for light interception by the overstory, and used to calculate an understory growth rate using understory light use efficiency (εu, 1.3 g/MJ). This biomass is returned to the soil surface as litter with a fixed nitrogen concentration of 2.1% with 44% of this N coming from fixation and the remainder being taken up from the soil mineral N pools (Pipai, 2013).

Bunch Development Model.

The new bunch development model seeks to more closely describe the main processes determining yield potential in Oil Palm and the impact of periods of water and nitrogen stress on future palm yield. The model now predicts the sex ratio (Female Flower Fraction), flower abortion and stress impacts on potential bunch size. Each of these is calculated at an appropriate stage in the life cycle of an individual cohort of bunches (Figure 41).

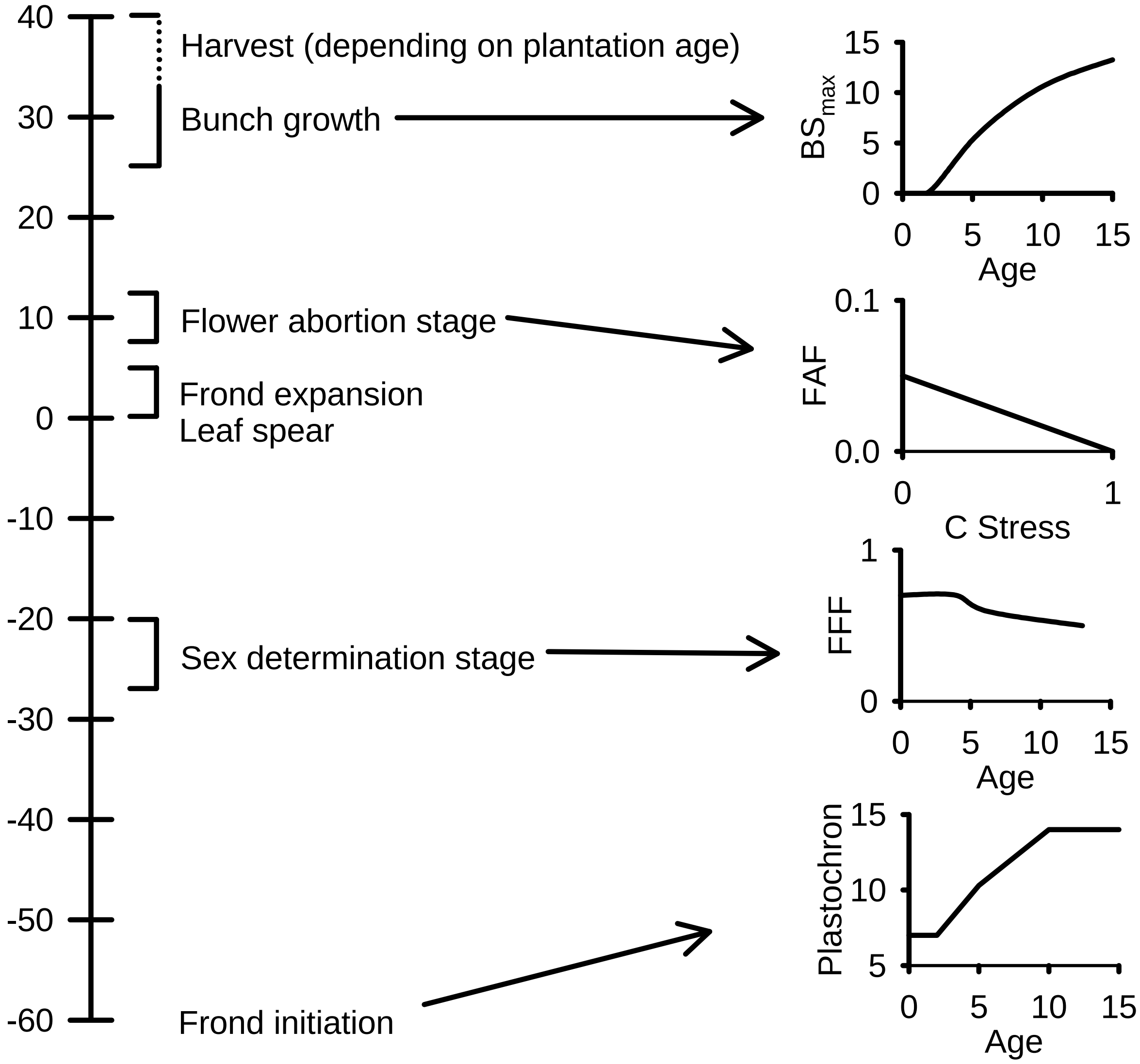


Figure 41. Basic model of bunch development used within the APSIM-Oil Palm model showing the timing of calculations for frond appearance (ie plastochron), female flower fraction (FFF), flower abortion fraction (FAF) and maximum bunch size (MBS).
(Each is calculated for a cohort of bunches where cohort rank is described using the axis shown where rank 0 is the spear leaf).

Model Testing
Four datasets have been assembled for use in model testing. Data on palm growth and production is readily available for each experiment. Data for soil and climate have been sourced from various sources. Soil hydraulic properties for volcanic ash soils were derived from pressure plate water retention data. Similar data for clay soils was deemed unsuitable, possibly due to difficulties in allowing sufficient time for equilibration of samples. Therefore, soil properties for similar clay soils were sourced from the APSoil data base (Dalgliesh and Foale, 1998) from Australia. Runoff curve number (Hawkins, 1996) was estimated to be 72 for clay soils and 50 for ash soils using data from PNG oil palm plantations (Banabas *et al*., 2008). Soil organic carbon and nitrogen and pH data was only available for Trial 324 for age 4 years. This may provide a limitation to the testing of the oil palm model. Climate data has similarly been assembled from a variety of sources. Daily solar radiation and air temperatures were obtained from global climate surfaces derived from satellite imagery. Testing of these data against available data for PNG suggested it to be suitable for our purposes. Daily rainfall was sourced for Popondetta and Ramu. Satellite-derived estimates of rainfall

were found to be inadequate for our purposes and so monthly data from the remaining sites was obtained and was disaggregated into daily rainfall totals using satellite-derived rainfall data. Initial testing of the model using these inputs has commenced and is showing promise.

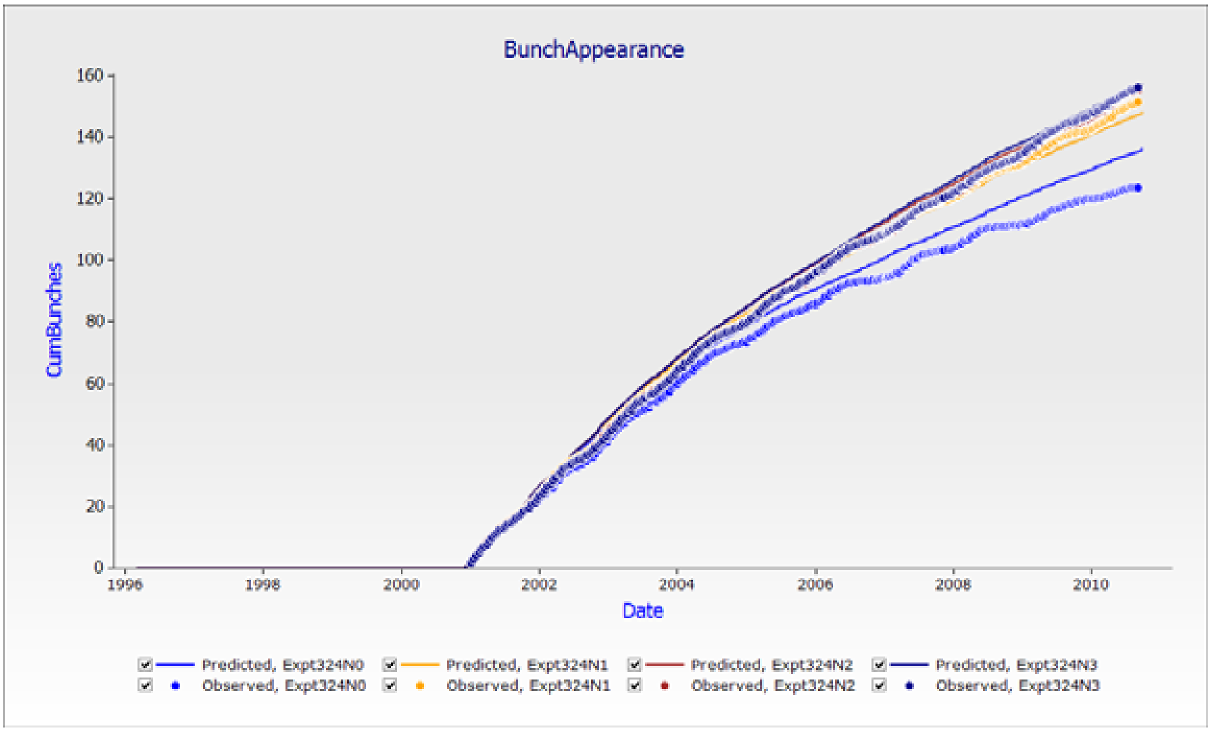


Figure 42. Predictions of cumulative bunch appearance (Bunches per palm) for Trial 324 at Sangara.

Objective 6: Implementation
Objective 6 depended so much on what was done in the other objectives. Many of the activities that took place during the previous 3 years continued in 2012 and are reported again here except for a number of additional aspects which will be specifically mentioned.

Potential indicators were identified after series of meetings with oil palm industry representatives in PNG and also in Cairns. Five oil palm smallholder growers in each of the 2 project sites (Hoskins – WNB) and Popondetta (Oro Province) were identified with the assistance of Oil Palm Industry Corporation extension staff. The farmers were met with and introduced to the project and agreed to work with the project. Other milestones under this objective depended on outputs from another 5 objectives and therefore have yet to be started. However although not specifically mentioned as expected activities and outputs from this objective, other activities have taken place that are either directly or indirectly related to this objective.
They included:

a) OPIC organised field days organised across the industry. The issue of how sustainable the oil palm system is a common question. Reply has been that there is a project looking into this question of soil and water sustainability in the oil palm systems in PNG. There have been radio broadcasts as well in New Ireland Province in 2012 and WNB making mention of the project.
b) Work progress was reported to the industry though the Local Planning Committee that discusses running of OPIC on project sites. The meetings are generally held on a monthly basis. Steven Nake was also involved in carrying out a road show in Hoskins and Popondetta on some of the sustainability activities.
c) At one of the project sites at Popondetta, excercise books were given to 5 selected growers to keep records of fertilisers and crop produced as a step towards trialling the indicators once outputs from the other objectives are completed.
d) The data management system is in dire need for improvement in the extension services for for management, and extension purposes. OPIC have recruited IT officers under the SADP program at Hoskins and Popondetta. A small information management committee comprising PNGOPRA, Higaturu Oil Palms Smallholders Technical Services Manager and OPIC IT, field and project managers was formed at Popondetta to ensure the work is up to speed and carried out to meet the requirements. In 2012, OPIC at Popondetta was issued licence to use OMP for smallholders. Data are entered by NBPOL at Higaturu and OPIC will only use the information. Reports and outputs were used from the Sustainability Project and will add value to the use of this software smallholder support. leaf sampling at Popondetta Smallholder blocks and Estate leaf sampling in Poliamba, full frond measurements, including leaf count and sampling at 0.6 of the frond length was carried out.
e) Two other joint project between PNGOPRA and OPIC with activities that relate to sustainability and are current are the food security and fish pond projects. They relate to sustainable use of space between palms and available water resources in oil palm blocks. The fish pond project was completed in 2012 while the food security project is continuing.

Capacity building
In addition, capacity is being built among PNGOPRA and other industry staff in several areas.

- Rachael Pipai from completed her Masters studies on N fixing at Adelaide University.
- Vudal University of Natural Resources (Rabaul and Popondetta Campuses) students on industrial training were involved in soil and plant sampling and measurements as part of their industrial training.
- PNGOPRA staff continue working with and learning techniques for specialised sampling of soil, water and gases.

References

Banabas, M., Turner, M.A., Scotter, D.R., Nelson, P.N., 2008. **Losses of nitrogen fertiliser under oil palm in Papua New Guinea: 1. Water balance, and nitrogen in soil solution and runoff**. *Aust J Soil Res* **46**, 332-339.

Chase L, Henson I. 2010. **A detailed greenhouse gas budget for palm oil production**. *International Journal of Agricultural Sustainability* 8:199-214.

Dalgliesh, N.P., Foale, M.A., 1998. **Soil Matters – monitoring soil water and nitrogen in dryland farming**. *Agricultural Production Systems Research U*nit, Toowoomba, Australia.

Goodrick I, Nelson PN, Banabas M, Wurster C, Bird MI. 2012. **Soil carbon balance following conversion of grassland to oil palm**. *Joint ASSSI and NZSSS Soil Science Conference 2012. Soil solutions for diverse landscapes*. 2-7 December 2012. Hobart, Australia. (poster)

Hawkins, R.H., 1996. **Runoff Curve Number: Has It Reached Maturity**? *Journal of hydrologic engineering* **1**, 11-19.

NBPOL 2012. **Carbon Footprint Report** 2011. New Britain Palm Oil Ltd

Nelson PN, Banabas M, Goodrick I, Gabriel E. 2012. **Soil fertility changes following conversion of grassland to oil palm**. *Joint ASSSI and NZSSS Soil Science Conference 2012. Soil solutions for diverse landscapes*. 2-7 December 2012. Hobart, Australia. (poster)

Nelson PN, Webb MJ, Banabas M, Nake S, Goodrick I, Gordon J, O'Grady D, Dubos B. *In prep*. **Methods to account for tree-scale variation in soil- and plant-related parameters in plantations**. To be submitted to *Plant and Soil*

Pipai R., 2013. **Biological Nitrogen Fixation By Cover Legumes Under Oil Palm Plantations In Papua New Guinea**. *School of Agriculture, Food and Wine. Faculty of Sciences. The University of Adelaide, Australia*.

Robertson M.J., Carberry, P.S., Huth, N.I., Turpin, J.E., Probert, M.E., Poulton, P.L., Bell, M., Wright, G.C., Yeates, S.J., Brinsmead, R.B., 2002. **Simulation of growth and development of diverse legume species in APSIM**. *Aust J Agric Res* **53**, 429-446.

ASSESSING NITROGEN FIXATION BY *CALOPOGONIUM CAERULEUM*, *PUERARIA PHASEOLOIDES* AND *MUCUNA PRURIENS* USING THE XYLEM UREIDE TECHNIQUE UNDER OIL PALM IN WEST NEW BRITAIN PROVINCE, PAPUA NEW GUINEA

Rachel Pipai

Introduction

The sustainable management of soil nutrients, and more generally soil health, is a priority concern for the Papua New Guinea oil palm industry as it is for most other agricultural systems in the world. Like other crops, oil palms need essential elements such as N, P, K and Mg in large amounts annually in order to maintain high fresh fruit bunches (FFB) production. Nutrients are supplied in the form of mineral fertilizers annually to meet nutritional requirements. When supplied in excess some fertilizers such as N could be lost to the environment and potentially affect environmental health by causing soil acidity and eutrophication in the water ways, while nitrous gas emissions contribute to greenhouse gases. The use of legume cover plants as an alternate source of N could be a more sustainable option in that legumes could independently fix atmospheric N_2 without the added mineral nitrate at the same time making N available to the palm during litter mineralisation which takes a longer period so any amount of nitrate leached would presumably consist of smaller amounts compared to a once-off fertilizer application. Legume cover plants have long been used under the PNG oil palm system for weed suppression and erosion control and also to contribute N to the oil palm system through biological N fixation, although amounts of N fixed have not been quantified for these legumes in PNG oil palm plantations. In this study, the amount of N_2 fixed by the different legumes under the oil palm system is being assessed using the xylem ureide technique. This technique was found to be useful to measure N_2 fixation in certain legume species that transport their fixed N_2 in the xylem sap as the ureides allantoin and allantoic acid; mainly legumes from the tribes Phaseoleae and Desmodieae within the Papilionaoideae sub family (Unkovich *et al.* 2008). Legumes that are non-ureide producers transport their fixed N_2 as amides and nitrates. The legumes used under PNG oil palm plantations; *Calopogonium caeruleum*, *Pueraria phaseoloides* and *Calopogonium mucunoides* are ureide transporters making the ureide technique applicable to assess N_2 fixation. *Mucuna pruriens*, a legume which was introduced recently in the PNG oil palm plantations also belong to this family, although its ability to transport ureides is unclear but is measured anyway in this study.

The xylem ureide technique provides an indirect measure of the amount of N_2 derived from the atmosphere (%Ndfa), best represented as relative ureide-N (RU-N) which is the percentage of ureide-N in the total sap N (ureide-N+nitrate-N+amino-N). Therefore it needs to be calibrated against a more reliable technique before being applied to measure N_2 fixation (Herridge 1982a; Herridge 1982b; Herridge and Peoples 1990). Soil nitrate reduces legumes' dependence on N_2 fixation, so the calibration technique basically involves the application of different levels of ^{15}N labelled nitrate fertilizers to legumes grown in an N-free medium to induce differences in the amount of N_2 being fixed (%Ndfa) by the legumes . The concentrations of ureides in the legume xylem sap should hypothetically decrease with increasing nitrate similar to the %Ndfa measured by ^{15}N isotope measurement. A regression analysis of stem RU-N against %Ndfa obtained by ^{15}N measurement showing strong positive correlation indicates that the RU-N technique is successfully calibrated. The xylem sap components could be analysed in the laboratory while the ^{15}N isotope could be measured using a mass spectrometer (Unkovich *et al.* 2008).

Materials and methods

Glasshouse experiment

The xylem ureide technique for the PNG legume species was calibrated in a glasshouse experiment in the University of Adelaide (Waite Campus) using ^{15}N isotope dilution for the legume cover species *C. mucunoides*, *P. phaseoloides* and *M. pruriens*, before being applied in PNG oil palm plantations to assess N_2 fixation by the same legume cover species.

Field Survey
A field survey carried out during December 2011 to February 2012 in West New Britain oil palm plantations measured the stem RU-N and total N in the standing shoot and litter biomasses of *C. caeruleum, P. phaseoloides* and *M. pruriens*. The stem RU-N and total N were analysed in the University of Adelaide. Other parameters measured included legume biomass per square meter and percentage of legume cover in oil palm plantations ranging from 2 to 25 years old. These were used to calculate the amount of N fixed per square meter and later extrapolated to kg N fixed/ha.

Results and discussion

Glasshouse

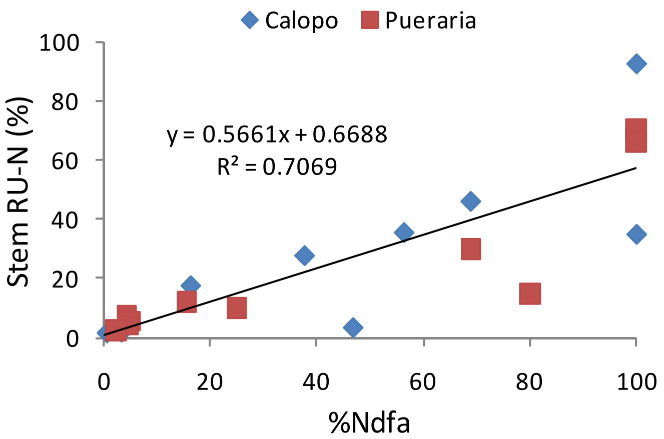


Figure 43. Regression and correlation of glasshouse stem RU-N and %Ndfa in C. mucunoides and P. phaseoloides from two harvests combined into a single ureide calibration.

The ureide technique was successfully calibrated in the glasshouse experiment for *C. mucunoides* and *P. phaseoloides*. The different levels of %Ndfa obtained by the ^{15}N isotope dilution in *C. mucunoides* and *P. phaseoloides* in the glasshouse experiment in Adelaide were highly correlated with the stem RU-N values. Since the stem RU-N and %Ndfa of *C. mucunoides* and *P. phaseoloides* were not significantly different from each other these values were combined for both species in a single calibration (Figure 43) to arrive at the equation *STEM RU-N = 0.5661(%Ndfa) +0.6688*. Field measures of stem RU-N in the legume species *C. mucunoides*, *P. phaseoloides* and *C. caeruleum* could now be inserted in this calibration equation to measure the %Ndfa. The calibration was inconclusive for *M. pruriens* since its mean stem RU-N was very low (<9%) in the glasshouse experiment while field values were higher (>20%) and outside the glasshouse range. The same calibration equation was then used for all three species to measure %Ndfa in field grown legumes.

Field
The stem RU-N analysed for the PNG legume samples inserted in the calibration equation above gave the %Ndfa values shown in
. Dependence on N_2 fixation was highly variable, ranging from 18 (*P. phaseoloides*) to 75% (*C. caeruleum*), and did not show any relationship with age of plantation. Generally, *Calopogonium caeruleum* fixed a higher proportion of atmospheric N_2 in West New Britain plantations compared to *Pueraria phaseoloides*. The amount of N_2 fixed in kg/ha in all legumes however was greatly influenced by the legume biomass and the estimated legume cover hence indicated potential for increasing inputs of fixed N by managing for greater legume cover. Amounts of N_2 fixed were 1.5 to 4.4 g/m^2 for standing shoot and 0.9 to 6.0 g/m^2 for litter equating to plantation estimates from 0.3 (*C. caeruleum*) to 34 (*P. phaseoloides)* kg N fixed/ha. These were conservative estimates since the study did not account for N in roots and furthermore only measured standing biomass rather than annual production.

Soil nitrate reduced the legumes' dependence on N_2 fixation in both the glasshouse Figure 44 a) Figure 44 b).

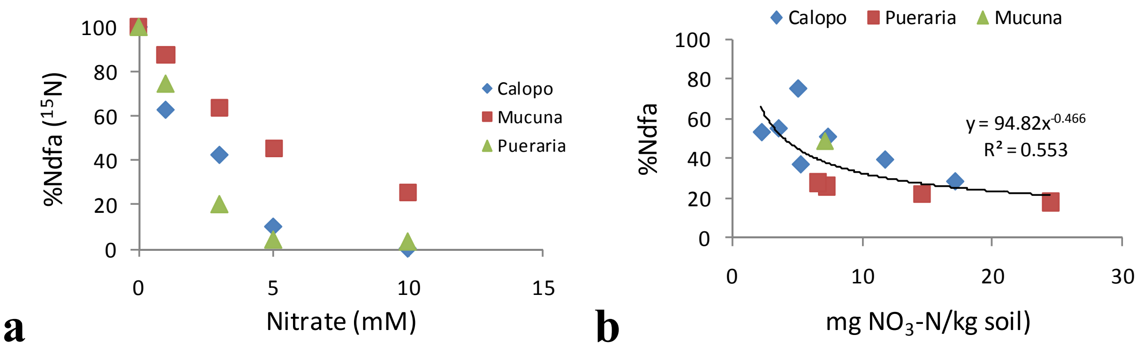


Figure 44. Graphs showing the effect of soil nitrate on legumes' dependence on N_2 fixation as observed in (a) the glasshouse experiment and (b) PNG field survey.

Table 111. Stem RU-N (%), %Ndfa and fixed N measured in grams per square meter in standing shoot and litter biomasses of legumes under different oil palm ages

Location	Age (years)	Stem RU-N (%)	s.d.	%Ndfa	s.d.	Fixed N in shoots (g/m^2)	s.d.	Fixed N in litter (g/m^2)	s.d.	Fixed N in shoot+ litter (g/m^2)	s.d.
C. caeruleum											
Kapiura	3	22.9	7.1	39.3	12.6	4.4	3.2	3.2	2.3	7.6	5.0
Mosa	4	29.4	9.2	50.7	16.2	4.2	0.5	6.0	2.8	10.2	2.6
Kapiura	5	43.0	33.7	74.8	59.5	3.4	2.8	2.2	1.6	5.6	4.3
Kapiura	7	21.6	8.2	36.9	14.5	1.6	0.5	1.0	1.4	2.6	1.7
Numundo	8	23.5	3.6	40.3	6.4			Data not collected			
Numundo	9	25.4	11.9	43.7	21.0						
Mosa	13	16.8	10.9	28.4	19.3	1.5	0.9	0.9	0.7	2.4	1.5
Numundo	16	37.5	14.6	65.1	25.8						
Mosa	18	31.7	15.7	54.9	27.6	1.6	0.6	1.4	1.0	3.1	1.4
Kapiura	25	30.7	15.7	53.0	27.8	2.0	1.3	0.9	0.5	3.0	1.7
P. phaseoloides											
Mosa	2	13.2	4.0	22.2	7.1	3.1	1.0	4.0	0.9	7.1	1.8
Kapiura	3	10.8	4.0	18.0	7.0	1.6	0.6	3.0	1.8	4.6	2.2
Mosa	4	15.4	10.8	26.1	19.0	2.4	1.4	4.7	3.5	7.0	4.4
Numundo	4	37.9	12.4	65.7	21.9			Data not collected			
Kapiura	5	16.4	8.8	27.8	15.5	2.0	1.6	3.5	3.3	5.5	4.8
M. pruriens											
Mosa	6	28.2	9.6	48.6	16.9	3.8	0.6	5.9	2.8	9.7	3.4
	mean	25.3		43.5		2.6		3.1		5.7	
	s.d.	9.5		16.7		1.1		1.8		2.7	

Conclusion

The xylem ureide technique was successfully calibrated in the glasshouse experiment and applied to measure N_2 fixation by *C. caeruleum*, *P. phaseoloides* and *M. pruriens* in West New Britain oil palm plantations. As much as 34 kg N/ha was fixed by *P. phaseoloides* at the time of sampling, although

N_2 fixation over time was not estimated in this survey. *Calopogonium caeruleum* fixed a higher proportion of N_2 (%Ndfa) than *P. phaseoloides* in West New Britain but the legume biomass and the percentage of legume cover affected the overall N_2 fixed in kg/ha. Further research is recommended to quantify legume biomass production over time, including litter and root accumulation and turnover. *Mucuna pruriens* did not transport a large proportion of fixed N as ureides so the ureide technique needs to be re-investigated for this species.

References

Herridge DF (1982a) Relative abundance of ureides and nitrate in plant tissues of soybean as a quantitative assay of nitrogen fixation. *Plant Physiology* **70**(1), 1-6.

Herridge DF (1982b) Use of the ureide technique to describe the nitrogen economy of field-grown soybeans. *Plant Physiology* **70**(1), 7-11.

Herridge DF, Peoples MB (1990) Ureide assay for measuring nitrogen fixation by nodulated soybean calibrated by 15N methods. *Plant Physiology* **93**(2), 495-503.

Unkovich MJ, Herridge DF, Peoples MB, Cadisch G, Boddey B, Giller KE, Alves BJR, Chalk P (2008) 'Measuring plant-associated nitrogen fixation in agricultural systems.' (Australian Centre for International Agricultural Research (ACIAR): Canberra)

COLLABORATION ON THE USE OF PLANT GROWTH REGULATORS

Introduction

PNGOPRA and the US-based biotechnology company, Valent BioSciences Corporation, entered into a multi-year collaboration to evaluate of the effects and benefits of Plant Growth Regulators in Oil Palm.

Plant Growth Regulators (PGRs) for oil palm have been little researched and consequently there is little to no commercial use. This differs considerably from the uses of PGRs in other crops where they are extensively used to increase the economic return of production through modification of fruit set, improved fruit size, higher quality yields, vegetative growth management, seed germination and growth, and reduction of labour costs.

PGRs include the five major plant hormone groups (gibberellins, cytokinins, auxins, ethylene and abscissic acid) and may be the natural plant chemicals or synthetic analogues. These plant hormones can act both singly and in combination to initiate or modulate various aspects of plant development and growth. For example, gibberellins can accelerate growth and increase cell size; cytokinins can increase the rate of cell division; and ethylene is responsible for the ripening of many fruits. PGRs also include molecules that have the opposite effect of the plant hormones; that is, anti-gibberellin and anti-ethylene compounds. For example, where gibberellins accelerate growth, the anti-gibberellins retard growth; anti-ethylene molecules delay ripening and fruit fall of many fruits.

Gibberellins and anti-gibberellins

Gibberellins have been shown to increase growth rate in many plants mainly through increases in cell size. This increase is used commercially to 'stretch' the rachis of grapes to allow for larger berry size, increases fruit size, increases internode length, stimulates growth under limiting conditions such as cold weather and can reduce fruit skin finish disorders. In Oil Palm, Gibberellin A3 (GA3) has been shown to decrease the time to flowering, increase male inflorescences and reduce frond number. Anti-gibberellins such as uniconazole and paclobutrazol can increase the number of female inflorescences and should also reduce palm height.

Cytokinins

Cytokinins can increase the rate of cell division and cell size, and are important 'anti-senescence' molecules. Commercially the cytokinins are used to increase fruit size, stimulate branching in fruit trees and to delay the over-ripening of vegetables. There appears to be no studies of cytokinins in Oil Palm.

Auxins

Auxins are associated with a wide range of plant physiological events and the greatest commercial use has been as herbicides, however, a number are used to improve agricultural productivity. Auxins can promote root growth, increase fruit set and parthenocarpy, and increase or decrease fruit abscission depending on application timing (2,4-D and AOA prevented fruit abscission)

Ethylene

Ethylene is the 'ripening' hormone and is used to ripen bananas, accelerate maturation to aid mechanical or more even harvesting and is also used to enhance latex flow in rubber trees. In Oil Palm ethylene (or ethephon) has been shown to accelerate fruit abscission from the bunch.

Abscissic Acid

Abscissic Acid (ABA) is commonly regarded as a 'stress hormone' and is often induced when the plant is under water-stress or some other form of stress. It is often also responsible for dormancy in the seeds of some plant species. ABA has only been commercially available for 12 months and its full utilisation in agriculture is still to be determined. In Oil Palm, ABA enhanced fruit shedding, probably by stimulating ethylene production.

Summary

The data being generated under this collaboration are currently the subject of a confidentiality agreement as there is the potential to protect the novel uses that are being developed.

Currently seven studies have been finalized and five research meetings between scientists of PNGOPRA, NBPOL and Valent BioSciences have been held at Dami.

It is expected that semi-commercial scale studies will be implement in mid-late 2013 in order to validate the experimental studies and to determine the benefits to growers and the mills.

2. ENTOMOLOGY SECTION

HEAD OF SECTION II: CHARLES F DEWHURST

SUMMARY

General operational work

There was a reduction in infestations reported in 2012 with 50 reports as compared to 74 reports in 2011. Operational visits by Entomology Section to smallholder blocks and plantations continued, and Pest Recommendations were produced and provided to OPIC divisional managers (smallholders) and plantation managers (company plantations). The treatment teams were generally well organised and worked efficiently under Smallholder Affairs (SHA) Department of NBPOL, with whom we work closely. Plantation Groups managed their own teams with varying degrees of success.
Control operations were also effectively completed in New Ireland Province; however no Targeted Trunk Injection (TTI) for oil palm pest control was undertaken on the mainland of PNG.
The insect composition of pest reports remained similar to previous years, but there were changes in abundance among the commonest taxa.

Projects

There was little activity with the Bill and Melinda Gates Foundation BREAD project. Consequently, the proposed visit by a PNGOPRA staff member to the UCLA Biological Control Lab at Riverside, California, USA did not materialise, which was disappointing.
There was no action by NAQIA in following up on the Notifiable Pest Status gazettal, an on-going issue for the last 6 years.

Bogia Coconut Syndrome (BCS)

A BCS vector and pathogen study was activated as an Small Research Acivity (SRA) through ACIAR to specifically target potential vectors ("*Identifying potential vectors of Bogia Coconut Syndrome in Madang Province, Papua New Guine*a", PC/2011/056). This project will be completed by the end of February 2013, as a short no-cost extension until February was agreed by ACIAR.

Laboratory extensions

Work began on the extension and upgrading of the Entomology Laboratory in August which was almost completed before Christmas. It is expected to be completed by February 2013, and it will be an essential upgrade for the Entomology Section, by providing additional space and resources. The portable donga provided through the Smallholder Agricultural Development Project (SADP) was also installed and is a valuable storage and workspace for our important reference collection and specimen preparation. It is air-conditioned has electricity and running water.

Smallholder Agricultural Development Project (SADP)

The SADP water monitoring project made a slow start, however with agreement for an additional year of funding for the Aquatic Biologist, the work progressed well and is reported below.

Conservation of Queen Alexandra Birdwing Butterfly (QABB)

Little new work with QABB was done, although a final draft of the major review of the work was finalised before Christmas and sent to our collaborator (Dr David Mitchell) at Conservational International (Alotau) for publication. A manuscript in in preparation with Dr Dale Smith (OPRS) on the chemistry of *Pararistolochia*.

Operational Research

Egg parasitoids and Life History studies
Laboratory rearing and releases of parasitoids continued. *Doirania leefmansi* (DL) numbers reared for field release were disappointingly low. This poor performance in rearing DL for release is being addressed. The numbers of *Leefmansia bicolor* (LB) produced during the year were acceptable.

The recently described parasitoid *Anastatus eurycanthae* (Gibson *et al*., 2012) continued to be mass reared and released in areas where *Eurycantha calcarata* (Giant Spiny Stick Insect) is found in West New Britain (WNB). This parasitoid is well suited to the host, as females are wingless and it is only the tiny males that can fly.
Field investigations into populations of *E. calcarata* uncovered some interesting new facts on the ecology of this insect including remarkable longevity and local movements.
Laboratory and rearing studies on life history and fecundity of sexavae have also proved very useful towards help developing possible modification of the methodology for the trunk injection regime and will be written-up. A staff member is working on this insect for her MPhil with Unitech.

Destructive Palm Sampling
Destructive palm sampling (DPS) analysis has also shown that there may in fact be a correlation between activity in the lower and upper canopy, however a major setback to the work occurred when the biometrician analysing these data left NBPOL.

Alternative insecticides
Work on looking for alternative insecticides to methamidophos did not progress much during 2012 due to a lack of insects and long delays with sourcing new insecticides. The officer working on this important aspect joined Entomology Section in February 2012.
We will be seeking approval for more rapid access and speedy import for new insecticides for testing, from the Department of Environment & Conservation (DEC) who will also be requested to treat PNGOPRA as “an Approved Scientific Institution” to enable us to more readily send material overseas for specialist identification. Currently every specimen has to be seen by a senior official at DEC before it can be brought back to Dami to be packed and sent overseas. The suggestion to use web-cam was rejected as there was no access by officials at DEC.

INTRODUCTION
The situation involving pest infestation reports improved in 2012 with a significant reduction in reports from those received in 2011. There were 51 reports received (19 OPIC and 32 Plantations). This reduction was largely due to **1**), the regular weekly “pest management meetings” with smallholder extension staff at OPIC and **2**), monthly meetings with plantation management resulting in the more closer working relationship coupled with efficient control teams provided by Smallholder Affairs (SHA) treatment teams and **3**), a new reporting form was prepared and implemented with a reminder to recipients that treatment (TTI) should begin no later than two weeks after its receipt.

General issues
Only 2 OPIC field days were held in 2012 (Table 7), and both were attended by entomology staff in conjunction with PNGOPRA Plant Pathology staff. Presentations were made by the participants during the field days. Weekly OPIC Pest and Disease meetings were regularly attended in WNB, but none took place in Popondetta or New Ireland.
OPIC Divisional Managers also continued to provide specimens (of adults and eggs) for research studies. Regular egg monitoring continued at Navarai Plantation, and *E. calcarata* adults were monitored regularly at Dire/Namova VOPs, although there were disruptions to the work due mainly to security issues.
Regular monthly meetings of NBPOL Plantation management staff were attended at Mosa HQ, and information was provided for the LPC meetings as required.

Insect material was added to the reference collection and data added to the database. The database on oil palm insects was maintained and now contains more than 600 records. This database is not solely pests but refers to insects found on oil palms as well as the natural enemies of oil palm pests. It is regularly updated.

A number of peer-reviewed scientific papers were also produced during the year; the full references are provided under publications.

Good collaboration with local and overseas research personnel continued. The project, Basic Research to Enable Agricultural Development (BREAD), moved slowly forward during the year, as we finally managed to get egg material sent to UCLA Biological Control labs at Riverside.

There was no response received from the Department of Environment and Conservation (DEC) in Port Moresby for the Queen Alexandra Birdwing Butterfly (QABB) project and neither did NAQIA take the Notifiable Pest Status further for gazettal, although a draft was sighted two years ago.

The Methamidophos Usage Database (MUD) underwent complete redesigning by IS Officer, Charles Tringin at PNGOPRA, Milne Bay and was still not fully operational by the end of 2012. We are concerned about the level of supervision with TTI, and we will plan to arrange regular and effective hands-on training for the treatment teams and their supervisors during the coming year.

The shade house for culturing Chrysomelidae, *Calligrapha pantherina,* a beetle which is an efficient biological control agent against the Broomstick weed, *Sida rhombifolia,* was rebuilt, repaired and re-stocked. Rearing tanks for bio-control agents for Water hyacinth and Water cabbage were re-stocked with infested material collected from the field and reared up in the lab.

The SADP/OPIC water quality invertebrate indicators monitoring project became operational during 2012, and finally all outstanding equipment arrived and was installed in the donga provided by the World Bank (through SADP project), which will act as a lab until the new entomology extension and refurbishment is complete. The Aquatic Biologist began work on this project in June 2012. Results of the project are reported later under applied research projects.

Staff numbers remained at 12 during 2012 (11 operational and 1 support staff). A Plant Protection Specialist (Insecticides-Dr Mark Ero) began work with PNGOPRA Entomology in January, 2 staff moved between Dami and Poliamba, 1 of who based at Dami will be working with Dr Ero on insecticides.

Research Officer, Mr Deane Woruba returned from his M.Phil. Studies at Charles Sturt University, Orange, Australia. His thesis had not been completed by the end of 2012 (after his resignation from PNGOPRA), however he will be expected to complete his thesis in 2013.

Work on Bogia Coconut Syndrome (BCS) continued during 2012 and was given a short unfunded extension toward the end of the year so the full report will be provided in 2013. Plant Pathology Section also received funding for analytical studies at MB laboratory through NAQIA. Results are presented in the Plant Pathology Section report.

OIL PALM PEST REPORTS
(RSPO 4.5, 4.6, 8.1)

Pest taxa reported in 2012
(RSPO 4.5, 8.1)
There was a noticeable drop in the frequency of reports for each taxon in 2012 compared to those reported in 2011. The major pest taxa (**species complex**) reported in 2012 for PNG remained the same as those reported in 2011, with a few variations in the minor taxa. The 3 most commonly reported taxa were the Tettigoniidae S. *decoratus*, *S defoliaria* and Phasmatidae *E. calcarata* (Figure 45 [i]). More reports came from plantations than the smallholders (OPIC). All major taxa reported by OPIC in 2012 were from WNB. There were no reports from NI or the mainland (Figure 46 [i]) and no pest infestations were reported from the Solomon Islands (GPPOL).
As for OPIC, all of the major taxa reported by the plantations in 2012 were from WNB. The only species reported from NI was *S. gracilis* (Figure 46 [i]).
For both sectors, reports of *S. defoliaria* (in WNB) were considerably reduced from last year. Report data suggest that *S. defoliaria* is gradually being replaced by *S. decoratus* in areas previously dominated by *S. defoliaria*. There is still confusion as to the correct taxonomic state for the specific separation within sexavae. It is hoped that Dr David Rentz will visit in early 2013 to help sort out some anomalies with Tettigoniidae taxonomy.
A peer-reviewed paper on the weevil recently reported from oil palms at Mamba Estate (Higaturu Oil Palms, Northern Province) and previously only recorded from coconut in Madang many years ago, was published (Dewhurst & Pilotti, 2012). Full reference of the paper is published under publications.

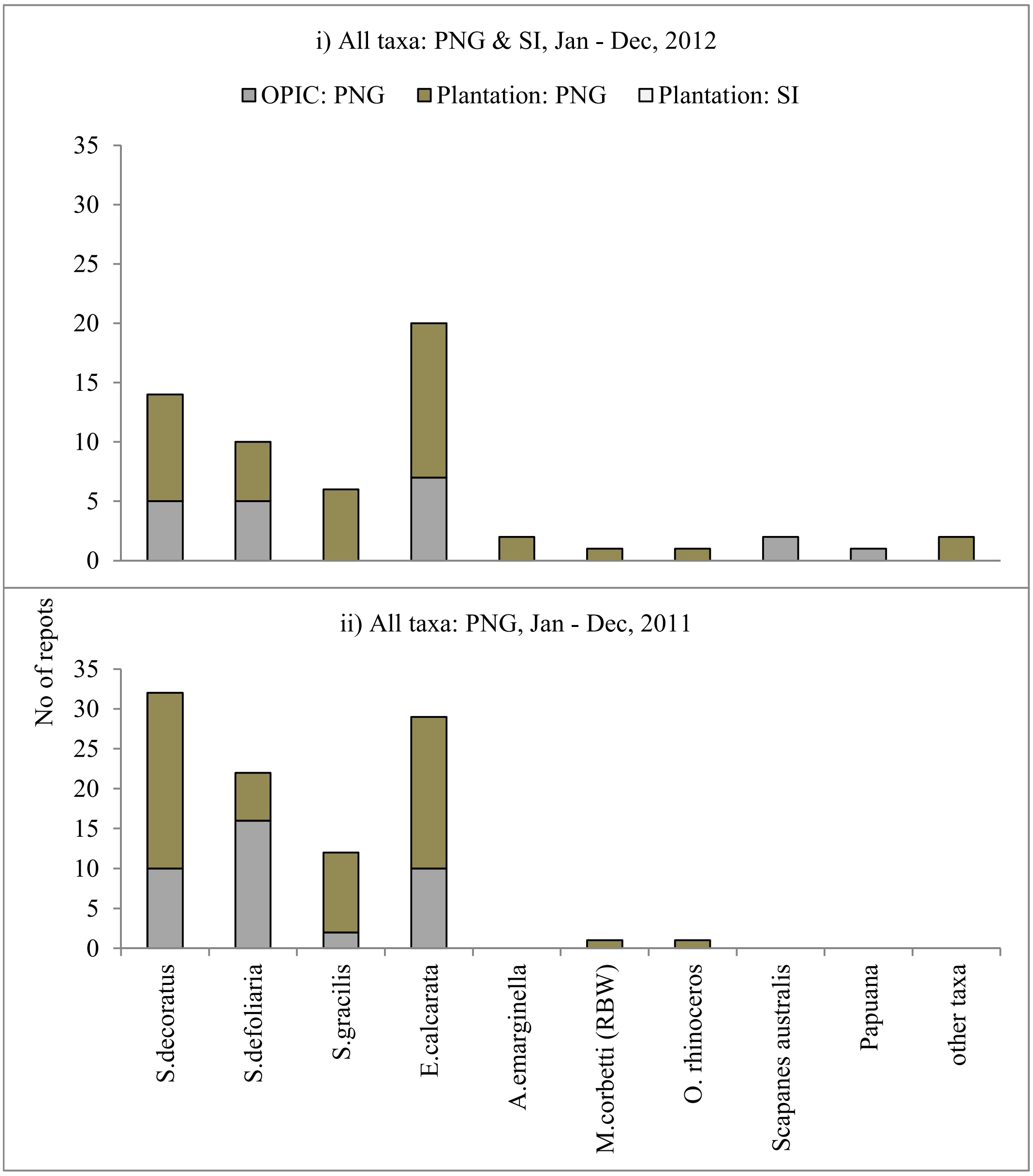


Figure 45 (i & ii). Pest taxa reported by OPIC and the plantations in PNG, and the plantations in Solomon Islands in 2012 (i) compared to those reported in 2011 (ii).

(

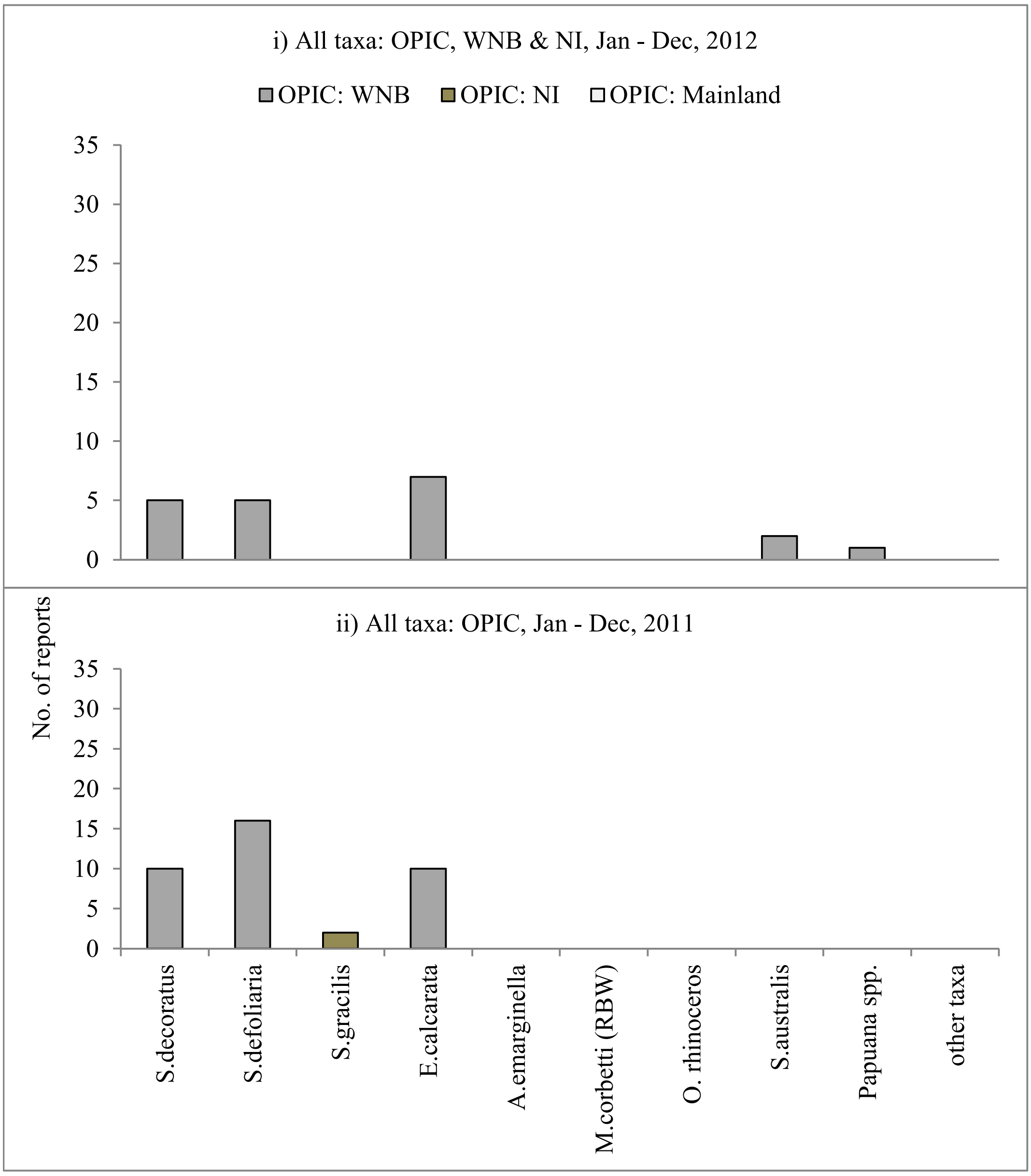


Figure 46 (i & ii). Pest taxa reported by OPIC in 2012 (i) from smallholder blocks compared to those reported in 2011 (ii).

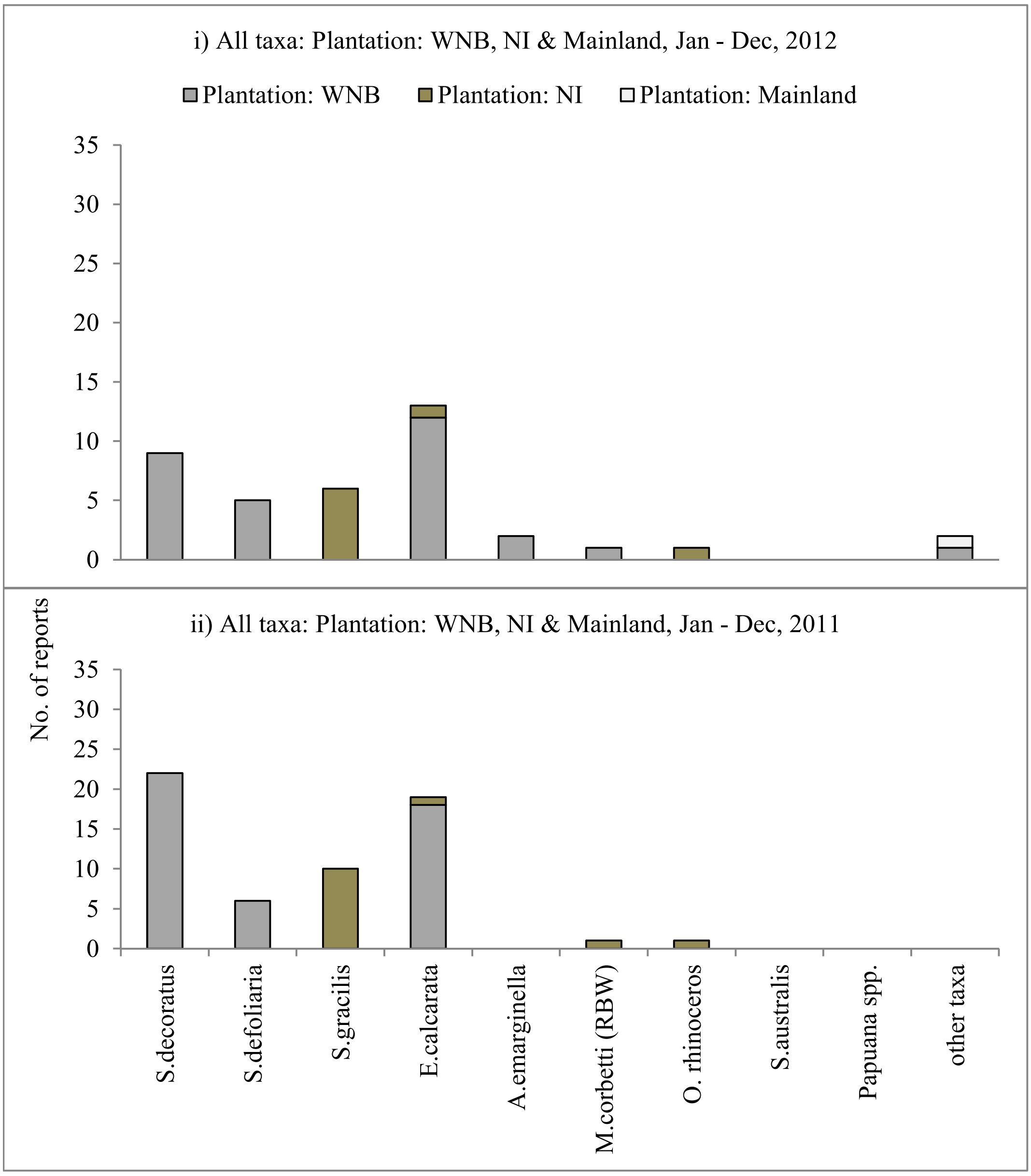


Figure 47 (i & ii). Pest taxa reported by plantations in 2012 (i) compared to those reported in 2011 (ii).

Pest Infestation Reports in 2012
(RSPO 4.5, 8.1)
Fifty one (51) infestation reports were received (32 from plantations and 19 from smallholder blocks) from PNG during 2012 (Figure 48 [i]). This is 31% less than those reported in 2011 (n= 74), which is encouraging (Figure 48 [ii]).

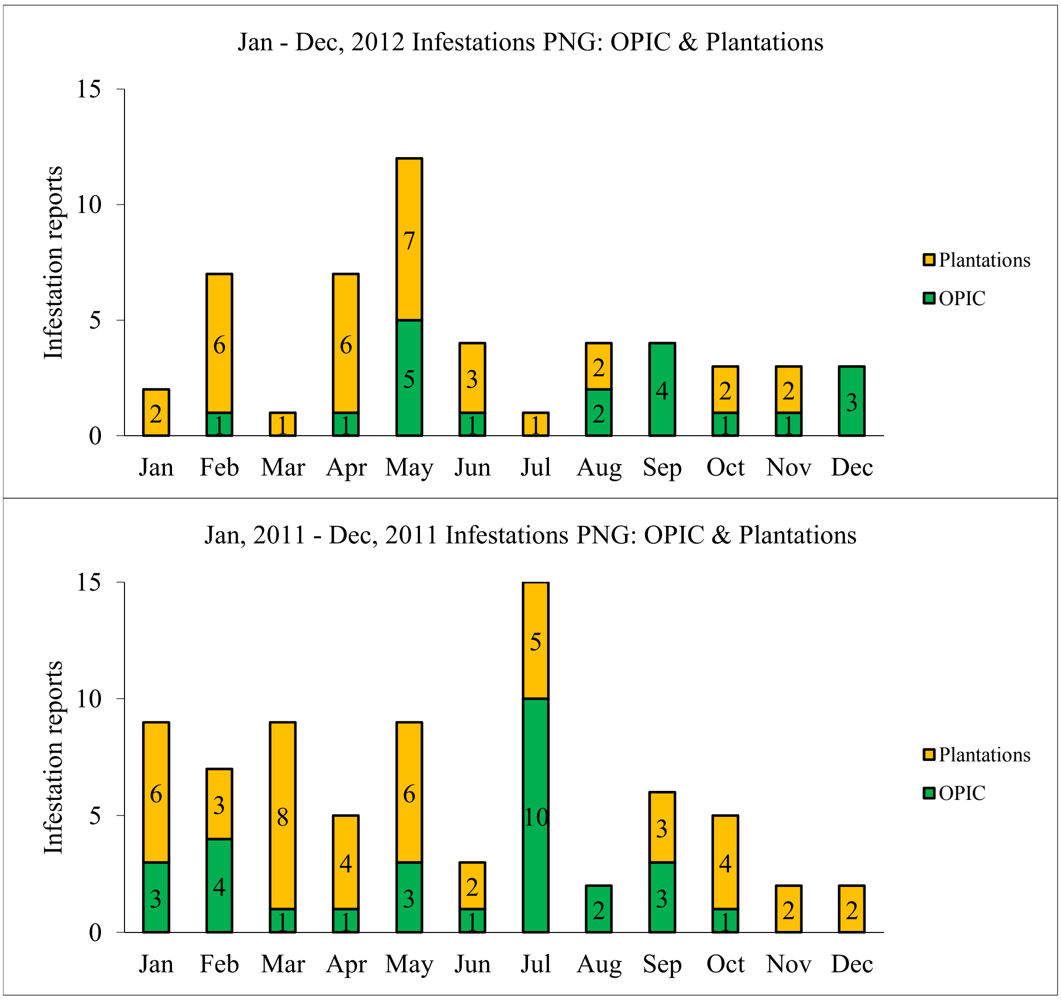


Figure 48 (i & ii). Pest infestation reports received from plantations and OPIC in 2012 (i) compared to reports received in 2011 (ii).

New Ireland

Seven (7) infestations of *Segestidea gracilis* were reported but only from plantations (Figure 46 [i]), a drop of 50% from 2011 (n=14) (Figure 46 [ii]). There were no reports from Smallholder blocks during the year, while Plantation pest activity remained low except for the months of April, June, August and October, when no pest reports were received.

West New Britain

Pest infestation reports from West New Britain (WNB) fell from the previous year (60 reports in 2011, to 43 this year a decrease of 28%) (Figure 49 [i & ii]). Of these reports, 19 (44%) were from smallholder growers and 24 (56%) were from plantations. West New Britain continues to report more frequent pest infestations than elsewhere, quite possibly due to the increased vigilance and effective reporting. Improved liaison with Smallholder Affairs (SHA) Department, and the regular meetings with OPIC made a great difference and brought improvement in the rapidity and efficacy of TTI.

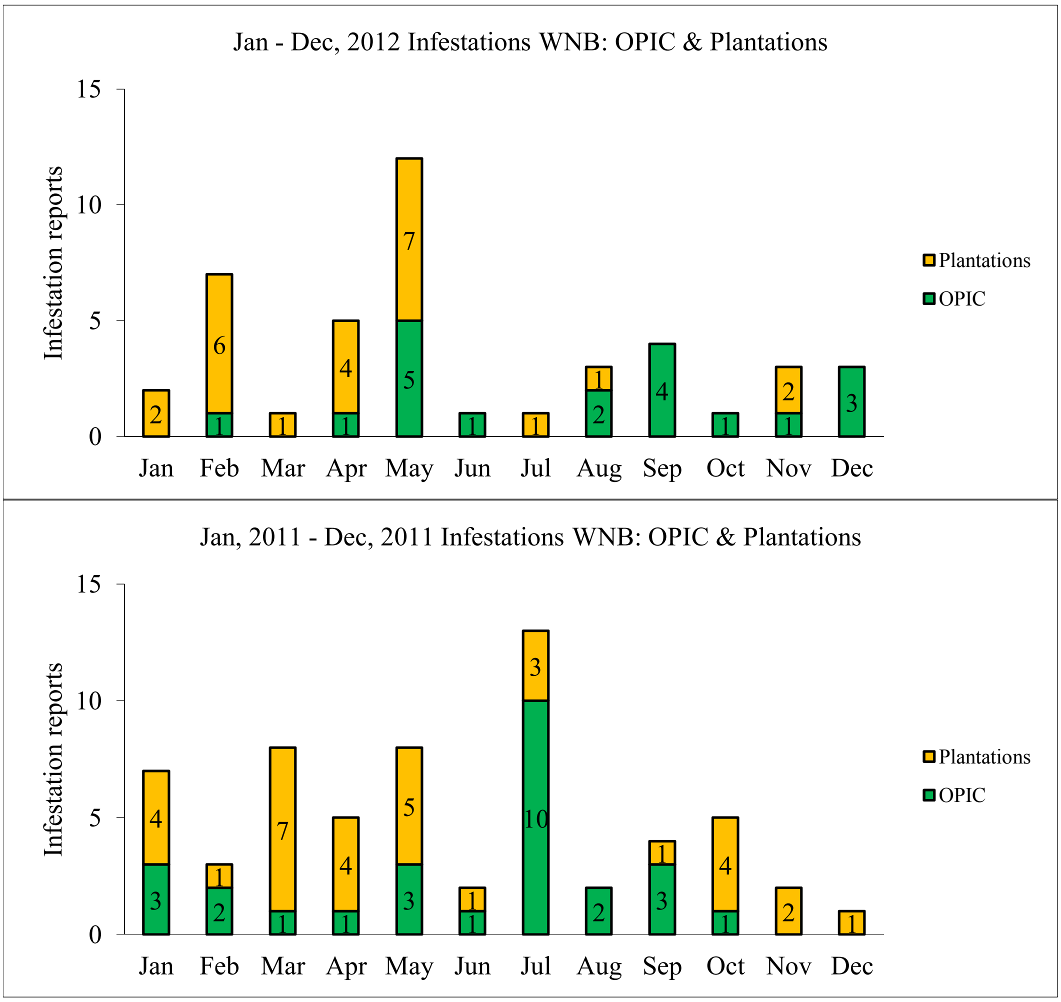


Figure 49 (i & ii). Pest infestation reports from plantations and OPIC for WNB in 2012 (i) compared with those received in 2011 (ii).

Mainland PNG:

Although there were no pest records from the mainland during 2012, routine monitoring of bagworms (*Manatha* sp. E and *Eumeta variegata* continued at Ambogo Estate (Higaturu), Northern Province. A detailed report is provided under Applied Research.

There were no reports of *Oryctes centaurus* during the year. Unconfirmed reports of sporadic attacks by *Papuana* sp., rats and weevils at Mamba Nursery were received. Similar attacks by a grasshopper (*Gastrimargus musicus*) (Plate 5) and the medium sized dark Cerambycid beetle (*Mulciber linnaei*) (Plate 4) was observed on replant palms at Embi Estate. Specimens are in the PNGOPRA collection.

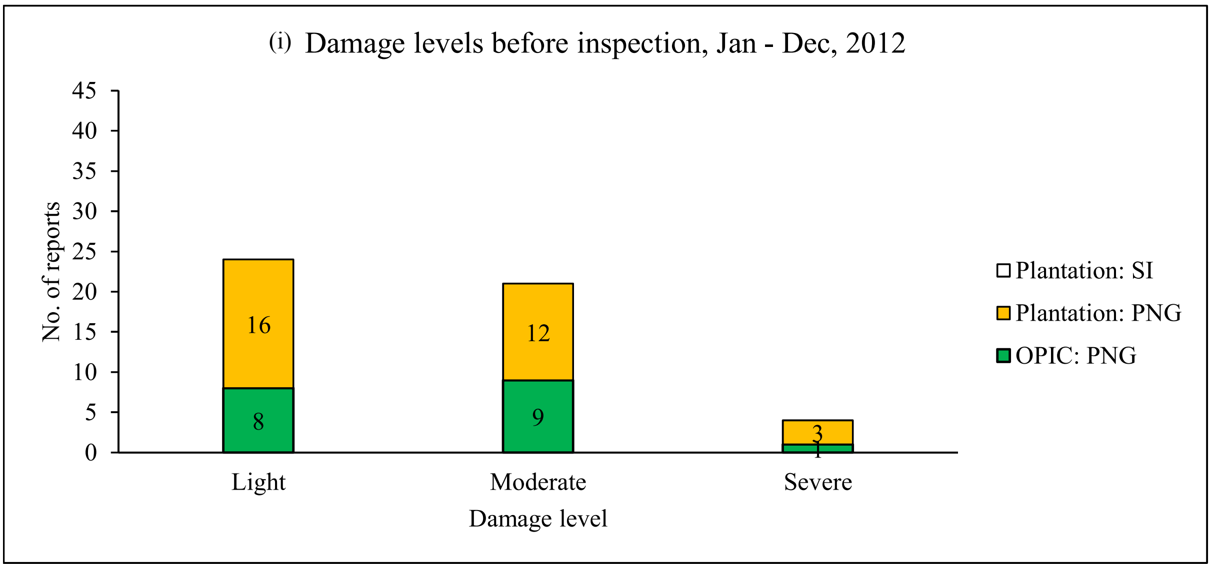
An unknown species of leaf miner was reported from Milne Bay Estates (MBE) in November 2011. It was monitored through in 2012 but no treatment intervention was required. Monitoring will continue in 2013, and its identity established. It is known to us a MBLM (Milne Bay leaf miner).

Solomon Islands:

Guadalcanal Plains Palm Oil Ltd (GPPOL). There were no pest reports received, although an unidentified Lepidoptera: Lymantriidae previously collected was found in very low numbers on oil palms again in 2012 (C. Pilotti, *pers. comm.*). Moths will be reared out and identified.

Pest Damage Levels, Management Recommendations and Targeted Trunk Injection (TTI) in 2012
(RSPO 4.5, 4.6, 8.1)

Where control intervention was required, this continued to be through Targeted Trunk Injection (TTI) using methamidophos. A new report form was introduced to encourage those responsible for control intervention (Divisional Managers from OPIC, Plantation Managers from Companies) to complete and return to PNGOPRA advising the start and completion dates for treatment operations. It is expected to be fully operational by 2013.
This new request form is in addition to MUD which was designed to track pesticide usage and movements only, and is provided as specifically requested to NBPOL Plantation Management. Reports of pests and all associated data are recorded, as they are received into the Pest Infestation Database (PID), maintained at the PNGOPRA Head Office, Dami. All infestation reports are routinely followed up in the field by entomology staff and PestRec reports outlining the management options are sent electronically to OPIC and Plantations, including TSD and management as required. The new form will also help improve on the reporting process.
More damage reports came from the plantations (31) than OPIC (18) in 2012 for PNG. No damage reports were received from SI (Figure 50 [i]). Light and Moderate damage levels, dropped from those reported in 2011. Light damage reports were lower by 36% (n = 12) for plantations and 33% (n = 17) for OPIC, whilst moderate damage reports dropped by 52% (n = 25) for plantations and 47% (n = 25) for OPIC. Severe damage reports remained at 3 in plantations and 1 for OPIC.



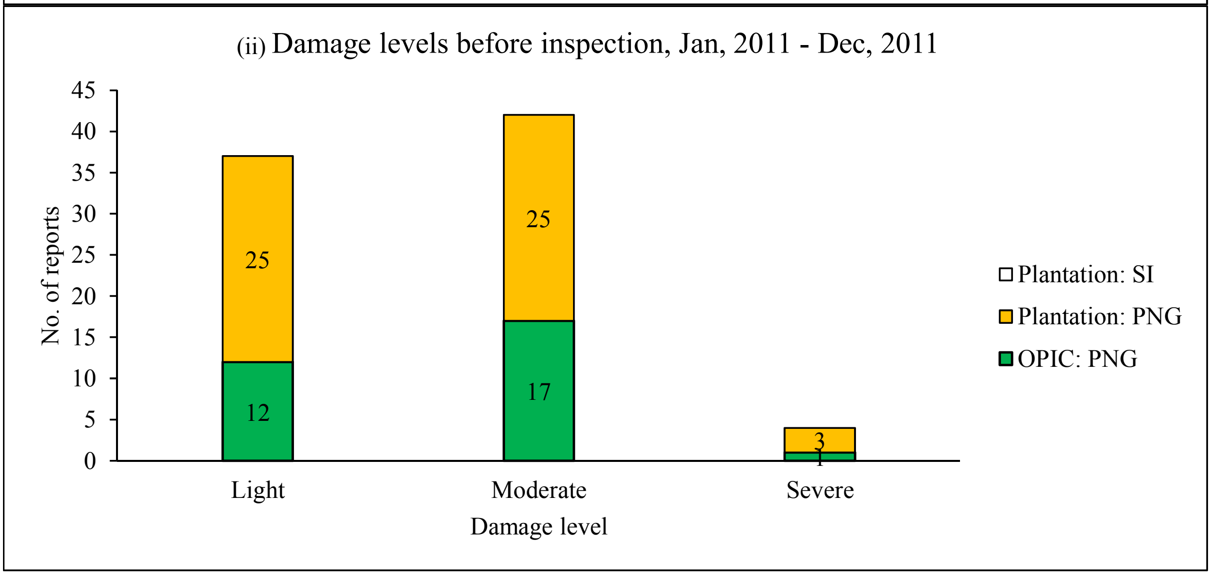


Figure 50 (i & ii). Pest damage reports received in 2012 (i) compared with pest damage reported in 2011

In 2012, 20 recommendations were sent to plantations recommending treatment (TTI) and 23 for monitoring, whilst for smallholder blocks 13 recommendations were sent recommending treatment and 14 for monitoring (Figure 51 [i]). Combined treatment (TTI) recommendation for plantation and OPIC in 2012 dropped by 41%, (n = 56) whilst monitoring recommendation dropped by 23% (n = 48) from the respective recommendations that were made in 2011 (Figure 51[ii]).
Handpicking is recommended when the host palms are deemed too small to be suitable for TTI, no handpicking recommendations were made in 2012. The reduction in the number of recommendations reflects effective monitoring and treatment programmes.
The number of overall recommendations were higher (plantations = 43, OPIC = 28) (Figure 51 [i]) than the number of pest infestation reports (plantations = 32, OPIC = 19) received (Figure 50 [i]), but this difference was due to some parts of plantations and smallholder blocks receiving recommendations for both monitoring and TTI.

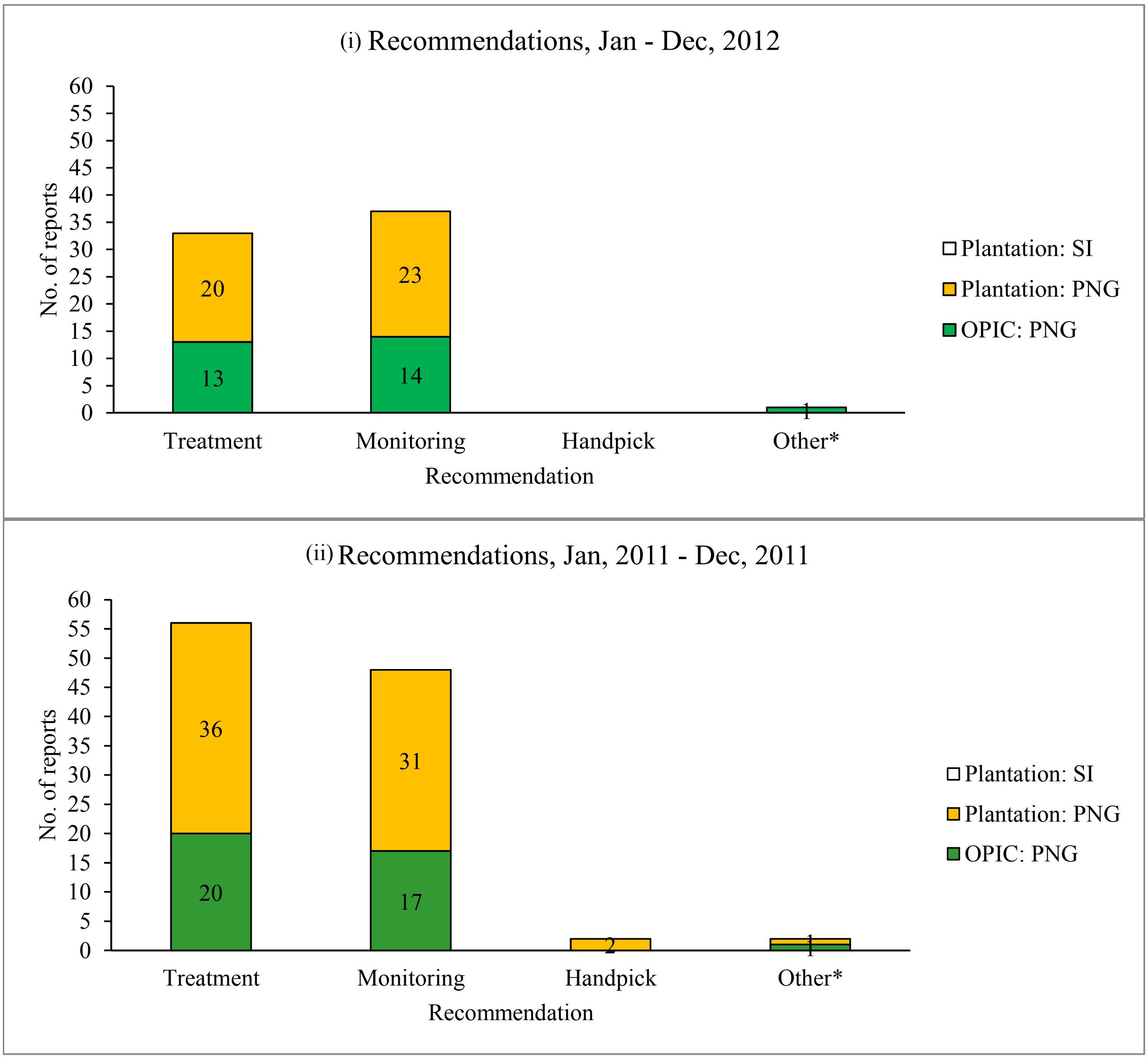


Figure 51 (i & ii). Recommendations sent to plantations and OPIC in 2012 (i) compared with recommendations sent out in 2011 (ii).

A smaller area[1] was treated for NBPOL plantations in WNB during 2012 (ca. 3000ha) than it was treated in 2011 (ca. 5000ha). Approximately 3,500L of methamidophos was applied during the year (2012) (Figure 52).
The area (ha) treated for smallholder blocks in WNB by the Smallholder Sexavae Treatment Team during 2012 was approximately 6,500ha. The volume (L) of methamidophos used was approximately 800L (Figure 53).
A larger area was treated for plantations (Figure 52) than for smallholder blocks (Figure 53).

[1] Area treated is an estimate as it will depend on the density of palms. Normally 128 palms/ha in plantations or 120 in smallholders blocks

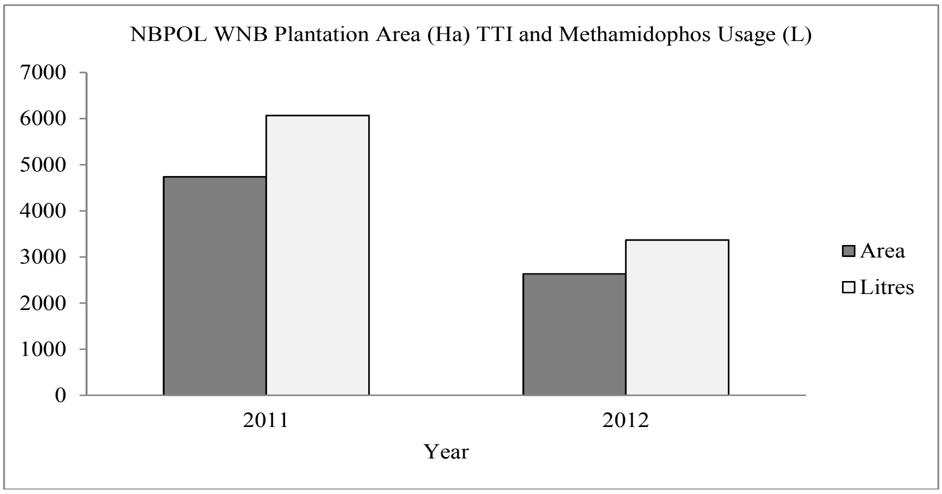


Figure 52. Area (ha) treated and volume (L) of methamidophos applied by NBPOL plantations in WNB in 2012. (Same information for 2011 is also provided for comparison).

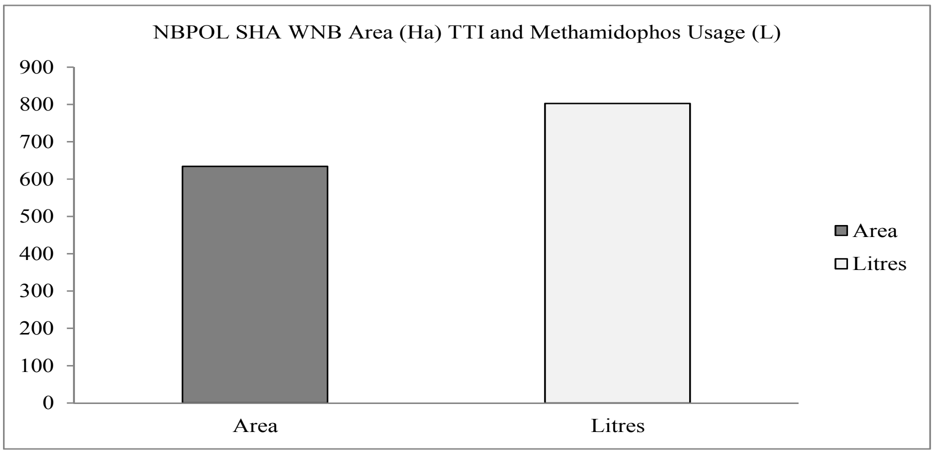


Figure 53. Smallholder block areas (ha) treated and volume (L) of methamidophos applied by the SHA Sexavae Treatment Team in WNB (Hoskins Project) in 2012.

In NI, the area treated (ca. 1,200ha) and the volume of methamidophos (ca. 1,800L) applied in 2012 remained about the same as those figures reported for 2011 (Figure 54). This result may be the same summary of an overlapping treatment programme between 2011 and 2012, as the number of infestation reports in 2012 (7) was half the number reported in 2011 (14). The figures that PNGOPRA Entomology Section routinely receives are summary figures rather than the daily treatment figures.

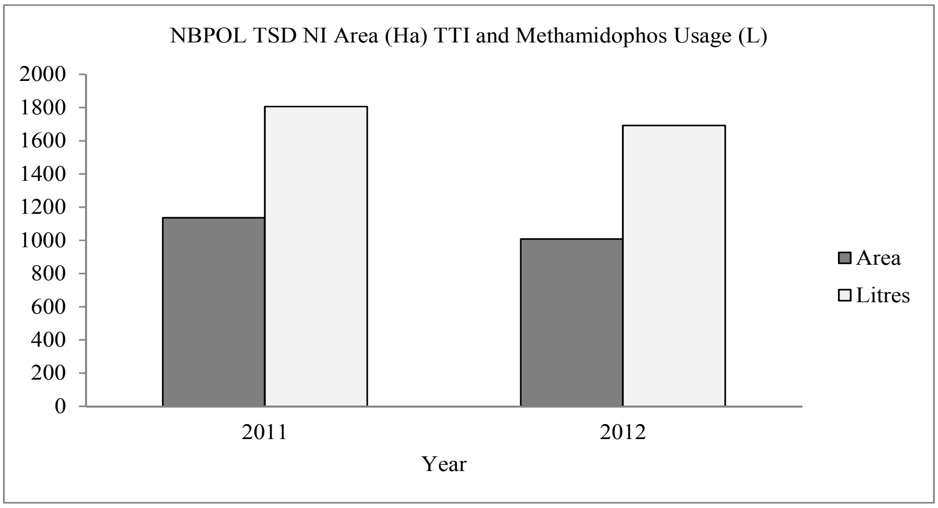


Figure 54. **Area (ha) treated and volume (L) of methamidophos applied by NBPOL, Poliamba in 2012. (Summary figures supplied by NBPOL TSD, Poliamba, NI).**

There was a slight drop in 2012 in the smallholder block areas (ha) treated at Bialla and the volume (L) of methamidophos applied compared to those in 2011. Approximately 580ha was treated and approximately 550L of methamidophos was used in 2012 (Figure 55Figure 54).

For Hargy Oil Palm, the area treated was approximately 800ha and the volume of methamidophos applied was approximately 840L in 2012 (Figure 55).

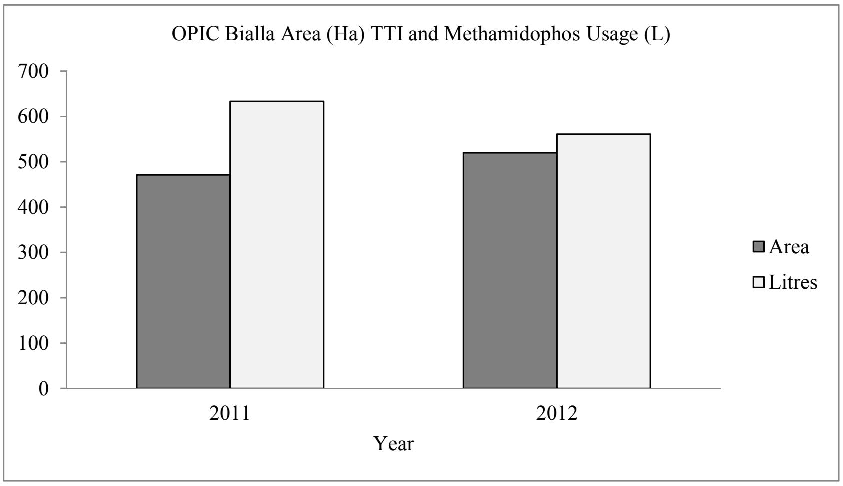


Figure 55. **Smallholder block areas (ha) treated and volume (L) of methamidophos applied at Bialla in 2012.**

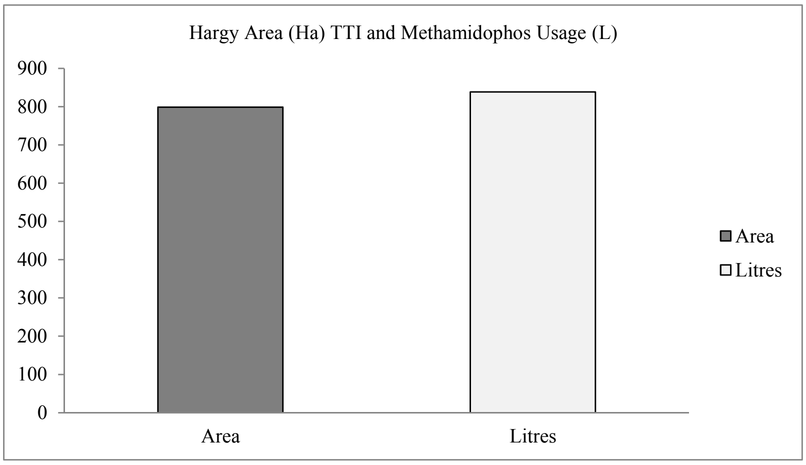


Figure 56. Area (ha) treated and volume (L) of methamidophos applied by Hary Oil Palms in 2012.

OTHER PEST REPORTS
RSPO(4.5, 8.1)

Lepidoptera

Noctuidae
Infestations by a noctuid moth (*Spodoptera litura* Fabricius) commonly known either as "leafworm" or "Cotton leafworm" was reported attacking leaflets of seedlings at Fileba Nursery near Poliamba, NI. Pheromone traps and pheromones were sourced from the Natural Resources Institute, Chatham, Kent, UK (Prof. David Hall) in 2011 and were first set up in the nursery on 4th August 2012. The traps were monitored daily throughout 2012 and trap data recorded. The number of moths trapped each month fluctuated during the year but dropped off completely in October. No more moths were trapped during the last quarter of the year. Trap monitoring will continue in 2013.

Lymantridae (Tussock moths)
No reports were received although larvae were collected from Milne Bay Estates (MBE), Hagita Nursery in November 2012 and adult moths reared. SI specimens were not successfully reared.

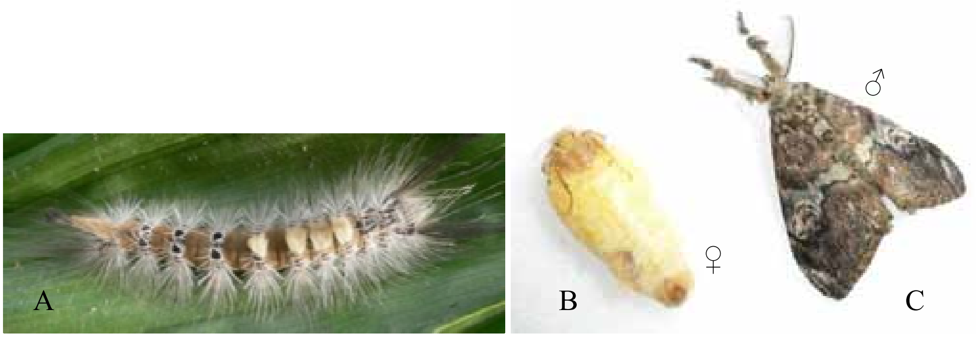


Plate 1. Larva (A), female (B) and male (C) of Lymantriidae moth (species to be identified, possibly *Olene* sp. or *Orgyia* sp.) (adult *id* Courtesy Dr Matthew Cock).

Peleopodidae (Xylorictidae) (Oil Palm Webworm)
There were no reports of the Oil Palm Webworm (*Acria* sp. nr. *emarginella*) received during the year.

Psychidae (bagworms)
There was a single report of the Rough Bagworm (RBW), *M. corbetti* attacking nursery palms at Bebere Nursery, WNB. Handpicking was recommended. Survey results of Smooth Bagworm (SBW) and Ice Cream Cone (ICC) sampling data from Ambogo Estate, Northern are presented under applied research.

Unknown leaf miner (Milne Bay Leaf Miner- MBLM)
An unknown leaf miner was reported from Milne Bay Estates (MBE) in November 2011. It was monitored through in 2012 but no treatment interventions were required. The pest will continue to be monitored in 2013. The species has not been identified as most attempts to rear them out in the lab failed. Efforts will be made in 2013 to rear them and identify this potential threat.

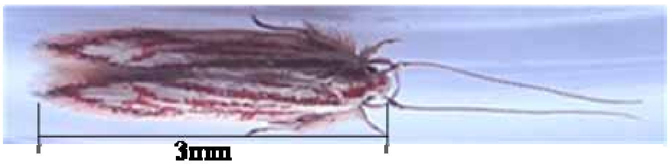


Plate 2. Milne Bay Leaf Miner (MBLM). Species still to be identified

Hemiptera

Lophopidae
No reports of *Zophiuma butawengi* (=*lobulata*) were received in 2012, and no progress was made on the establishment of mass rearing facility for *Zophiuma* parasites, however a larger externally funded research project for this and related studies with BCS will be prepared in 2013.

Coleoptera (rhinoceros beetles, weevils, white grubs)

Scarabaeidae

Dynastinae (Rhinoceros beetles)
Three (3) reports were received of rhinoceros beetles, one report for *O. rhinoceros* from NI (Lakurumau) and 2 reports of *S. australis* from WNB (one each from Kavui and Siki- smallholder blocks). Monitoring pheromone trap data for *O. rhinoceros* from Luburua (NI) is presented under Applied Research. There were no reports of *Oryctes centaurus* during the year. No progress was made with the attempts to send pupae over to the Natural Resources Institute in Kent, UK for further work on pheromone identification.

Papuana sp. (*woodlarkiana* or *hubneri*)

Plate 3. Male (A) and female (B) *Oryctes rhinoceros*. Male is smaller and has a long horn whilst female is larger and has a short horn.

A single report was received during 2012 from Mamba Estate, Northern Province (Kula Group-Higaturu) of *Papuana* sp. attacking nursery seedlings. Monitoring reports were not received.

Melolonthinae

Lepidiota reauleuxi
No reports were received during 2012.

Dermolepida spp. (Chaefer beetle)
There were no reports of damage by this complex of beetles during 2012, although beetles of this genus were often found on leaflets of oil palm. In 2011, J M Rowland (*pers. comm.*) suggested that the genus was in need of revision.

Cerambycidae (Longicorn beetle)
A single report of *Mulciber linnaei* attacking young palms at Embi Estate, Northern Province was received. The level of damage was not clearly established but past reports indicate it is a secondary pest.

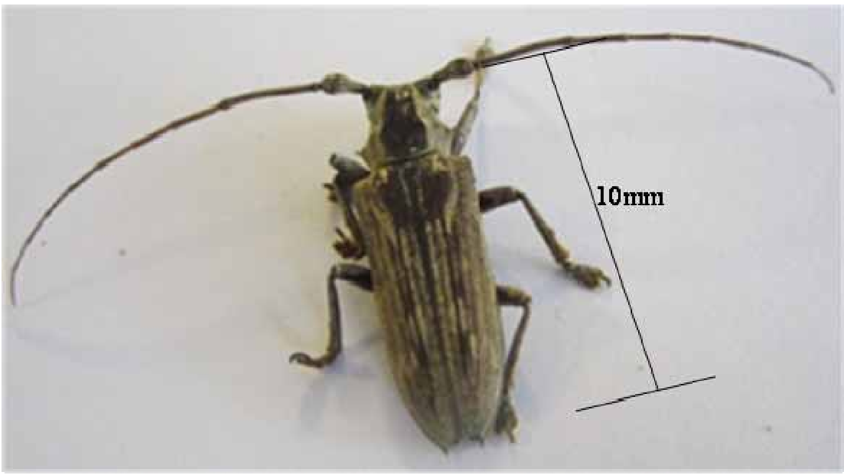


Plate 4. *Mulciber linnaei* Thoms. from Embi Estate, Higaturu Oil Palms, Northern Province

Curculionidae
A single unconfirmed report of weevils attacking seedlings at Mamba Nursery was received. The species has not been confirmed, as no specimens were provided but it is likely to be *Rhabdoscelus obscurus*. It will be confirmed as soon as specimens become available.

Diocalandra frumenti Marshall
No reports were received during 2012, although adults of this small weevil were frequently seen on cut frond-bases particularly at Navarai and Dami plantations.

Rhabdoscelus obscurus
No reports of the species attacking oil palm were received during 2012. There have been no further developments on the molecular analysis (DNA) work of the genus with the Natural History Museum (London, UK).

Rhynchophorus bilineatus (Black Palm Weevil)
This weevil was not reported as causing any damage during 2012.

Sparganobasis subcruciata
There were no reports of damage by the species in 2012. A paper describing this beetle has been published in the Australian Entomologist (Dewhurst & Pilotti 2012). Full reference of the paper is provided under publications.

Orthoptera

Acrididae

Austacris guttulosa (Australian Spur-throated Locust)
No reports were received in 2012. There was no further progress on the clearance process by DEC on the permit for the importation of the biopesticide that is used in Australia for the control of this species.

Gastrimargus sp. (musicus?)
A single report was received for the species to be attacking young palms (replant) at Embi Estate, Northern Province. The problem emerged as a result of inadequate cover crops within the replant area. The exposed sandy soil is used for egg-laying by the species and the emerging nymphs attacked the young replant palms. The problem dissipated once the cover crop developed.

Plate 5. Adult ♂ *Gastrimargus (?) musicus*. The hind wings have distinct bright yellow colour and black bands.

There were no reports of Giant African Snail attacking oil palm or cover crop (*Pueraria*/*Callopogonium* or *Mucuna*) during 2012.

Rodents and other Vertebrates

Rats
A single report was received on rats from Mamba Estate, Northern Province. Damage levels were low and no management intervention was required.

Other Vertebrates
No reports of other vertebrates were received during 2012.

WEEDS
(RSPO 4.5, 8.1)

Mikania micrantha (Mile a Minute Vine).
Releases of the biological control agent, *Puccinia spegazzini* (rust) was made under the ACIAR Project No. CP/2004/064. Follow-up surveys indicated that the rust was establishing in the field but the rate of suppression appeared very slow.

Sida rhombifolia (Broomstick):
This weed was cultivated in the green netting culture shade for bulking-up the biocontrol agent (Coleoptera: Chrysomelidae: *Calligrapha pantherina*). Targeted releases were made at two sites: Banaule- Kavui Division (n = 1,456) and Dire- Nahavio Division (n = 103) in 2012.

Eichornia crassipes (Water hyacinth):
Stock culture of the biological control agent (*Coleoptera: Bruchidae: Neochetina bruchi*) was maintained and targeted releases were made at three sites: Pasiloke- Nahavio Division (n = 43), Morokea- Nahavio Division (n = 20) and Buluma- Kavui Division (n = 52) in 2012. Host plants were collected from waterways in WNB as required to permit build-up of the weevil population.

Pistia stratiotes (Water lettuce):
The maintenance of the biological control agent (Coleoptera*:* Bruchidae*: Neohydronomus affinis*) inconsistent. The weevil numbers fluctuated and no releases were made in 2012.

DATA BASE OF THE FAUNA ON OIL PALM
(RSPO 4.5, 8.1)
One hundred and ninety eight (198) different taxa (including birds, mammals and reptiles) have been added to the Oil Palm Insect Database (OPID) (on PNGOPRA Entomology Drive) maintained at the Entomology Head Office, Dami. New information will be added as they become available. There are no other databases of oil palm related fauna in such detail available in the region.

ENDNOTE REFERENCE DATABASE (REPRINTS AND ABSTRACTS)
(RSPO 8.1)
The current number of reprints and abstracts references in the EndNote Database stands at 929. An increase of 54 records from the number of records reported in 2011 (875). This database is an important source of reference material for our work and up-dating is an on-going exercise. We are grateful to OPRS for access to the latest version of EndNote.

PEST INFESTATION DATABASE (PID)
(RSPO 4.1, 4.5, 8.1)
The original Microsoft Excel Spreadsheet format of PID was modified and the new form has been used. Outputs can be generated to cover aspects of infestation reports, pest taxa and infestation rates.

METHAMIDOPHOS USAGE DATABASE (MUD)
(RSPO 4.1, 4.5, 4.6, 8.1)
The Microsoft Access database was worked on but is not yet fully operational. It is pending input by the Information System Officer on the formatting and quality checking before it becomes fully operational.

SEED PRODUCTION UNIT (SPU) PEST MONITORING TRAPS
(RSPO 5.1, 8.1)
Pest monitoring traps at SPU were routinely monitored. No insect taxa of quarantine concern were identified.

APPLIED RESEARCH

Evaluation of alternative insecticides to methamidophos (Monitor®) for the control of sexavae and stick insects (ME, RD, EK)
(RSPO 4.5, 4.6, 8.1)

Introduction

Sexavae (Orthoptera: Tettigoniidae) and stick insects (Orthoptera: Phasmatidae) are serious pests of oil palm (*Elaeis guineensis* Jacq.) in PNG, particularly in WNB (PNGOPRA, 2010; Page, 2005). Both taxa damage the crop by eating the leaflets sometimes leaving only skeletonised fronds in severe cases. Foliage feeding reduces photosynthetic leaf surface area, resulting in reduced fresh fruit production (Page, 2005; Liau & Ahmad, 1995), and serious economic loss (Page & Dewhurst, 2010).

Currently, the only insecticide used through Targeted Trunk Injection (TTI) as part of the overall Integrated Pest Management (IPM) for sexavae and stick insect control on oil palm is Monitor®, a product with methamidophos (600g ai.) as an active ingredient. Methamidophos is an organophosphate (OP) and like many other organophosphate products, its use around the world has been restricted (Gosselin, 2006). Such restrictions impose a threat for a future ban on the product. It is therefore critical that alternative insecticides are tested against the pests and are recommended to the oil palm industry.

In 2012, two neonicotinoid insecticides (WHO Group 4A), second class nicotine derived insecticides were evaluated separately against Monitor®. The insecticides were Confidor® (imidacloprid as an active ingredient) and Actara® (thiamethoxam as an active ingredient). Confidor® is a soluble concentrate (200 SC) whilst Actara® is a wettable granule (250 WG).

Study procedure

The studies were conducted at Dami Research Station on six (6) year old Tenera palms. Females of field collected *S. decoratus* Redtenbacher (facultatively parthenogenetic species), and both males and females of *S. defoliaria* were used for the trials. These are the main pest species of sexavae on oil palm in WNB.

The standard TTI protocol outlined in Dewhurst (2006) was followed for insecticide application. Ten (10) ml of Monitor® and Actara® were applied whilst 30ml of Confidor® was applied. Thirty (30) ml of Confidor® was required to provide the equivalent of 6g active ingredient (the standard concentration used for Monitor®). Separate drench guns were used for the application of each insecticide.

Both field and laboratory bioassay feeding tests were carried out. For field feeding, the test sexavae were "bagged" on palms in the field using green shade net (as used in previous years), whilst for bioassay feeding, four (4) leaflets from each treated and control palms were collected every afternoon and fed to test insects kept in feeding cages held in screen house at the laboratory. The feeding cages were kept under ambient environmental conditions.

The trial was replicated 6 times for each treatment and cages contained 10 insects per palm.

Results

Feeding bioassay

Only field results for Confidor® evaluation are given however there were setbacks with laboratory bioassay study protocol which resulted in high insect mortality for all treatments including the untreated Control. The protocol was revised for a second study (Actara®), and the results from both studies are presented. Confidor® evaluation study was continued for 14 days whilst the Actara® study was continued for 27 days.

Percentage mortality of sexavae with time ("*time after TTI*") was used to evaluate the effectiveness of the insecticides against Monitor®. Percentage mortality in the insecticide treatments were corrected for natural mortality against untreated Control using the Abbott Correction Formula (Abbott, 1925).

In the trial evaluating the efficacy of Confidor®, and Monitor® 50% mortality was reached on Day 2 and 100 % mortality on Day 10, whilst Confidor® reached 50% mortality on Day 5 but did not give

100% mortality within the 14 days feeding period allowed (Figure 57). Earlier study on the same insecticide using 13.5ml did not give effective kill (PNGOPRA, 2004).
In the Actara® trial, both field feeding and laboratory bioassay trials attained 50% mortality on Day 4 for Monitor®. One hundred percent (100%) mortality was attained on Day 12 (Actara™) and Day 10 (Monitor) (Figure 58 & Figure 59).
Percentage mortality for Actara® remained <50% with the untreated Control throughout the 27 days of the trial (Figure 58 & Figure 59).

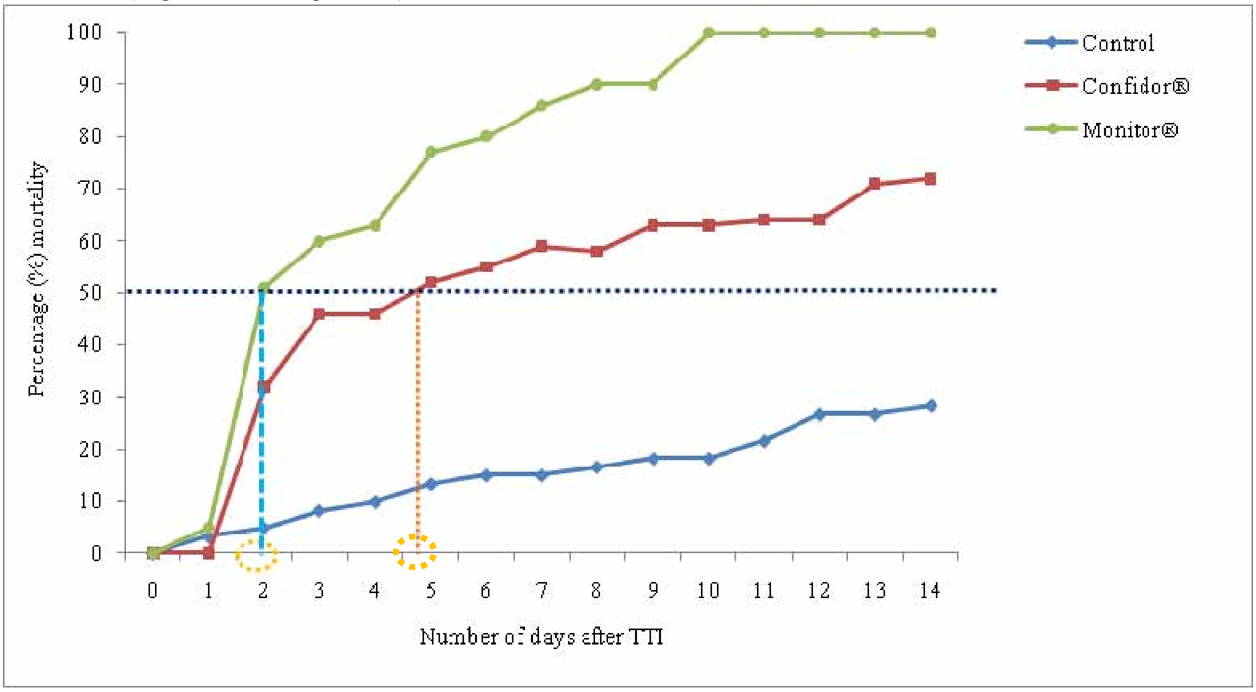


Figure 57. Percentage mortality of *S. decoratus* adult females for 14 days after targeted trunk injection (TTI) of Confidor® and Monitor® in the Confidor® evaluation trial (field feeding result).

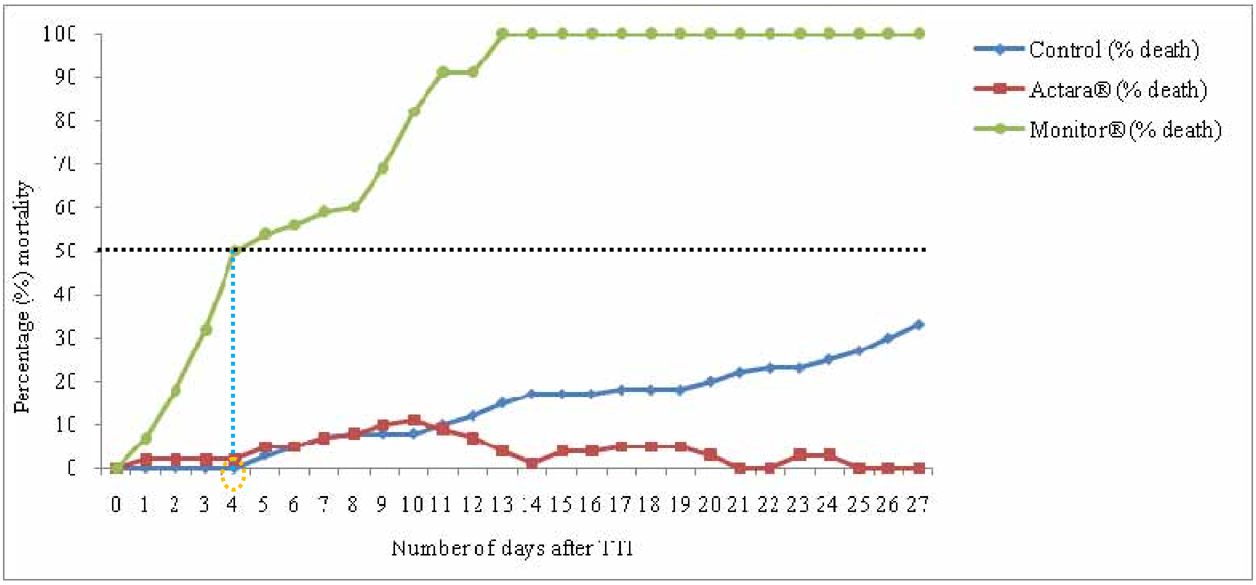


Figure 58. Percentage mortality of *S. defoliaria* adults over 27 days after targeted trunk injection (TTI) in the Actara® evaluation trial (field feeding result).

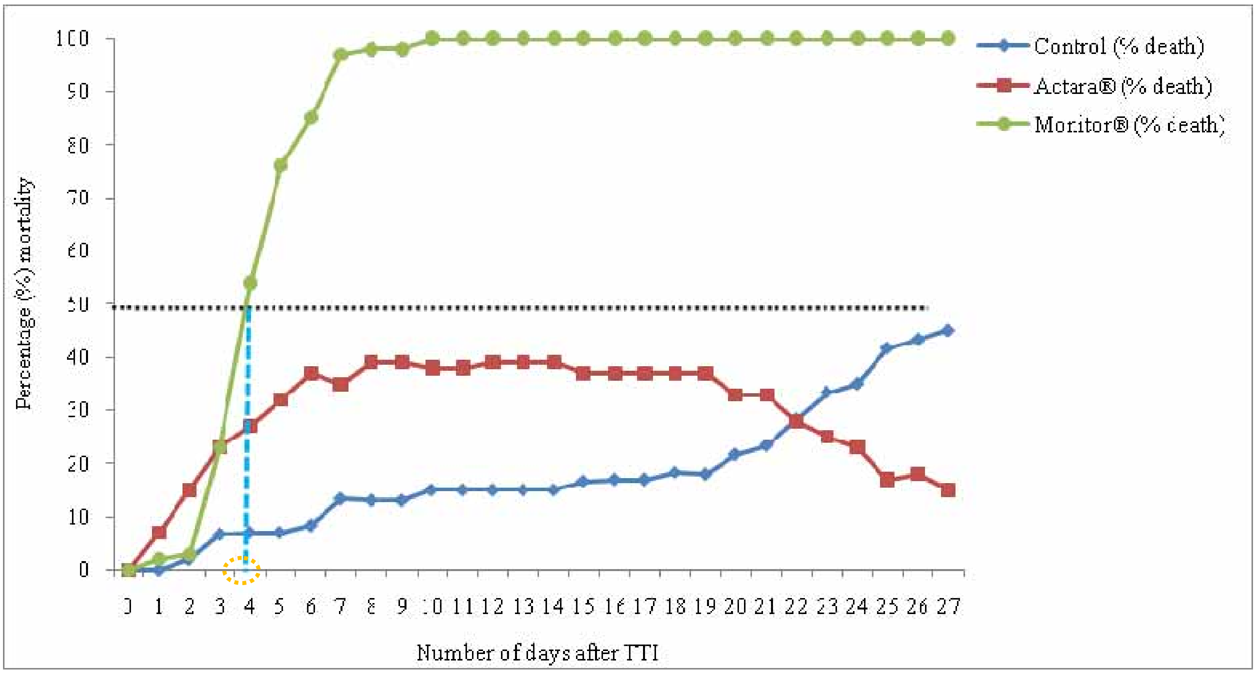


Figure 59. Percentage mortality of *S. defoliaria* adults for 27 days after targeted trunk injection (TTI) in the Actara® evaluation trial (bioassay feeding result).

Discussion and Conclusion

Confidor® killed test insects, but the effect was not as rapid as Monitor®. This delay will permit more damage to the palms as the insects continued to feed up until the time of death. High concentration of Confidor® may give a more rapid kill, but the use of higher concentration is not compatible with the current TTI protocol. Confidor® (200 SC) is therefore not as effective as Monitor® when used as a TTI process, and can not be recommended at these concentrations.

The granular formulation of Actara® was not effective against sexavae using TTI, but because this was as a wettable granule that required mixing for TTI a liquid formulation of Actara (thiamethoxam) will be tested as it may translocate more effectively than the dissolved granular formulation.

Additional insecticides including thiamethoxam-based liquid formulation insecticides will be evaluated in 2013.

Pheromone trapping of *Oryctes rhinoceros* L. (Rhinoceros beetle) in New Ireland Province (ME, EK, RD)

(RSPO 4.5, 8.1)

Background

Most of New Ireland Province is dominated by coconut plantations. Coconut palm is a major food source for *O. rhinoceros* larvae and infestation by this beetle in coconut in the Province has been recorded as early as 1952 (Bedford, 1976). Since oil palm is now grown adjacent to old abandoned coconut plantations, neglected coconut palms can create conducive breeding grounds for *O. rhinoceros*. It is therefore important that oil palms in replant blocks (new plantings) in the Province are regularly monitored for beetle attack. The pheromone trap programme was initiated after Rhinoceros beetle infestation was detected in overgrown seedlings at Fileba Nursery in 2011.

Study procedure

Single pheromone traps for *O. rhinoceros* beetles were set up at Maramakas and Baia plantations after *Oryctes* attack was detected on seedlings at Fileba Nursery. The traps were run from January to April, at which time it was decided that the number of beetles trapped was too low to warrant continuation of the trapping programme.

In March 2012, 8 pheromone traps were set up at the Luburua replant following reports of beetle damage on young palms in November 2011.
Two traps (trap numbers 1 & 6) were set up on 12/3/2013 and further 6 traps (trap numbers 2, 3, 4, 5, 7 & 8) were set up on 21 March 2013.
The traps were randomly put up in different blocks (T1= ABO 050, T2 = ABO 030, T3 = ABO 010, T4 = ABO 060, T5 & T8 = ABO 070, T6 & T7 = ABO 020) in the plantation. Figure 60 shows the locations of the trap and the block numbers.
The traps were checked daily, and the sexes of the beetles trapped determined and recorded. The number of beetles trapped and young palms damaged were high and the trap programme continued throughout 2012.

In June 2012, 30-40 females (depending on the number of beetles trapped) were randomly taken from traps 4, 5, 6 & 7 and dissected. The number of mature and immature eggs found was recorded to determine if any gravid females were trapped.

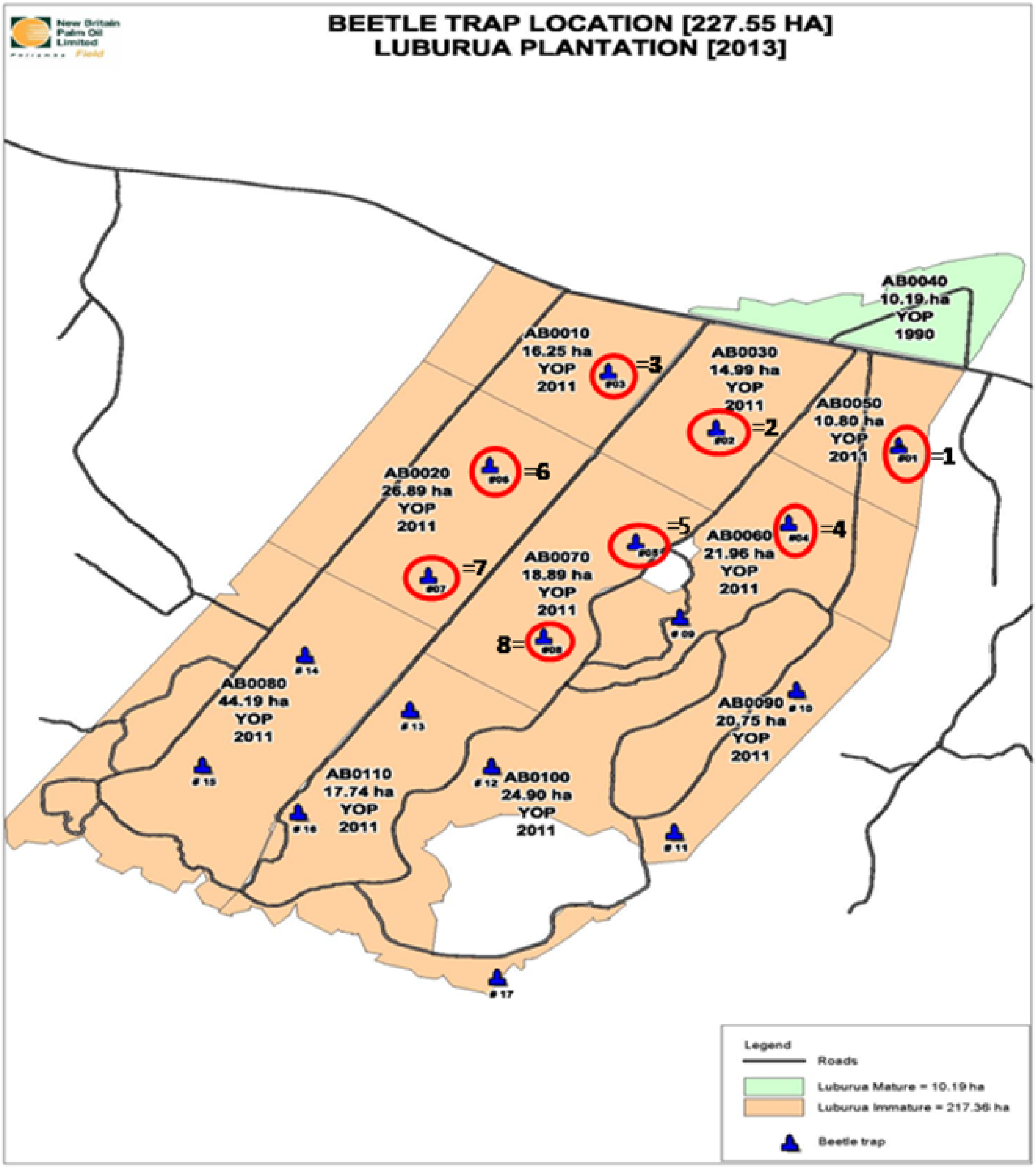


Figure 60. Map showing the number and locations of traps, and the block numbers. The pheromone traps that PNGOPRA monitors are marked in red (circled). The unmarked traps are monitored by the Technical Services Division (TSD) of NBPOL, Poliamba. (Map supplied by NBPOL, Poliamba).

Results

The number of Rhinoceros beetles trapped from Maramakas Plantation and Baia Plantation over four months (January to April) of trapping was low (Table 112). An average of 16 beetles per month was caught from Maramakas whilst 7 beetles per month were trapped from Baia.

Table 112. Number of *O. rhinoceros* caught in single pheromone traps from Maramakas and Baia over 4 months (January to April).

	Maramakas			**Baia**		
Month	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*
January	4	6	10	2	5	7
February	23	22	34	2	2	4
March	0	7	7	4	11	15
April	4	8	12	1	2	3
Overall Total	**20**	**43**	**63**	**9**	**20**	**29**

Females outnumbered males every month (male [9,728]: female [12,529] sex ratio = 1: 1.3) from the Luburua replant. Highest number of beetles was recorded during November and December. The mean number of beetles trapped per month was 2,150. The pheromones were losing their efficacy after 3 months (Figure 61).

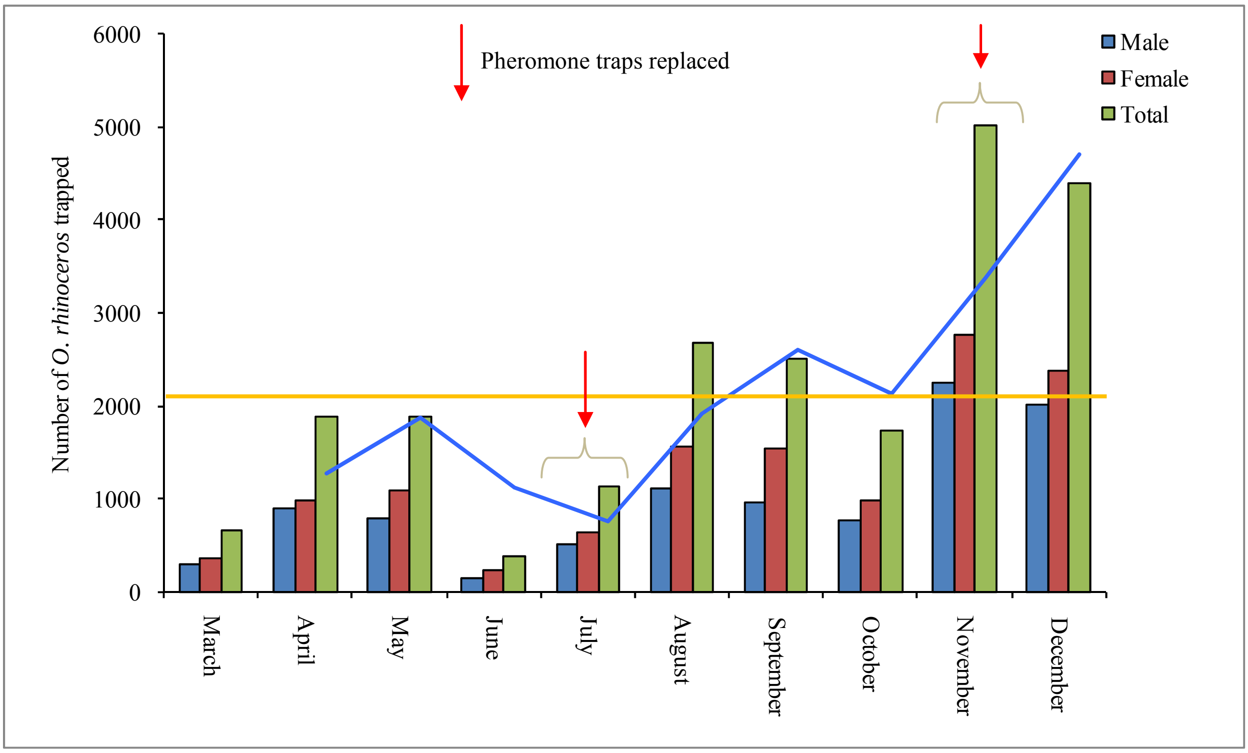


Figure 61. Number of male and female *Oryctes rhinoceros* trapped from the Luburua replant per month (9 months trapping).

The number of beetles trapped during the period (March to December) was 22,026 (Table 113). Between 2,000 and 3,400 beetles were caught in all traps except for Trap 1 that caught less than 2,000 beetles (1,691). In most of the traps, there was a drop in the number of beetles caught during June-July and October from Luburua replant. The number of beetles trapped increased once the pheromones were replaced.

Table 113. Number of *O. rhinoceros* beetles caught per pheromone trap from Luburua replant in 2012.

	T1	T2	T3	T4	T5	T6	T7	T8	Total
March	88	108	153	18	122	48	53	64	**654**
April	150	9	338	374	332	81	258	327	**1869**
May	69	58	237	306	109	197	284	472	**1732**
June	54	9	11	12	15	0	261	19	**381**
July	30	0	0	390	343	1	305	0	**1069**
August	40	238	262	570	453	367	419	330	**2679**
September	0	413	382	233	230	549	192	509	**2508**
October	0	358	331	0	0	505	0	545	**1739**
November	638	582	627	649	602	675	581	563	**4917**
December	622	470	491	545	565	656	576	553	**4478**
Total	**1691**	**2245**	**2832**	**3097**	**2771**	**3079**	**2929**	**3382**	**22026**

Coloured rows are months where there were noticeable drop in the number of beetles were trapped.

The percentage of young palms damaged by *O. rhinoceros* at the Luburua replant was 26% but all of the palms have recovered from the damage and are growing well. Fresh damage at the time of the census was only 0.41% (Table 114). None were reported to have been killed as a result of beetle attack,

Table 114. Number of palms in the monitored blocks at Luburua replant, and the percentages of palms damaged (but recovered) and the freshly damaged palms (Census done in January 2013).

Block No.	Trap No.	Total number of palms	% of palms damaged (but recovered)- Jan 2013 census	% of fresh palm damaged by *O. rhinoceros* (Jan 2013 census)
ABO010	3	2012	4 (566)*	0.08(11)*
ABO020	6 & 7	3408	8 (1045)*	0.29(40)*
ABO030	2	1890	1 (188)*	(0)*
ABO050	1	1204	3 (388)*	(0)*
ABO060	4	2856	5 (728)*	(0)*
ABO070	5 & 8	2400	5 (680)*	0.04(6)*
Total		**13770**	**26 (3595)***	**0.41(57)***

*(*The numbers in brackets are the actual figures).*

For the period where female dissection was done, more mature eggs were found than immature eggs (Figure 62). The highest numbers of mature eggs (3,988) were found in November. No dissection was done in October because no beetles were caught from sample traps, where female beetles were normally taken for egg dissection.

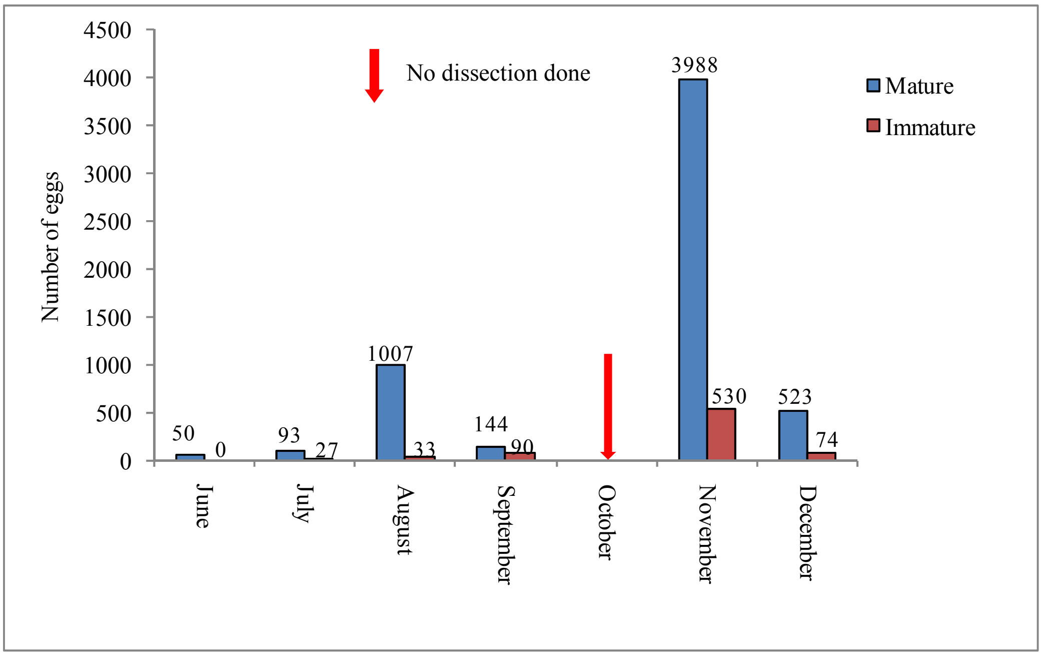


Figure 62. **Number of mature and immature eggs found in females taken from traps 4, 5, 6 and 7 and dissected (n = 443). No dissection was done in October as no beetles were caught in sample traps.**

Discussion and conclusion

Low numbers of *O. rhinoceros* beetles were trapped from Baia and Maramakas, but the plantations should continue to be monitored during future replanting as the trapping indicated that beetles are present within the area.

Whilst large numbers of young palms (3,595) at Luburua replant were damaged by *O. rhinoceros*, none of the damaged palms died. They all have recovered and are growing well. The damaged palms in these blocks will be monitored and throughout the production period yield data collected to assess the impact of the damage on fresh fruit bunch production.

Although the percentage of fresh palm damage was very low (0.41%), the number of beetles caught in pheromone traps remained high (22,026) implying that they may be entering the oil palm replant area from surrounding breeding reserves. With large neglected old coconut plantations surrounding the replant area it is likely that the beetles are breeding within the coconut plantations, as old abundant coconut plantations provide ideal breeding grounds for *Oryctes* beetles.

As a large number of gravid females were trapped (as shown by the dissection results), the population of will be reduced. Pheromone trapping has been employed as a tool for pest monitoring and mass trapping (Chung, 1997), and also used as part of *Oryctes* IPM programme in oil palm and coconut plantations (Ho, 1996; Kamarudin & Wahid, 2004).

The pheromone trapping programme and egg dissection will be continued into 2013. The potential for using the biological control agents *Metarrhizium anisopliae* and baculovirus as part of *Oryctes* IPM programme will be considered.

Oryctes rhinoceros is not currently of economic importance in oil palm in WNB or the mainland.

Psychidae (Bagworm) monitoring in Northern (Oro) Province (ME, SN)
(RSPO 4.5, 8.1)

Introduction

Monthly surveys of bagworms (*Eumeta variegata* [Smooth Bagworm] and *Manatha* sp. *E* [Ice Cream Cone Bagworm]) were conducted at Ambogo Estate in Northern Province. The survey began in 2010 and continued throughout 2011 and 2012. This is a regular monitoring survey following sporadic outbreaks of the pests within the Estate. *Manatha* sp.E: the scientific peer-reviewed paper on the bagworms of oil palm is still not published.

Survey procedure

A standard sampling method has been applied for the survey following a standard protocol: *the survey team walked through every 10th row and collected bagworm bags from fronds 17 and 25 of every 4th palm in each row* (10% sample). The bags were taken back to the laboratory and dissected, and the information on the contents of the bag recorded.

Results

Although there were inconsistencies in sampling, Figure 63 shows that the number of live *Manatha* sp. *E* recorded during survey increased in 2011 from 2010 but dropped in 2012 with the total number collected remaining below the average for most of the months. The total number of *Manatha* sp. *E* collected in 2012 (1,367) was lower than those collected in 2011 (2,432), and the number of live insects (1,367) collected was lower than the number of dead insects (1,414) collected (Table 115). The number of *E. variegata* bags collected in 2012 was well below the mean (Figure 64). No smooth bagworm bags were collected for most months in 2012, especially during the last 6 months of the year. The total number of live *E. variegata* collected in 2012 was 27 (Table 115).

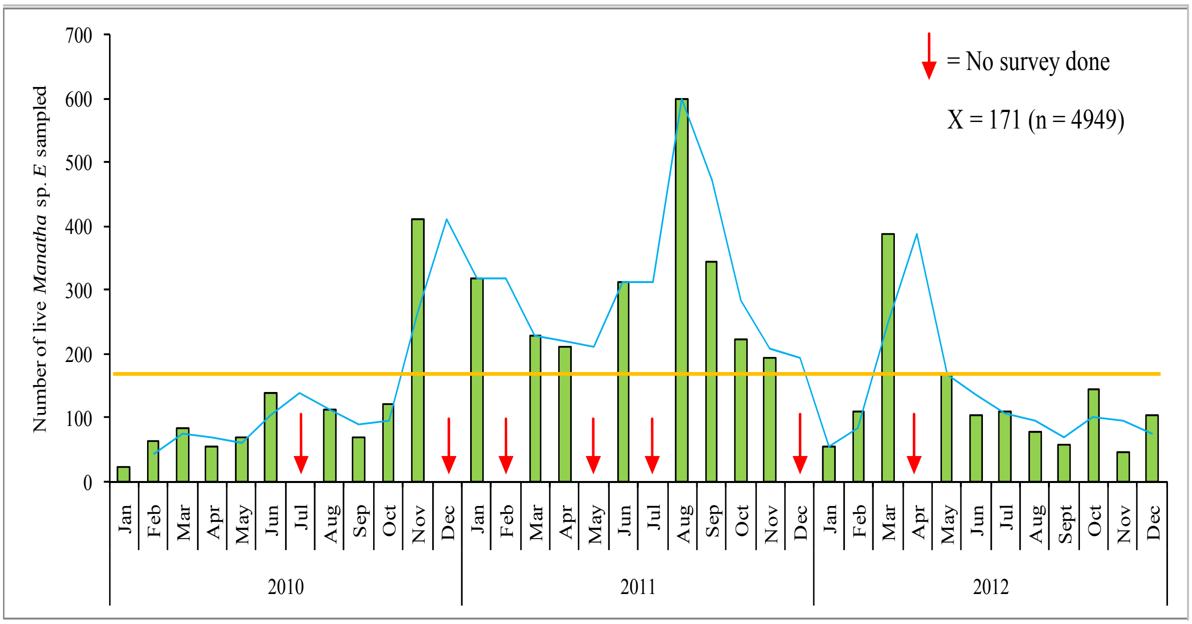


Figure 63. Comparison of total number of *Manatha* sp. *E* (= *conglacia*) sampled each month over three years (2010, 2011, 2012) (n = 4949, mean per month = 171). (No sampling was done in July and December for 2010, February, May, July and December for 2-11, and April for 2012).

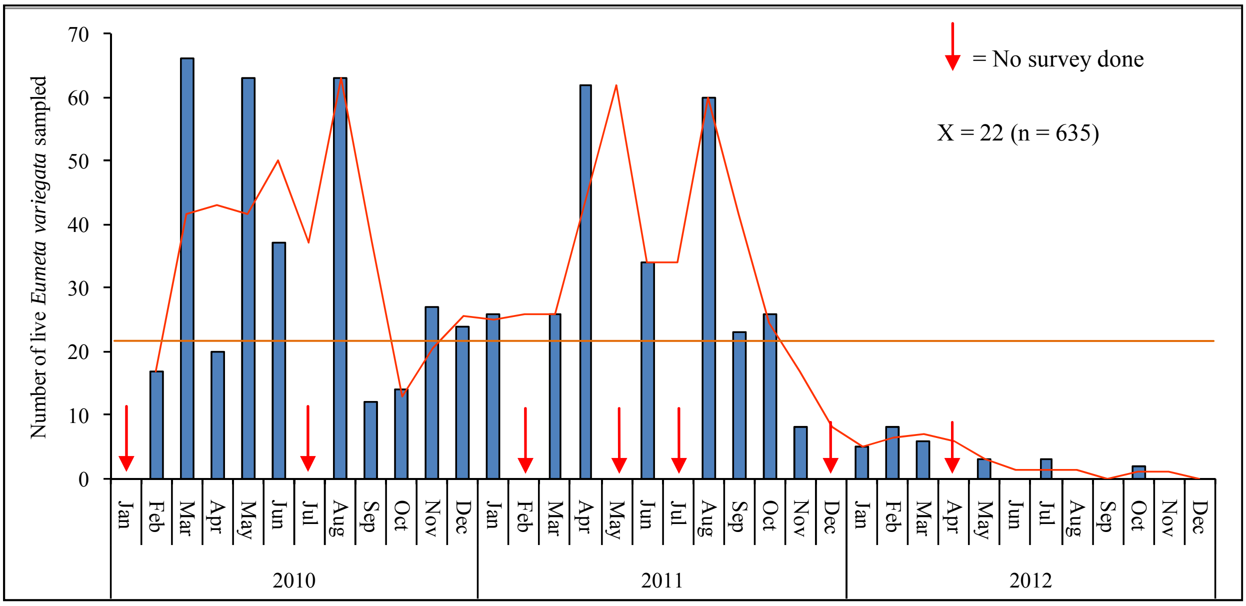


Figure 64. Comparison of total number of *Eumeta variegata* sampled each month over three years (2010, 2011, 2012) (n = 635, mean per month = 22). No sampling was done in January and July for 2010, February, May, July and December for 2011, and April for 2012.

Table 115. Total number (alive and dead) of *Manatha* sp. *E* and *Eumeta variegata* collected from Ambogo Estate, Northern Province. For comparison with samples from 2010, 2011 and 2012.

	E. variegata			*Manatha* sp. *E*		
	2010	**2011**	**2012**	**2010**	**2011**	**2012**
Number alive	343	265	27	1150	2432	1367
Number dead	45	41	21	540	1277	1414
Total	**388**	**306**	**48**	**1690**	**3709**	**2781**

Discussion and conclusion

The high number of dead Ice Cream Cone (ICC) bagworms collected compared with the live ones indicate that natural enemies may be keeping them in check. The numbers of bagworms have declined from 2011, there is therefore no need for any insecticide treatment (although it was recommended in 2011 Annual Report, when numbers increased significantly); nevertheless surveys will be continued in 2013.

The smooth bagworm numbers sampled declined in 2012 and will cease at the end of the year.

Further work is still required to identify the natural enemies responsible for mortality of both species.

The descriptive paper for the undescribed species of bagworms (with Peter Hättenschwiler, Switzerland) is still on-going and progressing slowly, due to the lack of suitable female pupae for descriptive purposes.

Sexavae (*S. decoratus* and *S. defoliaria*): Fecundity, Survival and Embryonic Development
(RSPO 4.5, 8.1)

Background
This study is the continuation from the fecundity and survival studies conducted in 2010 and 2011 but with increased sample size for one of the species. The increase in sample was necessary to improve the confidence level of the data. Information derived from detailed life history studies will enable us to make more informed decisions on the management of the pests.

Study Methodology
The trials were conducted separately for each species (*S. defoliaria* and *S. decoratus*) using laboratory reared adults. For *S. decoratus* (n = 30) recently fledged adults (a facultatively parthenogenetic species) were used, whilst for *S. defoliaria* (n = 10) freshly mated females were used. Mating in *S. defoliaria* was confirmed by the presence of the large spermatophore and spermatophalyx on the female.

The following parameters were obtained for each female:
POP= Pre-Oviposition Period (days): between fledging and oviposition for *S. decoratus*, and between mating and oviposition for *S. defoliaria*.
ELP= Egg Laying Period (days).
TEL= Total Eggs Laid
PELS= Post Egg Laying Survival (days)
LIFE= Number of days survived from fledging to death
Eggs laid by each species were collected and maintained in an outside rearing cage under ambient environmental conditions. Eggs laid on different days were kept in separate batches. After 7, 14, 21, 28, 42, 56, 70, 84, 98, 112 and 126 days from oviposition, representative samples 25 eggs were removed, weighed and dissected to determine the embryonic developmental stage.
The study was conducted between April and November. Results from the work done in 2010 and 2011 are included for comparison.

Results
For *S. decoratus*, all parameters measured across the three years (2010, 2011, and 2012) were similar although different sample sizes were used. POP, was 25 days longer in 2010 than it was in 2011 and 2012 studies (Figure 65). The mean POP, TEL, PELS and LIFE periods for *S. decoratus* from the 3 different studies were 43, 41, 7 and 86 days respectively. The mean number of total eggs laid (TEL) was 71 (Figure 66).
Similarly, the parameters measured also did not differ across the three years for *S. defoliaria* except for the total eggs laid (TEL) where there were notable differences between the 3 years (Figure 67). The mean POP, TEL, PELS and LIFE periods for *S. defoliaria* from the 3 different studies were 8, 30, 9 and 48 days respectively. The mean number of eggs laid (TEL) was 67 (Figure 68).

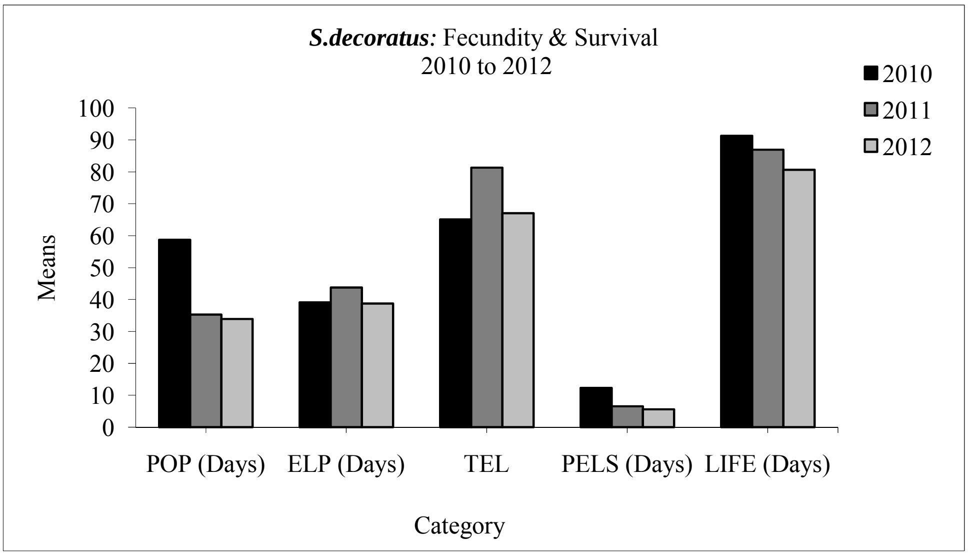


Figure 65. Mean POP, ELP, TEL, PELS and LIFE of *S. decoratus* for studies conducted in 2010 (n = 15), 2011(n = 20) and 2012(n = 30).

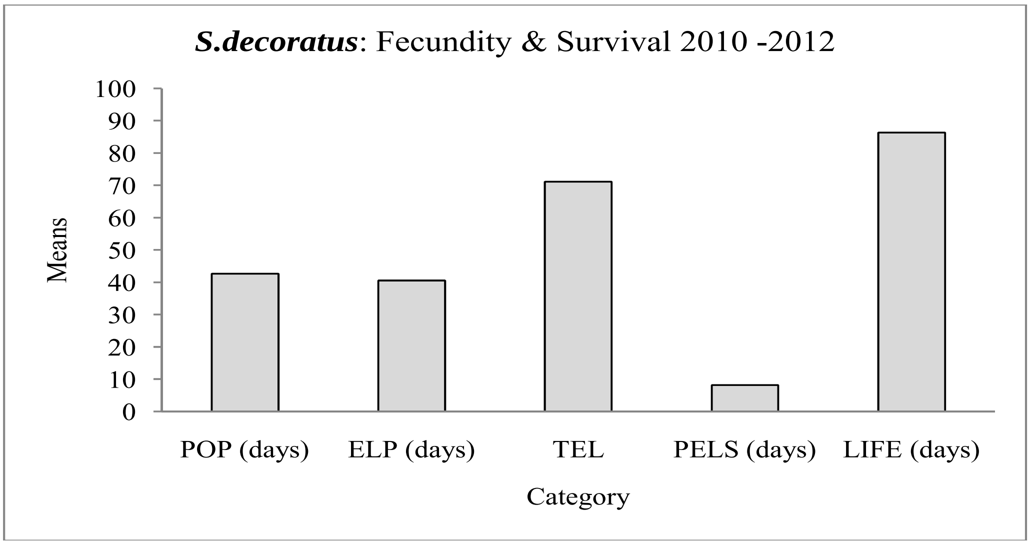


Figure 66. Combined means of POP, ELP, PELS and LIFE for the three (2010, 2011, 2012) studies for *S.* *decoratus* (n = 65).

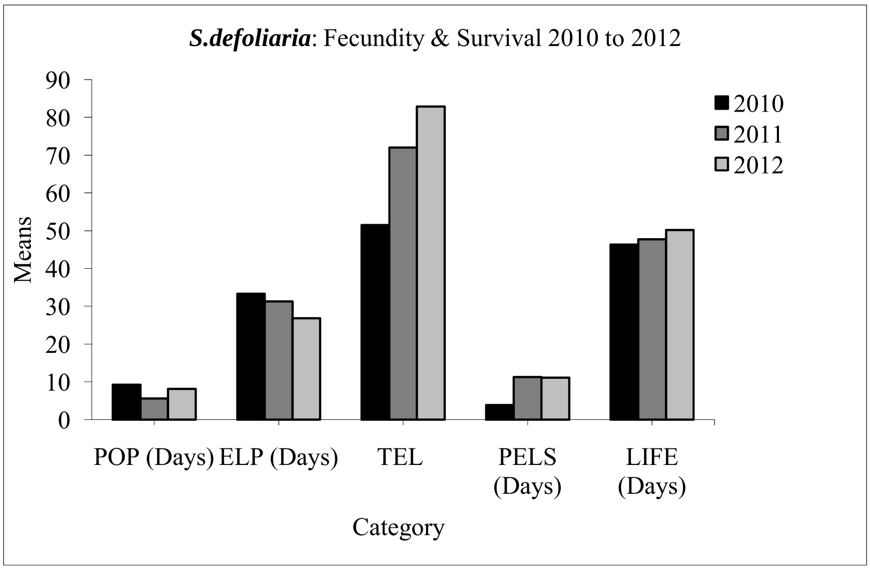


Figure 67. Mean POP, ELP, TEL, PELS and LIFE of *S. defoliaria* for studies conducted in 2010 (n = 10), 2011 (n = 7) and 2012 (n = 10).

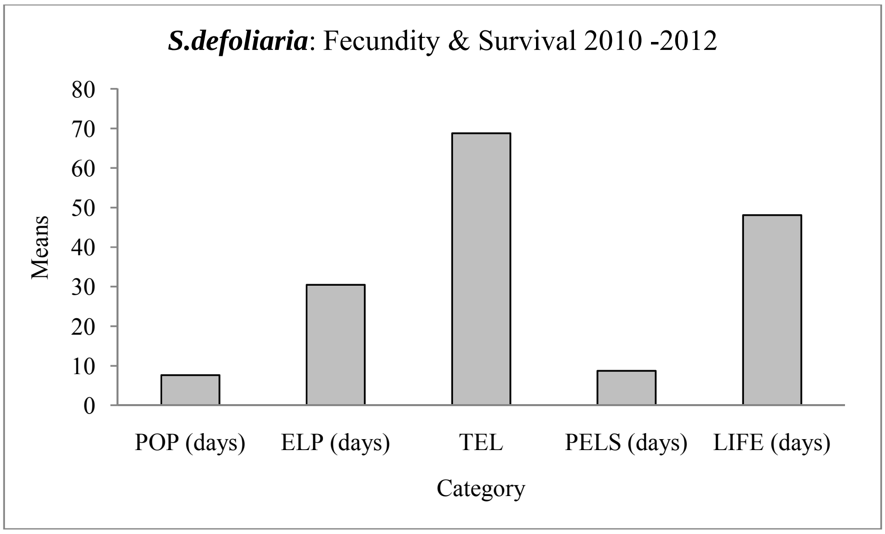


Figure 68. Combined means of POP, ELP, TEL, PELS and LIFE for the three (2010, 2011, 2012) studies for *S. defoliaria* (n = 27).

For *S. decoratus* most eggs were laid between 31-70 days (Figure 69), whilst for *S. defoliaria* it was between 11-20 days (Figure 70). *S. decoratus* had longer egg laying period ranging from 11 to 120 days, with the main laying period between 31-70 days (Figure 69); whilst for *S. defoliaria* egg laying started 5 days after mating (exclusive of the period between fledging to mating) and continued up to 100 days with most eggs laid between 11-20days (Figure 70), which makes both species very similar in this aspect.

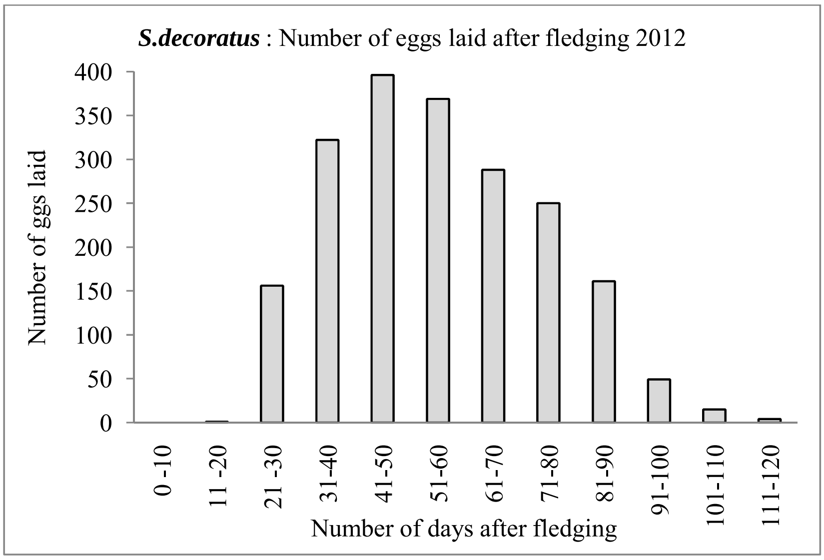


Figure 69. **Number of eggs laid by *S.decoratus* over time after fledging (n = 30).**

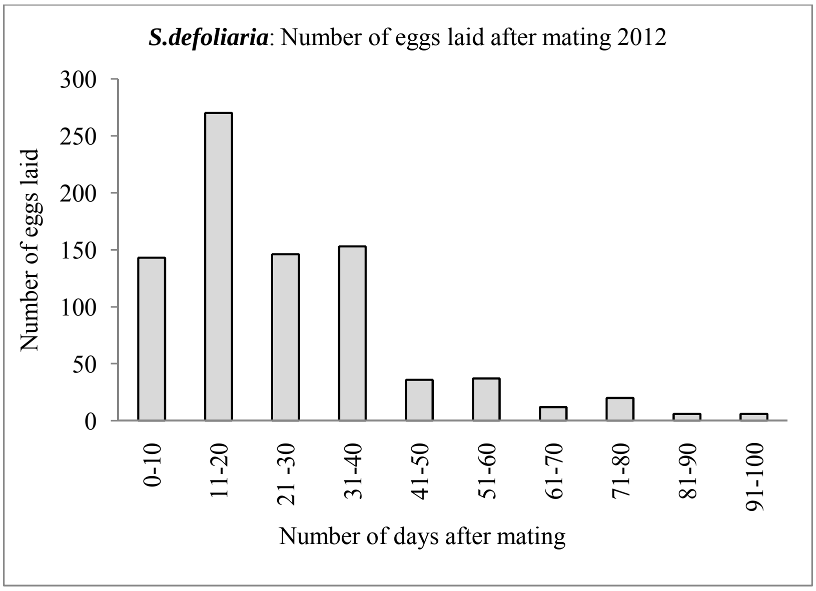


Figure 70. **Number of eggs laid by *S. defoliaria* after mating (n = 10).**

Embryonic development

In both species (*S. decoratus* and *S. defoliaria*), there was a progressive weight gain from one embryonic stage to another (Figure 71 & Figure 72), although the mean weight of *S. decoratus* eggs was greater at each stage than the mean weight of *S. defoliaria* eggs (Figures 33 & 34). The mean weight for *S. decoratus* eggs at embryonic stage 25 was 0.05g (Figure 71) whilst for *S. defoliaria* it was 0.04g (Figure 72).

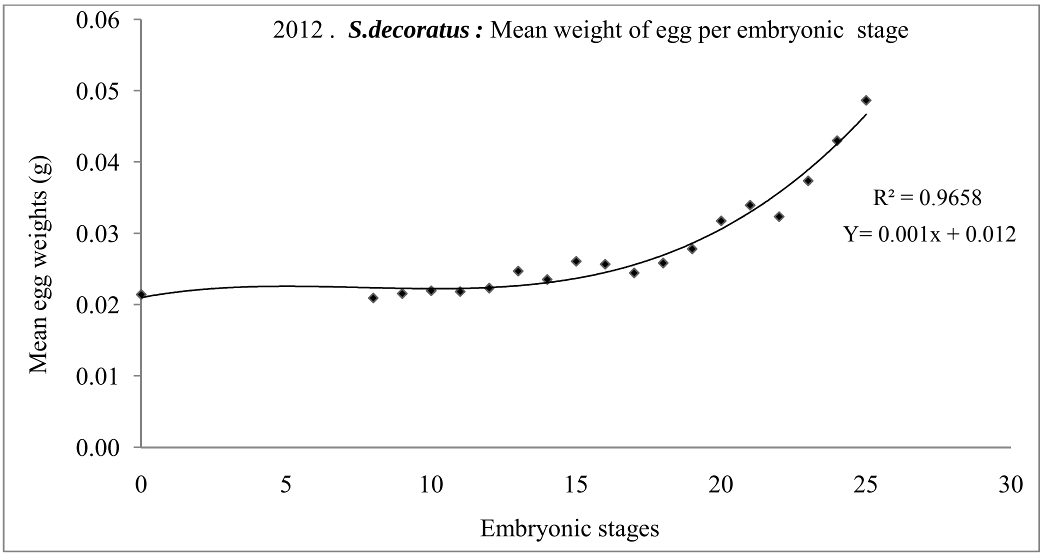


Figure 71. Mean weight (g) of *S.decoratus* eggs weighed against each embryonic stage (n= 819).

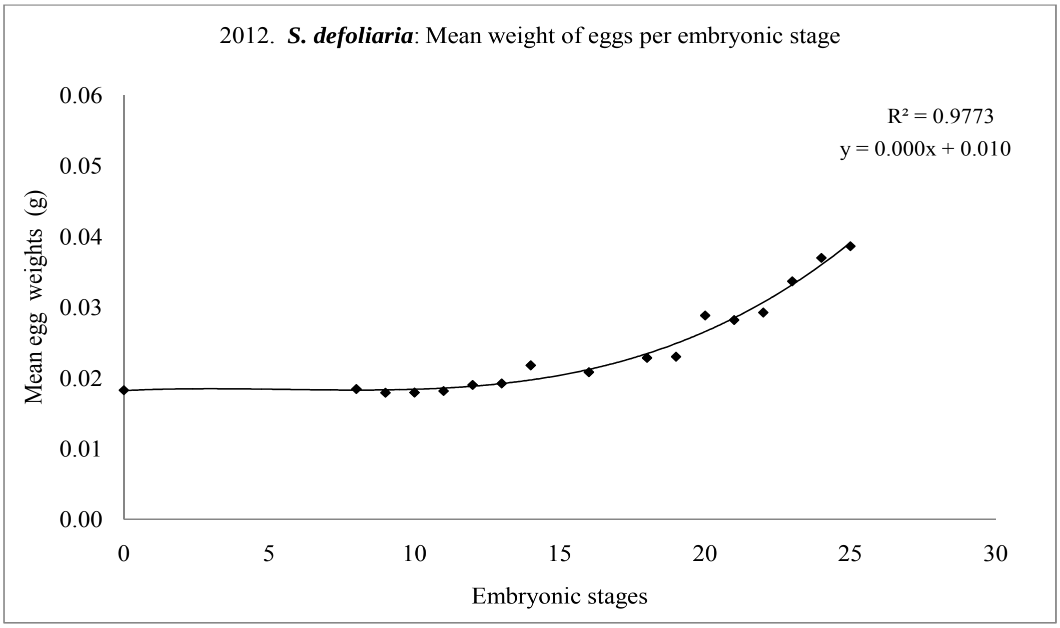


Figure 72. Mean weight (g) of *S. defoliaria* eggs weighed against each embryonic stage (n=643)

Discussion and conclusion

S. decoratus is larger and heavier than *S. defoliaria* and this is reflected in their longevity and fecundity. Interestingly, they do not survive as long as *S.defoliaria*. The reasons for the differences in the rest of the parameters remain to be determined. There is a strong relationship between egg weight and Embryonic stage (R^2=0.9773), and Stage 25 appears to be the last stage before hatching. The key issue then is how long is it before hatching once the key Stages are reached. Improvement on our understanding of the hatching predictions will influence TTI decisions.

Regular OPIC Sexavae Egg Sampling and Dissection Programmes for Monitoring: Siki and Buvussi Divisions of the Hoskins Project, WNB
(RSPO 4.5, 8.1)

Background
Sampling of pest eggs in the field is important for pest monitoring and for developing management plans. Sexavae eggs were sampled weekly from two OPIC Divisions (Buvussi and Siki) of the Hoskins Project throughout the year (2012) and provided to PNGOPRA at the weekly Pest meetings held at Nahavio HQ

Results
Almost double the number of eggs were sampled from Siki (n = 5,076) than the number of eggs collected from Buvussi (n = 2, 672), however a higher percentage of the eggs (approximately 80%) of the eggs were dead from Siki sampling. At both sites, there were more dead eggs than hatched and unhatched eggs. Number of dead eggs remained above 50% throughout the year except for September. The percentage of unhatched eggs remained below 10% for both sampling sites throughout the year. Peak hatching at both sites occurred in September with 60% of the eggs hatching. No eggs were sampled from Siki Division in November, towards the end of the year, the number of unhatched eggs began to increase (Figure 73 & Figure 74). The majority of eggs were *S.defoliaria*.

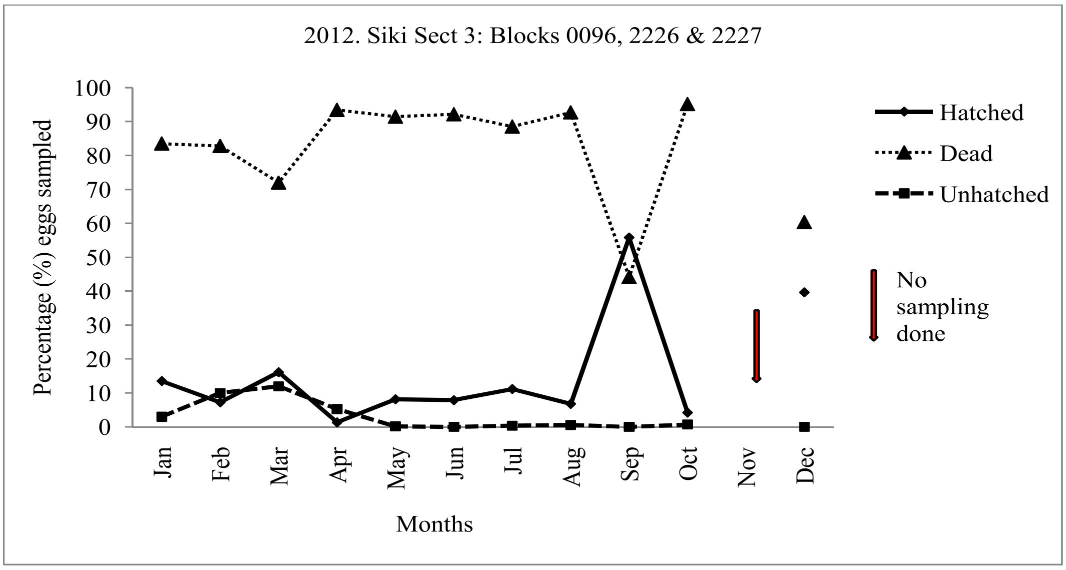


Figure 73. Regular OPIC egg sampling results from Siki (Section 3: blocks 0096, 2226, 2227) in 2012 (n = 5,076).

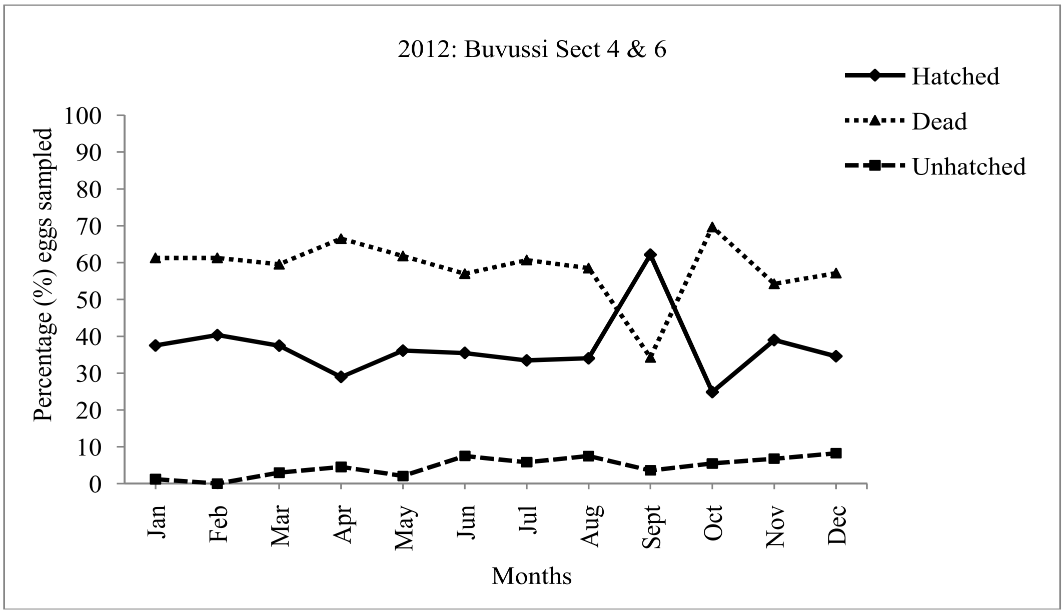


Figure 74. Regular OPIC egg sampling results from Buvussi (Section 4 & 6) in 2012 (n = 2,672).

Discussion and conclusion

At both sites, the percentage of unhatched eggs was low suggesting although towards the end of the year numbers increased, which may result in increased sexavae activity in 2013. The cause for the high percentage of dead eggs at both sites is not known, however it is likely to be due to control by natural enemies (predators and parasitoids). Sampling eggs at both sites will be continued in 2013..

Biological Control Agents Rearing and Releases

(RSPO 4.5, 8.1)

Background

As part of the on-going activity with Integrated Pest and Weed Management (IPWM) of the major pests & weeds, biological control agents are reared for release to suppress pest and weed numbers in oil palm growing areas, primarily in West New Britain (as most reports received are from WNB).

IPM activities for 2012 include rearing of sexavae (*Segestes decoratus, Segestidea defoliaria,S. gracilis*) and stick insect (*Eurycantha calcarata*) egg parasitoids, as well as a better understanding of the distribution and monitoring of the internal parasitoid of *S. defoliaria* (*Stichotrema dallatorreanum*) while continuing with attempts to introduce it into the WNB *S. decoratus*.

Biological control agents for weeds *(Sida rhombifolia*, *Eichornia crassipes* and *Pistia stratiotes*) are also reared in the lab and *ad hoc* releases are made. Other IWM work includes the chemical control of *Mimosa pigra*, and *ad hoc* monitoring of the impact of *Puccinia spegazzinii* the rust fungus as a control agent of *Mikania micrantha* in parts of WNBP.

Methodology

Parastitoid rearing

Adult sexavae were collected and placed into cages and were allowed to lay eggs in sand trays. Eggs were collected and set up in numbered jars. Emerging parasitoids were placed into the jars containing specific number of host eggs to be parasitized. After 14 days, a sample of 10% of the eggs were removed and put into a separate container for actual parasitism rates to be calculated. The remainder of the eggs were released in the field after having been contained in wire mesh bags.

Eurycantha calcarata egg parasitoids

Eggs from *E. calcarata* were collected weekly and set up in labelled jars and exposed to parasitoids. Emerging parasitoids were counted and recorded before being released into areas where stick insects occur. Males of *Anastatus* are fully winged, while females are apterous (lack wings).

Results

Anastatus sp. releases began in October 2011 and was on-going throughout 2012. Numbers released in 2011 & 2012 are given in Figure 75.

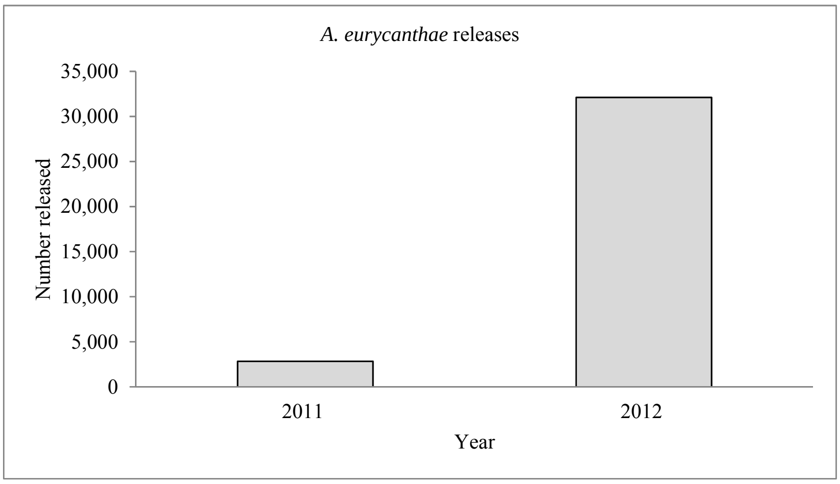


Figure 75. Numbers of *Anastatus* sp. released in 2011 and 2012.

The estimated *L. bicolor* (Hymenoptera: Encyrtidae) egg parasitoids of sexavae releases for 2012 were 987,264 compared to 719,770 in 2011 (Figure 76).

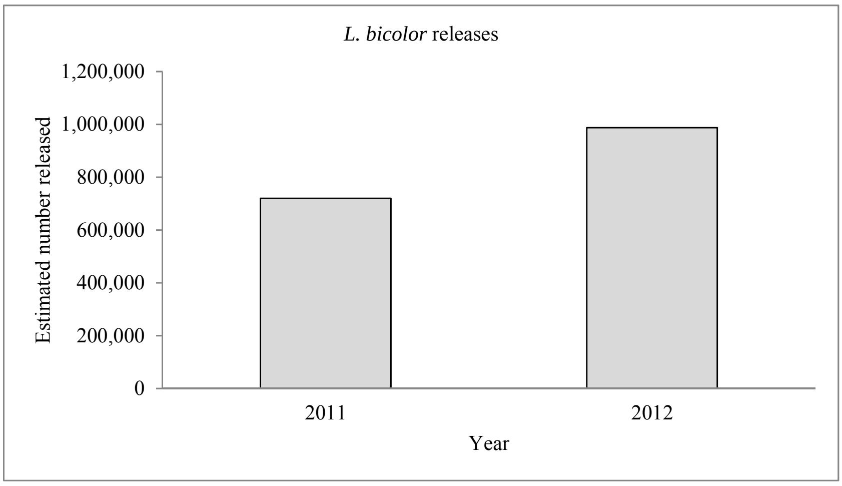


Figure 76. Estimated number of *L. bicolor* (Lb) released in 2011 and 2012.

Doirania leefmansi (Hymenoptera: Trichogrammatidae) rearing and field releases continued in 2012, but with lower numbers released. In 2011, the estimated cumulative releases of *D. leefmansi* were 4,081,939 compared to releasing only 739,776 parasitoids in 2012 (Figure 77).

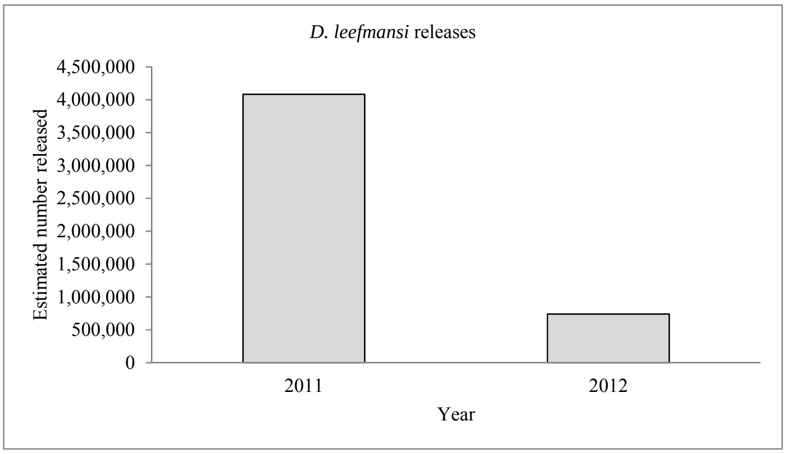


Figure 77. Estimated number of *D. leefmansi* (Dl) released in 2011 and 2012.

Stichotrema dallatorreanum rearing

Field collected adults of *S. defoliaria* were checked for the external presence of *S. dallatorreanum* and if showing signs they were placed into cages and monitored for the emergence of the of female 1st instar larvae. Only parasitised males of *S. defoliaria* were subsequently released into the field while the females were used to permit *S. dallatorreanum* to complete its life cycle, and for first instars to emerge and parasitize a new host. Three hundred and thirty-five (335) parasitised male *S.defoliaria* were released into the field as compared to 140 released in 2011 (Figure 78).

We still have not succeeded in establishing this parasitoid in *S. decoratus*. *Stichotrema dallatorreanum* from the Madang *S. decoratus* were also not reared successfully on *S. decoratus* from WNB, suggesting that the two spatially separated *S. decoratus* are genetically different. This aspect warrants further investigation.

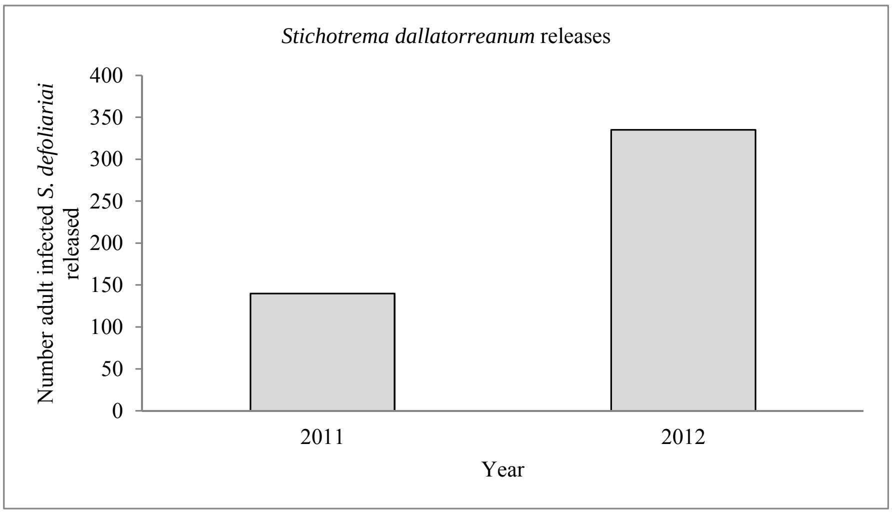


Figure 78. Number of *S. defoliaria* adult males infected with *S. dallatorreanum* released in 2011 and 2012.

Removal of Cane Toads from moat at office

Cane toads (*Bufo marinus*) continued to be collected from the moat surrounding the office, and euthanized. Total of 9,782 adults and many egg batches have been removed over the last 6 years.

Rodents

Rats (*Rattus* sp.) were a major constraint in our rearing programme during 2012 by entering the cages and eating the captive insects. This resulted in large losses of stock insects and eggs. There are plans for rodent-proof surrounding for the cages.

Discussion

In 2013 we aim to improve the laboratory rearing of parasitoids. Areas for releases of each biological control agent have been identified and will be scheduled for visits in 2013.

Doirania leefmansi population in the laboratory collapsed 3 times during the year, and was replaced with wild collected stock. Parasitoid rearing work was severely disrupted by new building works at the laboratory, which is expected to be completed in early 2013.

Work with rearing and release of the recently described stick insect egg parasitoid *A. eurycanthae* (Hymenoptera: Eupelmidae) (Gibson, 2012) continued, as host material was readily available in WNB. Our field work was disrupted on a number of occasions by local unrest in the area where wild stock was normally collected.

The rearing of bio-control agents of weeds continued with releases being made on an *ad hoc* basis. The rust fungus *P. spegazzinii* was widely distributed but was not effective in controlling *M. micrantha* where it was found. Impact is likely to take time before it becomes noticeable (M. Day, *pers. comm.*).

Galls produced by the Gall Fly, *Ceccidochares connexa* (Diptera: Tephritidae) in Siam Weed (*Chromolaena odorara*) were well established and there is a noticeable effect with reduced flowering, although the weed is still widespread.

Field Monitoring of Pollinating Weevil (*Elaeidobius kamerunicus*)

(RSPO 8.1)

Background

Strong pollinating weevil numbers are required in the field for successful pollination of oil palm. Effective pollination is essential for fresh fruit bunch production. It is therefore important that regular monitoring of weevil populations is conducted.

Study procedure

Male inflorescences (single male flower bunch from single palm) were collected monthly from two different sites (Dami and Galewale-Hoskins) to monitor the weevil populations. Samples of spikelets were removed from the base, middle and top sections of the large male inflorescence and set up in the laboratory. Emerging weevils were counted and sexed before being entered to the spreadsheet to estimate the total weevil population per male inflorescence and thence these figures are further extrapolated to estimate numbers per hectare.

Results

At both sites, there was no correlation found between weevil numbers and rainfall (Figure 75 & Figure 76).

The number of weevils sampled fluctuated during both years (2011 and 2012) for both sites. At Dami, the numbers were high during the first quarter (Jan – Apr) but were lower during the second quarter and picked up again in the last quarter (December) (Figure 79). There was no clear pattern for Galewale VOP samples (Figure 80).

For the total number of weevils sampled, more weevils were reared from Galewale spikelets in 2011, and in 2012 samples, more weevils were reared from Dami spikelets (Figure 81).

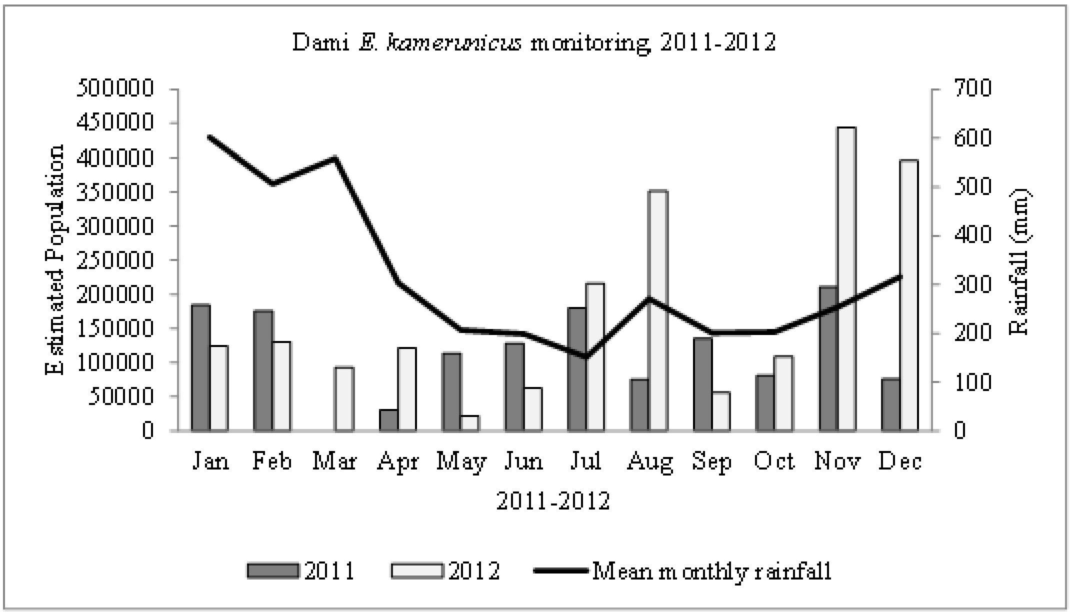


Figure 79. Number of pollinating weevils sampled each month from Dami in 2011 and 2012 plotted against the average monthly rainfall.

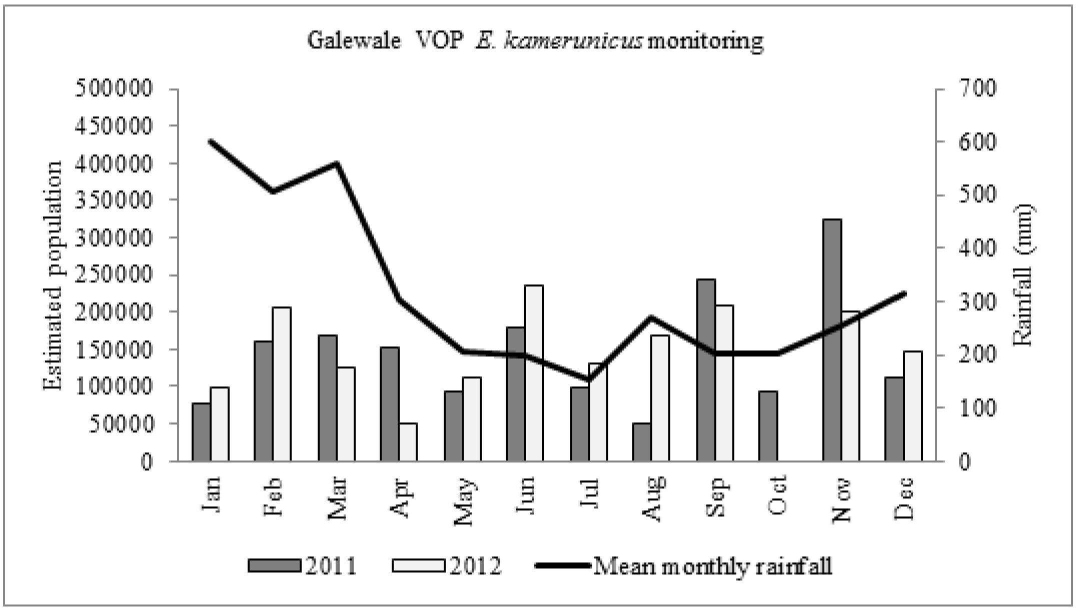


Figure 80. Number of pollinating weevils sampled each month from Galewale VOP in 2011 and 2012 plotted against the average rainfall.

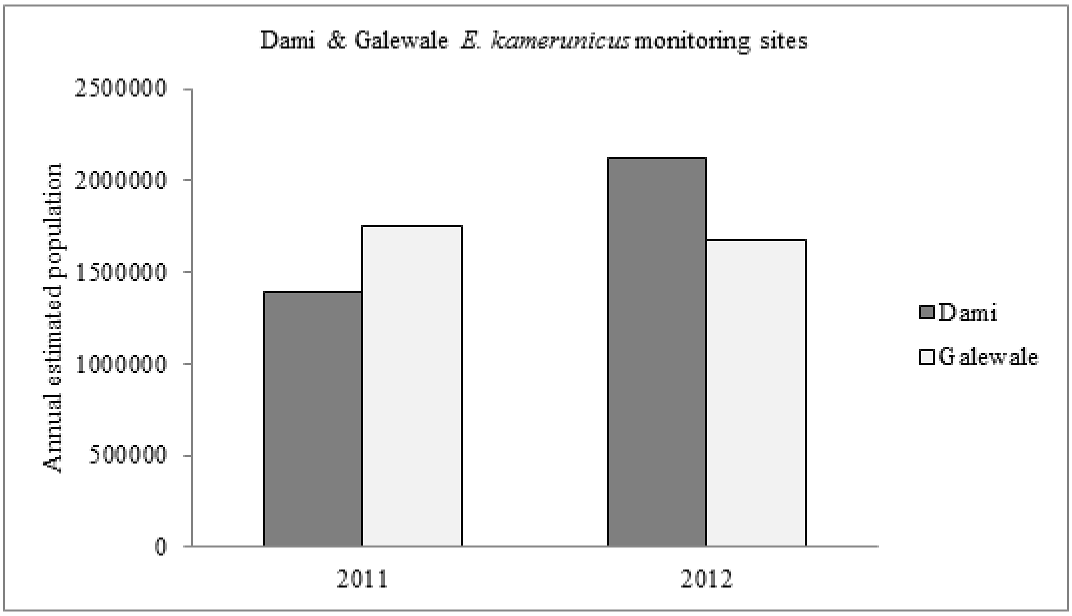


Figure 81. Total number of weevils sampled in 2011 and 2012 from Dami and Galewale VOP.

Discussion and conclusion

The estimated monthly pollinating weevil populations sampled from both sites were high, and remained within close range of the numbers estimated to be required (200,000 per hectare) for successful pollination. The sampling of weevils at these sites will be continued in 2013.

Arthropod Survey Program for Stream Health Monitoring (Smallholder Agricultural Development Project- SADP Project

(RSPO 4.4, 8.1)

Background

Brian Kiely was hired as the SADP Aquatic Biology Specialist, to work within the Entomology Section and began work on the project in February 2012. The project is designed to develop a means of effectively and expeditiously monitoring water quality in freshwater occurring within smallholder oil palm areas in West New Britain and Oro Provinces, Papua New Guinea. The project will culminate in the development of protocols for water quality monitoring using aquatic macroinvertebrates which can be used by individuals with minimal entomological knowledge and experience.

Introduction

Initial activities involved following up on and completing equipment orders made during the previous year as well as inventorying equipment which had already arrived. The minimum amount of equipment necessary for conducting field sampling for aquatic macroinvertebrates had arrived by June 2012, at which time selection and sampling of reference sites began.

Work on the project has thus far occurred in phases which are described in the following sections:

- Literature: Compilation and Review
- Sourcing and acquisition of taxonomic resources
- Preliminary scouting and site selection
- Development and use of Field and Laboratory Procedures
- Processing and enumeration of Macro-invertebrate specimens collected

Current status
To date, the project has been developed to collect semi-quantitative data from reference sites with the purpose of evaluating the accuracy of the following assumptions:

- That streams which are minimally impacted by oil palm activities (that is, they represent 'natural conditions') will show a higher proportion of invertebrate taxa which are relatively intolerant of poor water quality and in-stream habitat.
- That streams with high quality in-stream habitat will show greater diversity of invertebrate taxa present. Additional stream sampling, especially of streams obviously impacted by human activities will be necessary for the sake of comparison with reference conditions. Such comparative sampling is scheduled for 2013.

Literature Compilation and Review
The primary literature on which the protocols developed for the SADP Arthropod Survey Program for Stream Health Monitoring will be based were obtained from a number of government agencies via the internet and publications held by PNGOPRA (Entomology).
Primary among these are:

- *Protocols for Sampling Macro-invertebrates in Wadeable streams in New Zealand, 2001*. This document formed the basis for the surveys of macroinvertebrates in Oro and West New Britain conducted by Douglas Environmental Services for OPIC in 2006. The report prepared by Douglas Environmental Ltd. which summarized their findings was moderately useful.

- *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition, US Environmental Protection Agency,* (Barbour *et. al.,* 1999). This document describes the general methods by which bioassessments using macroinvertebrates as indicators are conducted in the United States. Additionally, this document provided templates with which field data was collected at each site sampled during the establishment of reference conditions in West New Britain, PNG.

- *Stream Invertebrate Grade Number- Average Level (SIGNAL) 2 Scoring System for Macroinvertebrates ('Water Bugs') in Australian Rivers, 2003*. This document is critical for the eventual assessment of individual streams and rivers within smallholder areas. SIGNAL scores are based on extensive scientific research focusing on the tolerance of various aquatic invertebrates to impairments in water quality. Scores from 1 to 10 are assigned to each family of organism. These scores represent a given taxon's ability to endure environmental stressors such as increased turbidity, low levels of dissolved oxygen, degraded and/or limited in-stream habitat, and increased nutrient loads due to natural and anthropogenic causes. A <u>higher</u> SIGNAL score indicates an organism that is less tolerant of degraded water quality.

  SIGNAL scores assign a relative score to all families of aquatic insects occurring within Australia. No such work has been done in PNG, and slight variations in SIGNAL tolerances for taxa occurring in PNG are expected, and, in some cases, documented (Boyero *et al.,* 2009). However, the scores assigned for insects in Australian waters is sufficient for this project as it is unlikely that any families collected in PNG will not also occur in Australia, although there may be species occurring in PNG that do not occur in Australia.
  SIGNAL scores, appropriate indicators will be developed which will form the basis of the ratings of stream health in subsequent surveys using the protocols developed for this project.

Additional resources were collected from scholarly websites pertaining to the creation of indicators, or measures of the composition of the aquatic insect community of streams, for use once data has been collected in the field.
Indicators specific to the aquatic macro-invertebrate assemblages observed in WNB and Oro Provinces will form the basis for comparison between streams within the project area. Table 116 lists a number of potential indicators of water quality based on the macro-invertebrate assemblages observed at a given site. Additional indicators will be identified as sampling continues during the first

half of 2013. Such relative measures of water quality will form the basis for the procedures through which the end users of the protocols will be competent to assess water quality using macro-invertebrate assemblages.

Table 116. Examples of macroinvertebrate-based indicators of water quality, their expected response to decreasing water quality, and description.

Metric	Expected response to increasing stress	Description
EPT (Ephemeroptera; Plecoptera; Trichoptera)	Decrease	Total of all taxa in the Orders Ephemeroptera, Plecoptera, and Trichoptera
Taxa Richness	Decrease	Total number of taxa represented in a sample
Percentage Filtering Collectors	Decrease	Percentage of taxa who obtain food resources by filtering fine particulate organic matter from the water column
Percentage Intolerant Taxa	Decrease	Percentage of total taxa with SIGNAL scores greater than 6
Percentage Tolerant Taxa	Increase	Percentage of total taxa with SIGNAL scores less than 3

Identification and Acquisition of Taxonomic Resources

Taxonomic keys are essential to correctly identify aquatic invertebrates collected during field surveys. , The vast majority of protocols reviewed require identification of specimens to the Family level. That is, most bio-assessment protocols employed by state agencies in New Zealand, Australia, and the United States do not involve identifying collected specimens to genus and/or species. The identification to Family will allow the protocols developed for use by SADP to adequately describe aquatic invertebrate assemblages in surveyed streams with regard to water quality. Identification to Family will allow the protocols, and the indicators by which assemblages will be assessed, to employ the SIGNAL scores described above.

Future sampling of streams showing signs of deleterious impact with respect to in-stream habitat and buffer (or lack thereof) is scheduled to begin in April or May 2013, depending when water levels subside.

There is a paucity of taxonomic keys available which are specific to Papua New Guinea. As a result, it is likely that many aquatic insect specimens that may be collected during field surveys will constitute new species and are yet to be described. A library of additional taxonomic resources will be needed in order to identify, and if necessary, describe, previously unknown species of aquatic insects; however, the underlying assumption for protocols undergoing development for the present project is that sufficient information with regard to water quality can be gleaned through identification of specimens to Family level.

Preliminary scouting and site selection

Maps of the project area were obtained and analysed to identify stream reaches in which relatively undisturbed conditions were likely to exist- these sites comprised the reference sites to which streams impacted by oil palm activities will be compared. Approximately two weeks were spent in the field visiting and making notes of these sites. Additionally, time was spent identifying sites at which the protocols developed for this project will be employed in the future to assess water quality. These include streams where human impacts were present, including those lacking buffer or riparian zones, a high degree of sedimentation, stream reaches where washing and bathing sites were present, as well as sites with an obvious lack of habitat and/or natural stream morphology due to the physical alteration (e.g. channelization) of a given length of stream (Plate 6).

Plate 6. **Stream showing relatively natural conditions (*left*) versus a stream showing obvious signs of human impact (*right*).**

It is crucial that relatively undisturbed streams are identified within the project area prior to implementing field sampling on stream sites within smallholder oil palm area (Herbst, 2004). By first assessing the aquatic invertebrate assemblages in undisturbed streams/ reference sites, a list of aquatic taxa occurring in relatively high quality streams will be compiled. Statistical analyses and measures of water quality based on the aquatic invertebrate assemblages will then be identified for streams within the study area.
These data will constitute the baseline/reference data against which data collected will be compared to assess the relative impact of oil palm or other human activities.

Development and Employment of Field and Laboratory Procedures
A review of numerous Government Agency's protocols for the assessment of water quality using macroinvertebrates as indicators revealed two primary types of field sampling protocols, namely single and multi-habitat sampling approaches was undertaken. Single habitat sampling involves sampling of a given stream length based on the single most dominant in-stream habitat type. These techniques differentiate streams broadly based on their substrate (e.g. sandy or rocky). Similar divisions are found among other sampling techniques where streams may be differentiated as either high or low gradient (Barbour *et. al*., 2006).

Multi-habitat sampling protocols, identify all available in-stream habitat types (e.g. riffles, runs, areas of sandy versus rocky substrate, and emergent and riparian vegetation) and sampling of each habitat type is conducted in proportion to their overall availability within a stream site (Barbour *et. al*., 2006).

This method was selected for this project to provide a clear representation of the full diversity of macroinvertebrates present at a given stream site based on all available in-stream habitats.

Sites selected as constituting reference conditions were sampled during the first three weeks of June 2012. Sites range from Salelebu in the East of WNBP to Silovuti (Ove) in the West. Field sampling was conducted at reference sites according to Standard Operating Procedures (SOPs) devised during the project for the reference site sampling phase of the project. These protocols describe the method by which all reference sites were surveyed, how pertinent data was recorded, and how collected samples were processed for later enumeration in the laboratory to identify taxa present. SOP's were refined as required. Nineteen reference sites (19) were selected from more than 40 potential sites (). Each site was assessed using the SOPs for Field Work.

All field activities were conducted with the assistance of Solomon Sar of PNGOPRA, Entomology Section.

Figure 82. **Distribution of reference sites in West New Britain Province.**

Processing and Enumeration of Collected Macroinvertebrate Specimens

Samples collected during fieldwork were processed according to the SOPs developed for laboratory work. Semi-qualitative methods devised were based largely upon the *New Zealand Protocols for Sampling Macroinvertebrates in Wadeable Streams* (Stark *et al*., 2001). Initial processing of macroinvertebrate samples was conducted on-site in the field. Following preservation in a minimum of 70% ethanol, samples were returned to the laboratory for further processing and enumeration of macroinvertebrates.

Back in the laboratory, sub- samples were taken by removing at least 200 specimens from each sample according to the SOP's. Each of the specimens from the sub-sample was then identified to Family for most taxa. Exceptions to this were the Chironomidae (Order Diptera) which were further identified to sub-family. Certain non-insect groups (including Gastropoda and Acarina) were not identified beyond the Order level due to a lack of adequate taxonomic resources.
All reference site specimens were enumerated and recorded on Excel spreadsheets by early February 2013. Table 117 lists all taxa collected from the 19 sampled reference sites. Included in this table are the functional feeding group (mode/method obtaining food resources) and SIGNAL grades, if established, for each taxon (Chessman, 2003; Yule 2010; http://www.mdfrc.org.au/bugguide). Both criteria will be used during data analysis and metric development during 2013.

Table 117. **Taxa collected from 19 reference sites including functional feeding groups (FFG) and SIGNAL scores (if known and established).**

Order (unless noted otherwise)	Family (unless noted otherwise)	Sub-family	Functional Feeding Group	SIGNAL Score
Ephemeroptera	Caenidae		GC	4
Ephemeroptera	Baetidae		GC	5
Ephemeroptera	Leptophlebiidae		SCR, GC	8
Trichoptera	Hydropsychidae		FC	6
Trichoptera	Calocididae/Helicophididae		SHR	9
Trichoptera	Calamoceratidae		SHR	7
Trichoptera	Glossosomatidae		SCR	9
Trichoptera	Leptoceridae		FC, PR, SHR	6
Trichoptera	Philopotamidae		FC	8
Trichoptera	Ecnomiidae		PR, GC	4
Trichoptera	Polycentropodidae		FC	7
Odonata (Epiproctophora)	Libellulidae		PR	4
Odonata (Epiproctophora)	Austrocoruliidae		PR	10
Odonata (Epiproctophora)	Hemicorduliidae		PR	5
Odonata (Zygoptera)	Protoneuridae		PR	4
Odonata (Zygoptera)	Lestidae		PR	1
Odonata (Zygoptera)	Megapodagrionidae		PR	5
Odonata (Zygoptera)	Chlorocyphidae		PR	
Odonata (Zygoptera)	Isosticidae		PR	3
Odonata (Zygoptera)	Coenagrionidae		PR	2
Diptera	Ceratopogonidae		PR, GC, SCR	4
Diptera	Dixidae		FC	7
Diptera	Tanyderidae		Possibly SHR	6
Diptera	Dolichopodidae		PR, Possibly SHR	3
Diptera	Tipulidae		PR	5
Diptera	Simuliidae		FC	5
Diptera	Tabanidae		PR	3
Diptera	Athericidae		PR	8
Diptera	Chironomidae	Tanypodinae	GC	4
Diptera	Chironomidae	Orthocladinae	GC	4
Diptera	Chironomidae	Chironominae	GC	3
Hemiptera	Veliidae		PR	3
Hemiptera	Naucoridae		PR	2
Hemiptera	Hebridae		PR	3
Hemiptera	Gerridae		PR	4
Coleoptera	Carabidae		PR	3
Coleoptera	Elmidae (larvae)		GC	7
Coleoptera	Elmidae (adult)		SCR	7
Coleoptera	Scirtidae (larvae)		FC	6
Coleoptera	Curculionidae		SHR	2

Coleoptera	Hydrophilidae (larvae)		PR	2
Mecoptera	Nannochoristidae		PR	10
Lepidoptera	Crambidae/ Pyralidae		SCR, SHR	2
Class Collembola	FFG and SIGNAL assigned to class		GC	1
Acarina	FFG and SIGNAL assigned at ordinal level		PR	6
Class Gastropoda	Ancylidae		SCR	1
Decapoda	Atyidae		GC, FC, PR	4
Phylum Platyhelminthes			various	not established

Abbreviations for functional feeding groups: FC = Filtering Collector; GC = Gathering Collector; PR = Predator; SCR = Scraper; SHR = Shredder

Publications

Dewhurst, C. (2012). Invertebrate Pests of Oil Palm in the Provinces of West New Britain and New Ireland, Papua New Guinea, and Aspects of their Management. *The Planter, Kuala Lumpur,* **88** (1032): 185-198.

Dewhurst, F.C. and Pilotti, C.A. (2012). First record of the base-borer weevil, *Sparganobasis subcruciata* Marshall (Coleoptera: Curculionidae: Dryopthorinae), from Oil Palm (*Elaeis guineensis* Jacq.) in Papua New Guinea and its association with decaying stem tissue. *Australian Entomologist*, **39**(3): 197-207.

Gibson Gary A. P., Dewhurst Charles, Makai Simon (2012). Nomenclatural changes in *Anastatus* Motschulsky and the description of *Anastatus eurycanthae* Gibson n. sp. (Eupelmidae: Eupelminae), an egg parasitoid of *Eurycantha calcarata* Lucas (Phasmida: Phasmatidae) from Papua New Guinea. *Zootaxa,* **3419**: 53–61 (2012).

Day M. D., Kawi A., Kurika K., Dewhurst C. F., Waisale S., Saul-Maora J., Fidelis J., Bokosou J., Moxon J., Orapa W., and Senaratne K. A. D. (2012). *Mikania micrantha* Kunth (Asteraceae) (Mile-a-Minute): Its Distribution and Physical and Socioeconomic Impacts in Papua New Guinea. *Pacific Science,* **66** (2): 213-223.

TRAINING, FIELD DAYS AND RADIO BROADCASTS

(RSPO 1.1, 4.8, 8.1)

In-house and external training remains an important focus for Entomology Section. Whenever external training opportunities arise staff are sent to attend the trainings, as part of our on-job training programmes. We also encourage visits to the section and are involved in regular trainings for both the plantations and smallholders.

Three (3) staff from the section attended 5 different trainings during the year. All the trainings were provided by NBPOL and couducted at Mosa Training Centre.

OPIC field days in 2012 were affected by the national general elections. Two (2) field days were held in 2 different VOPs and 171 people (167 adults [146 males & 21 females] and 4 children) attended (Table 118). Two (2) separate trainings were provided to selected staff from Lolokoru Plantation (11 males and 2 females [total =13]) on how to conduct male inflorescence census. Four (4) radio programmes were made in WNB during the year, and was widely heard throughout the province.

Table 118. Training activities provided by Entomology Section in 2012.

Date	OPRA Centre	Event	No. staff providing training	Initials	Location	Number of attendees (radio-coverage)				Area of training
						M	F	Child	Total	
14/12/12	Dami	OPIC Radio Program	2	SS, SM	Radio WNB	WNB coverage				Introduction to entomology & its role in oil palm industry
3/01/12	Dami	OPIC Radio Program	2	SS, SM	Radio WNB	WNB coverage				Major pests of oil palm
16/4/12	Dami	OPIC Radio Program	2	SS, SM	Radio WNB	WNB coverage				Bio-control programmes
9/11/12	Dami	OPIC Radio Program	2	SS, SM	Radio WNB	WNB coverage				Summary
10/04/12	Dami	OPIC Field Day	1	SM	Kae VOP	87	7	0	94	Training for new growers (infill)
10/09/12	Dami	OPIC Field Day	2	SS, SM	Wenge VOP	59	14	4	77	Training for new growers (infill)
11/06/12	Dami	Male Infloresce-nce Census	1	SS	Lolokoru	6	1	N/A	7	First training
12/06/12	Dami	Male Infloresce-nce Census	1	SS	Lolokoru	5	1	N/A	6	Follow-up training

SS= Solomon Sar, SM = Simon Makai, M= Male, F= Female

Table 119. Training Entomology Section staff attended in 2012.

Date	OPRA Centre	Staff attended	Area of training	Training provider	Location of training	Comment
23/01/2012	Dami	TM	MS Word	IT Job Training Center	Mosa	Beginner course
24/01/2012	Dami	TM	MS Word	IT Job Training Center	Mosa	Intermediate course
25/01/2012	Dami	TM	MS Excel	IT Job Training Center	Mosa	Beginner course
26/01/2012	Dami	TM	MS Excel (Intermediate)	IT Job Training Center	Mosa	Attendee commented that not enough was covered
16/03/2012	Dami	SS	Managing Performance Appraisal	IT Job Training Center	Mosa	
19/07/2012	Dami	TM, AY	Electronic Record and File Management	IT Job Training Center	Mosa	Importance of Data Entry
20/07/2012	Dami	TM, AY	Electronic Record and File Management	IT Job Training Center	Mosa	Importance of Data Entry
24/09/2012	Dami	SS	Project Management (Beginner & Intermediate)	IT Job Training Center	Mosa	Beginner course
25/09/2012	Dami	SS	Project Management (Beginner & Intermediate)	IT Job Training Center	Mosa	Beginner course
26/09/2012	Dami	SS	Project Management (Beginner & Intermediate)	IT Job Training Center	Mosa	Intermediate coarse
27/09/2012	Dami	SS	Project Management (Beginner & Intermediate)	IT Job Training Center	Mosa	
14/11/2012	Higaturu	BS	Weather observation training	National Weather Service	Higaturu	

SS= Solomon Sar, TM= Tabitha Manjobie, AY = Amalia Yalu, BS = Banabas Sapau

STUDENT TRAINING

A third year degree student from PNG University of Natural Resources and Environment (UNRE) was attached with the Entomology Section at Dami from July to December 2012. As part of his 6 months training with us, he completed a research project on the effect of varying field sanitation conditions on targeted trunk injection (TTI) programmes. Both the hard and electronic copies of the full report of the study are available on the Entomology Drive of the PNGOPRA server.

Two (2) additional students from the same institution that were attached to the PNGOPRA Higaturu sub-Centre for 6 months industrial training spent one week (26-30/11/2012) with the entomology section at the centre to gain general exposure of the entomology activities that are carried out at there.

IPM WORKING GROUP MEETING WITH HARGY OIL PALMS
(RSPO 8.1)
No IPM Working Group (IPMWG) meetings were held during 2012.

INTERNATIONAL CONFERENCESS
Head of Entomology attended the Fourth IOPRI-MPOB International Seminar: "Existing and emerging pests of oil palm advances in research and management." 13th – 14th December 2012. At the Grand Royal Panghegar Hotel, Bandang, Indonesia. HoE presented poster entitled "Oil Palm Pests of Papua New Guinea". This conference was well organized but the content was somewhat out-dated.
He also attended the Fifth International Symposium for the development of integrated pest management for sustainable agriculture in Asia and Africa. 18th – 20th December 2012. The Magellan Sutera, Sutera Harbour Resort, Kota Kinabalu, Sabah, Malaysia. HoE presented the same poster entitled "Oil Palm Pests of Papua New Guinea". This was a very good meeting with useful contacts made and information gleaned.

DONOR FUNDED PROJECT REPORTS
There were no full donor funded project reports compiled in 2012. The ACIAR funded Bogia Coconut Syndrome (BCS) Project was given a short unfunded extension toward the end of the year (2012). The financial report was provided in 2012, but the full report will be completed in early 2013. The Executive Summary of the project is provided below.

Identifying potential vectors of 'Bogia Coconut Syndrome' in Madang Province, Papua New Guinea. PC/2011/056.

Executive Summary

Coconut is a major cash crop and source of livelihoods for smallholders in all coastal regions of Papua New Guinea (PNG). It is known that there are diseases caused by phytoplasmas (or related organisms) affecting coconuts around the world. The best-known most widespread, and destructive of these diseases is Coconut Lethal Yellowing Disease (CLY).

Bogia Coconut Syndrome (BCS) was so named by the Technical Committee set up to investigate this unknown affliction that was causing the death of coconuts in the Bogia District of Madang Province in Papua New Guinea. It consists of members from The National Agriculture Quarantine and Inspection Authority (NAQIA), Coconut and Cocoa Research Institute (CCI), *Kokonas* Indastri Koporesen (KIK), Papua New Guinea Oil Palm Research Association (PNGOPRA), National Agricultural Research Institute (NARI), New Britain Palm Oil and Ramu Agri Industries and is represented by technical staff. The Committee meets irregularly.

Little is known of the causal pathogen (described only as, 'similar' to lethal yellowing) of Bogia Coconut Syndrome (BCS) in PNG, and nothing was known of the possible vectors. Concern has recently increased sharply with an outbreak of what appears to be of this disease much further SE nearer to Madang town than its original site in Bogia District. This spread has huge economic and social implications and the implied threat of spread to other coconut and oil palm producing areas. The spread of BCS in coconuts coupled with the potential for spread to other crops such as Betel nut and bananas poses an even greater threat to the oil palm industry within the Province and possibly elsewhere in the country – as it is acknowledged that all the major pests and diseases have spread to oil palm from coconut.

Coconut palms have been monitored in the Furan area of the Madang Province for almost 2 years (L Kuniata *pers. comm.*) and the observations confirming the increasing incidence of symptomatic and dead coconuts indicates a high probability that any vectors of phytoplasmas will be found in this area. A visit to the CCIL coconut seed garden at Omuru also revealed many specimens of plant hoppers (*Zophiuma*) which were collected and tested as being possible vectors.

The study involved intensive sampling of targeted insect taxa for any possible vectors in coconuts, as well as *Areca* palm (betel nut), Sago palms, Taro, non-native *Spathodea campanulata,* and banana (especially 'yawa' banana) which were growing in village gardens in the Furan area. The insects and plant samples collected were screened for phytoplasmas in the PNG OPRA Plant Pathology Laboratory in Milne Bay.

Positive samples were obtained in these preliminary analyses. Thirty-five samples with positive diagnoses were sent to MAF BioSecurity, Tamaki, Auckland, New Zealand for the identification of the samples using DNA sequencing.

At the time of preparation of this report, sequencing results have not yet been received.

VISITORS TO ENTOMOLOGY SECTION (DAMI HEAD OFFICE) IN 2012

Eight one (81) official visitors were addressed by entomology staff at the Dami Entomology Head Office during 2012. Organizations from which the visitors came included:

BMT-OPIC
BOPGA
DEC-POM
HOPL
GOK Planning
Halburn Constructions
HOP
Indonesia
JCU- Townsville
NARI
Papua Mining Ltd
PNGOPRA (other sections)
PNPM
RAIL
SADP
Serene Developments Ltd
SHA (NBPOL)
SIPEF
University of Adelaide
UNRE

NBPOL	Wellington Management, Singapore
OPIC (Bialla, Hoskins, Popondetta)	World Bank

REFERENCE CITED

Abbott, W.S. (1925). A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology*, **18:**265-267.

Barbour, M.T., Gerritsen, J., Snyder, B. D., and Stribling, J.B. (1999): *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.* EPA 841-B-99-002. US Environmental Protection Agency; Office of Water; Washington D.C.

Barbour, M.T., Stribling, J.B., and Verdonschot, P.F.M. (2006). The multihabitat approach of USEPA's rapid bioassessment protocols: benthic macroinvertebrates. *Limnetica* **25**(3): 839-850.

Bedford, G.O. (1976). Observation on the biology and ecology of *Oryctes rhinoceros* and *Scapanes australis* (Coleoptera: Scarabaeidae: Dynastinae): Pest of coconut palms in Melanesia. *Journal of Australian Entomological Society*. **15**: 241-251.

Boyero, L., Ramirez, A., Dudgeon, D., and Pearson, R.G. (2009). Are tropical streams really different? *Journal of North American Benthological Society* **28**(2): 397-403).

Chessman, B. (2003). *SIGNAL 2- A Scoring System for Macro-invertebrates ('Water Bugs') in Australian Rivers, Monitoring River Health Initiative Technical Report no. 31.* Commonwealth of Australia, Canberra.

CHUNG, G.F. (1997). The bioefficacy of the aggregation pheromone in mass trapping of *Oryctes rhinoceros* (L) in Malaysia. *The Planter*. **73**(852): 119- 127.

Gibson, G.A.P., Dewhurst, C. and Makai, S. (2012). Nomenclatural changes in *Anastatus* Motschulsky and the description of *Anastatus eurycanthae* Gibson n. sp. (Eupelmidae: Eupelminae), an egg parasitoid of *Eurycantha calcarata* Lucas (Phasmida: Phasmatidae) from Papua New Guinea. *Zootaxa*, **3419**: 53-61.

Gosselin, P. (2006). Risk management directives for methamidophos, (Letter). California Department of Pesticide Regulation, California, USA.
http://www.cdpr.ca.gov/docs/emon/pubs/rm_directives/rmd_methamidiphos.

Herbst, D.B. (2004). Establishing reference conditions for streams and measuring ecological responses to management actions using aquatic invertebrate biological assessments. *Proceedings of the Sierra Nevada Science Symposium*: 133-141.

HO, C.T. (1996). The integrated management of *Oryctes rhinoceros* (L) populations in the zero burning environment. *Proc. of the 1996 PORIM International Palm Oil Congress - Agriculture Conference* (Ariffin, D; Mohd Basri, W; Rajanaidu, N; Mohd Tayeb, D; Paranjothy, K; Cheah, S C; Chang, K C and Ravigadevi, S eds.). PORIM, Bangi. p. 336-368.

Kamarudin, N. and Wahid, M.B. (2004). Immigration and activity of *Oryctes rhinoceros* within a small oil palm replanting area. *Journal of Oil Palm Research*. **16**(2): 64-77.

Liau, S.S and Ahmad, A. (1995). Defoliation and crop loss in young palms. *In Proceedings of the 1993 PORIM International Palm Oil Congress.* Eds Sukaimi, J.; Darus, A.; Rajanaidu, N.; Dolmat, T.T.; Paranjothy, K.; Wahid, M.B.; Henson, I.E. and Choong, C.K. Oil Palm Research Institute of Malaysia, pp 408-427.

Page, B.W. (2005). Sexava pests of oil palm. *The OPRAtive Word*. Technical Note 6. PNGOPRA, Dami, West New Britain Province, Papua New Guinea.

Page and Dewhurst (2010). Sexava: Cost of no control. *The OPRAtive Word*. Technical Note 20. PNGOPRA, Dami, West New Britain Province, Papua New Guinea.

PNGOPRA (2010). Annual Report. Dami, West New Britain Province, Papua New Guinea.

PNGOPRA (2004). Annual Report. Dami, West New Britain Province, Papua New Guinea.

Stark, J.D., Boothroyd, I.K.G., Harding, J.S.; Maxted, J.R., and Scarsbrook, M.R. *2001: Protocols for Sampling Macroinvertebrates in Wadeable streams in New Zealand.*

Yule, C.M. (2010). Trophic relationships and food webs of the benthic invertebrate fauna of two seasonal tropical streams on Bougainville Island, Papua New Guinea. *Journal of Tropical Ecology* 12: 517-534.
WEBSITE: Identification and ecology of Australian freshwater invertebrates. http://www.mdfrc.org.au/bugguide

3. PLANT PATHOLOGY SECTION

HEAD OF SECTION III: DR CARMEL PILOTTI

EPIDEMIOLOGY AND CONTROL OF BASAL STEM ROT

Introduction

Ganoderma disease levels and control continue to be monitored in all plantations. Data presented here has been summarized from that received from Milne Bay Estates Ltd., Poliamba Ltd., Higaturu Oil Palms Ltd. and New Britain Palm Oil Ltd. All data has been corrected where possible and only infections for 2012 are included. Disease incidence data is based on original stand.

Disease progress in first and second generation oil palm

Milne Bay Estates

Disease levels in Milne Bay were below 1% for most Divisions in 2012 (Figure 83). Exceptions to this were Bomata and Tamonau Divisions. The disease levels at Tamonau were elevated due to the high number of palms recorded as suspect. These palms may not have been identified in the 2011 survey.

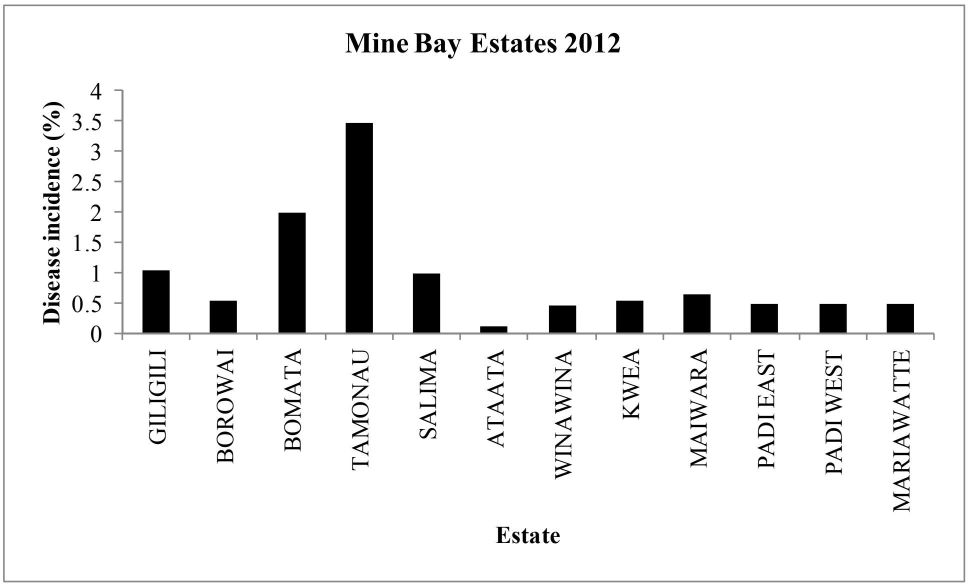


Figure 83. Disease incidences recorded in 2012 for Milne Bay Estates plantation Divisions. (Unaudited data supplied by MBE).

VOP Ganoderma surveys – Milne Bay

Disease surveys were completed for blocks with palms less than 10 years old. These had been omitted in previous surveys of mature plantings.

In addition to surveys, blocks were also manually mapped in order to prepare the blocks for marking and sanitation prior to replanting. All diseased palms in blocks due for replant have been marked and in addition, all 1988 plantings have also been assessed and marked for Ganoderma removal. GPS data collection in these blocks has commenced and is on-going. A total of 331 blocks were manually mapped and row numbers allocated for reference. Of these, 78 had GPS coordinates recorded but maps are yet to be generated. A summary of the work completed in each area is provided in Table 120. Some areas were completed in 2011 and these are indicated. Data for these areas was included in the 2011 Annual Report.

Table 120. Status of *Ganoderma* surveys and mapping in VOP blocks in Milne Bay Province at the end of 2012.

AREA	Blocks surveyed	Blocks mapped	GPS
RABE/GEHUA	1	1	0
WAEMA	4	4	0
LEASEHOLD	0	0	completed 2011
YANEYANENE	0	0	completed 2011
GABUGABUNA	13	13	2
LAVIAM	6	6	0
LAUTEWATEWA	2	2	11
KERAKERA	3	3	4
LUAHABA	3	3	0
GUMINI	11	11	8
NAURA/BARAGA	6	6	8
KAPURIKA	13	13	0
DELAMA	0	0	completed 2011
KILAKILANA	23	23	0
DIUDIU	0	0	completed 2011
MARAYANENE	5	5	10
IPOULI	41	41	0
SIASIADA	43	43	0
TAMONAU	0	0	0
MILA	34	34	0
WELLA/BWAUNA	10	10	0
IWAME/DAYOGE	23	23	16
FIGO	17	17	0
ATA'ATA	34	34	5
BOROWAI	34	34	0

Poliamba Ltd.

Levels of disease at Poliamba for 2012 are shown in Figure 84. Nalik and Noatsi Estates recorded in excess of 2% for the year which is a concern as many of the blocks in these Estates are either due for replant in 2013-2014 or were replanted in 2012.

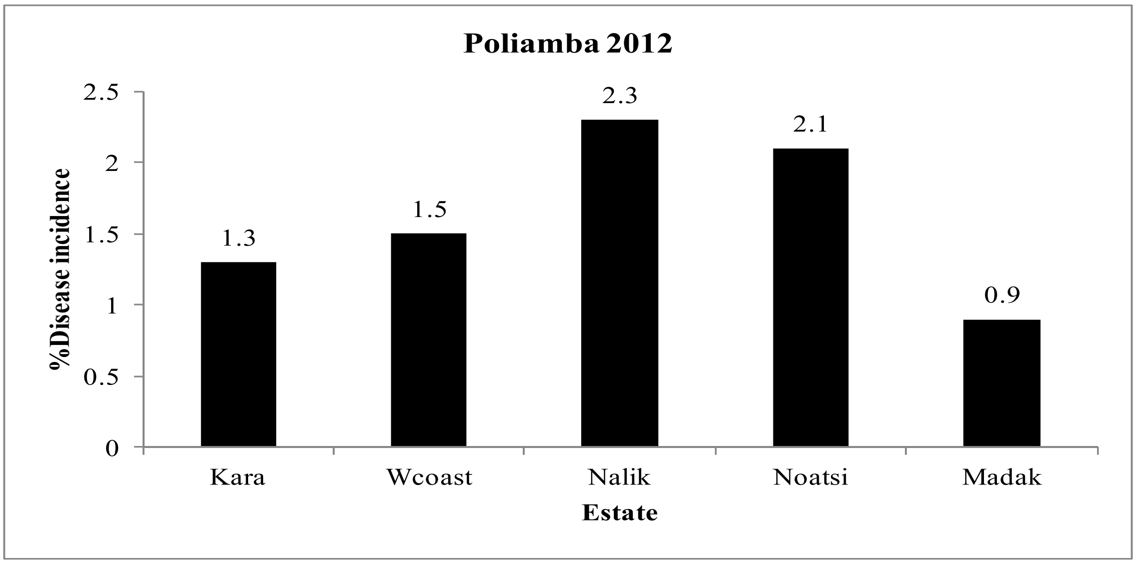


Figure 84. Disease incidences (confirmed *Ganoderma* only) recorded for each Estate at Poliamba Ltd. in 2012.

Cumulative disease progress for Poliamba Ltd. by planting date is shown in Figure 85. Palms planted in 1994 have the lowest incidence of BSR compared to areas with older (1989-91) palms. Disease levels in 1997 plantings are rapidly approaching the levels found in older plantings at the same age and if the current trend continues, will exceed the disease levels in the earlier plantings by age 20.

Data for individual blocks in each Estate are shown in Figure 86 to Figure 90. Survey data received from Poliamba indicated some block disease incidences of over 4% for 2012. This data clearly represents palms not removed from previous surveys and has been omitted pending verification. There continues to be a large variation in disease levels amongst blocks within each Estate.

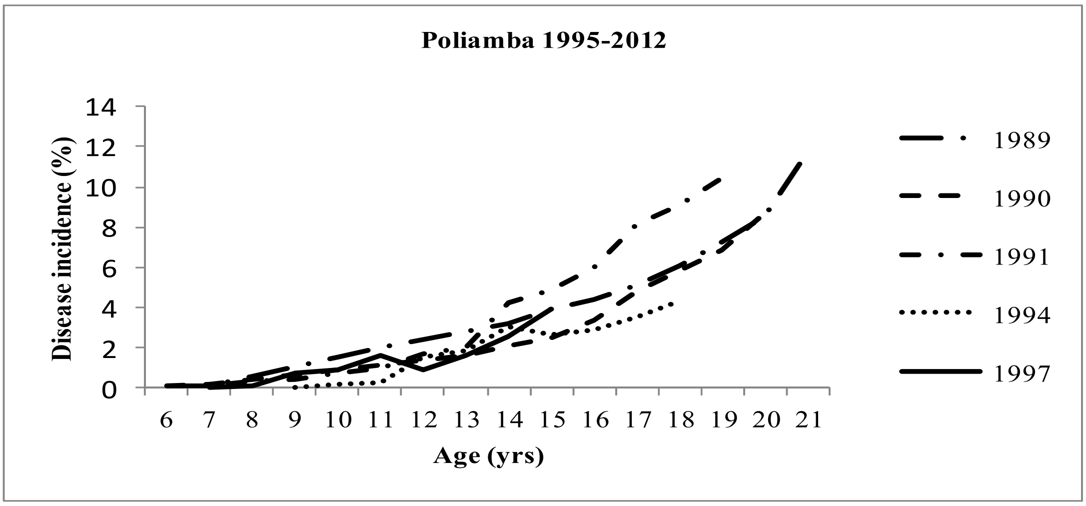


Figure 85. Cumulative disease progress recorded for oil palms of different ages from 1995 to 2012 for Poliamba Ltd.

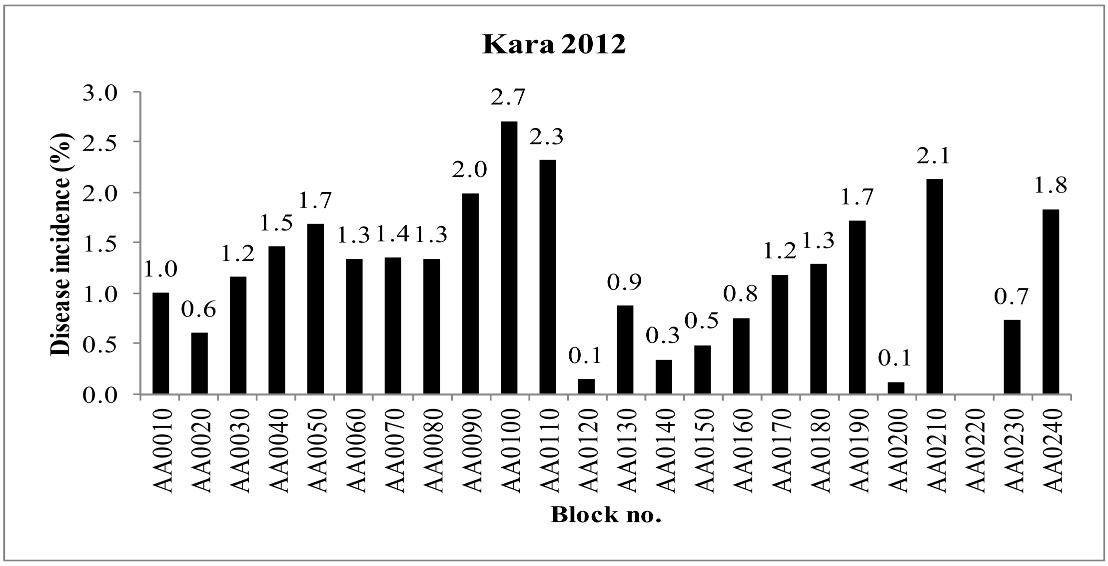


Figure 86. *Ganoderma* disease incidence recorded for blocks within Kara Estate, Poliamba Ltd. in 2012.

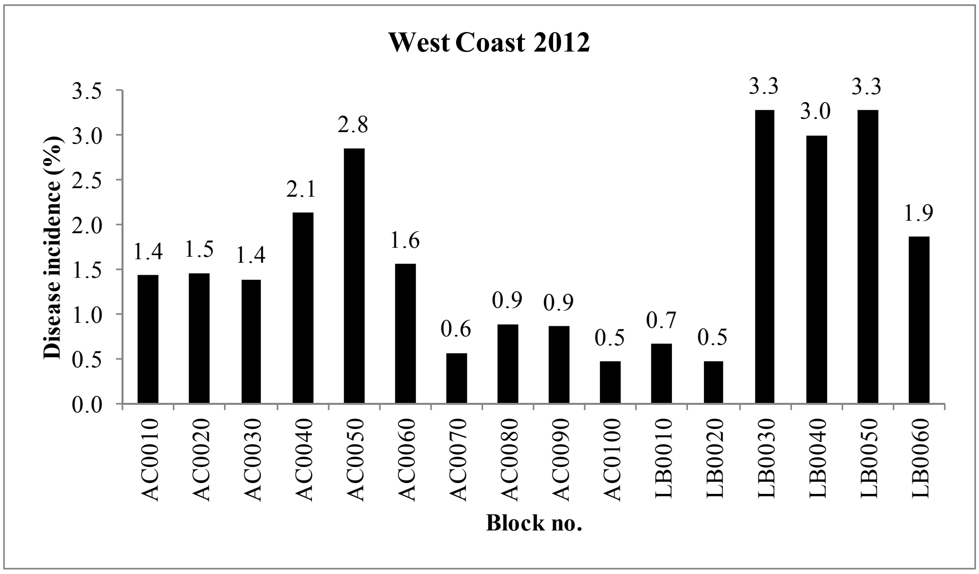


Figure 87. ***Ganoderma*** **disease incidence recorded for blocks in Nalik West Estate, Poliamba Ltd. in 2012.**

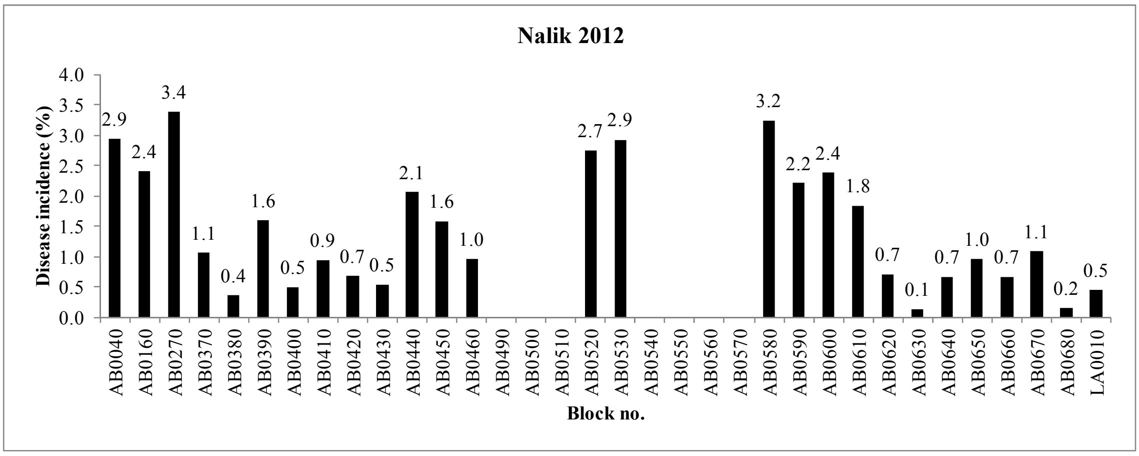


Figure 88. ***Ganoderma*** **disease incidence recorded for blocks in Nalik East Estate, Poliamba Ltd. in 2012.**

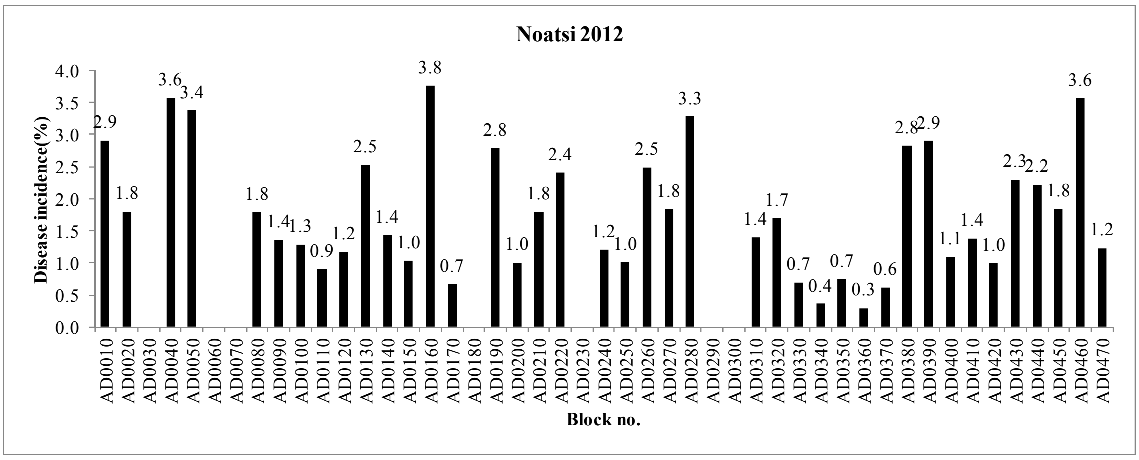


Figure 89. ***Ganoderma*** **disease incidence recorded for blocks in Noatsi Estate, Poliamba Ltd. in 2012.**

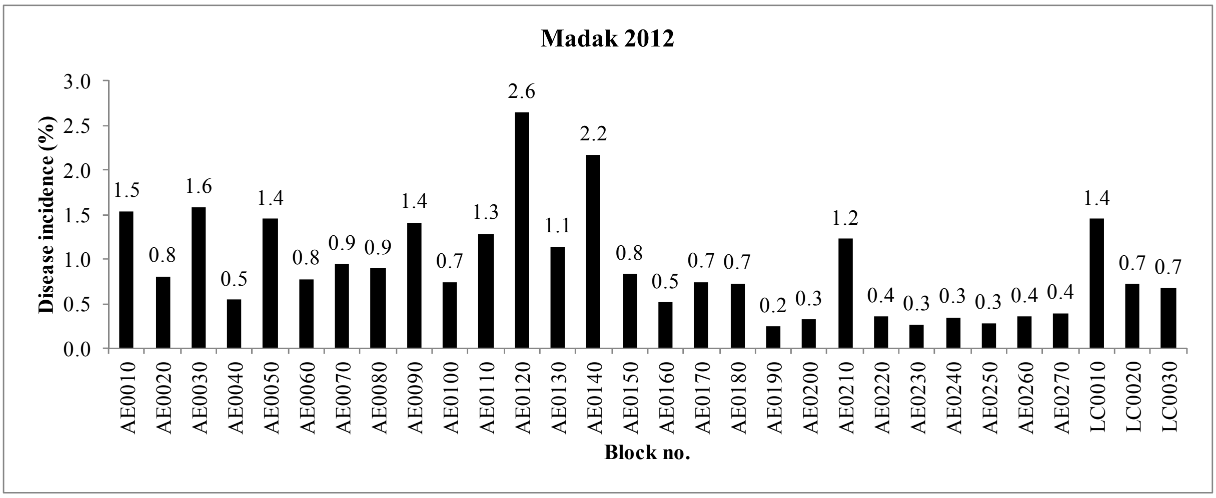


Figure 90. ***Ganoderma*** **disease incidence recorded for blocks in Madak Estate, Poliamba Ltd. in 2012.**

Higaturu OP Ltd.

At Higaturu Estate, disease incidence means ranged from 0.15% to 0.4% for 2012 (Figure 91). The higher disease incidence at Sumberipa compared to Sangara is of concern as plantings in Sangara Estate are older. The low disease levels for Embi are also surprising given that some of the first records of disease at Higaturu were from Embi.

Disease data for individual Estates are shown in Figure 92 to Figure 95. Sumberipa Estate 2000, 2001, 2002 and 2004 plantings recorded the highest disease incidence for 2012, higher than the 1990 plantings at Ambogo Estate and the 1996 plantings at Sangara Estate. Disease rates were below 0.5% in all other Estates.

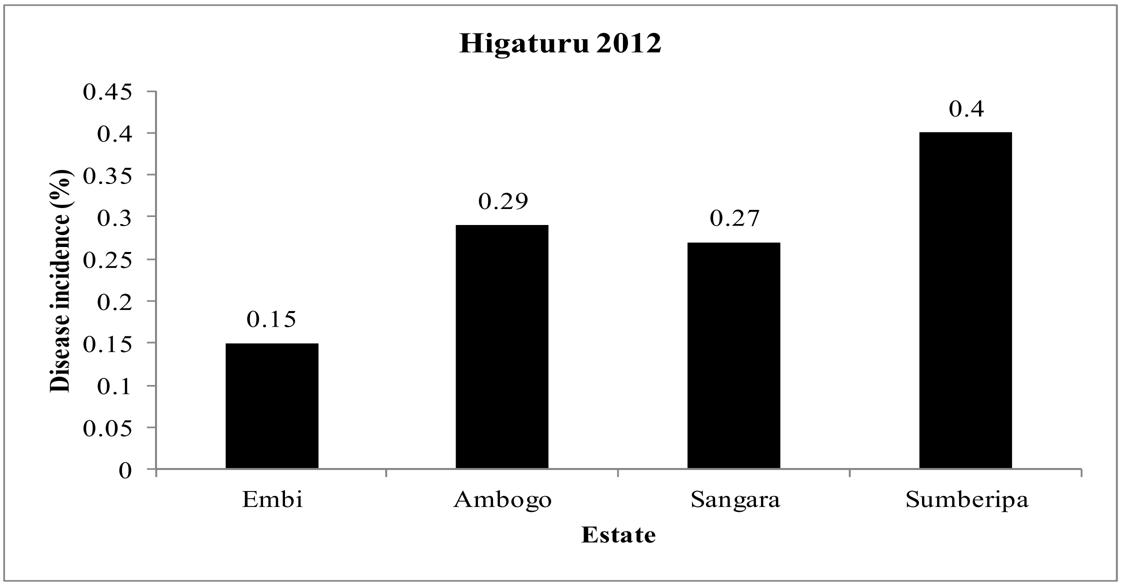


Figure 91. Mean ***Ganoderma*** **disease incidence recorded for each Estate in 2012 at Higaturu Oil Palms Ltd. (Data supplied by TSD Section. Higaturu Oil Palms Ltd).**

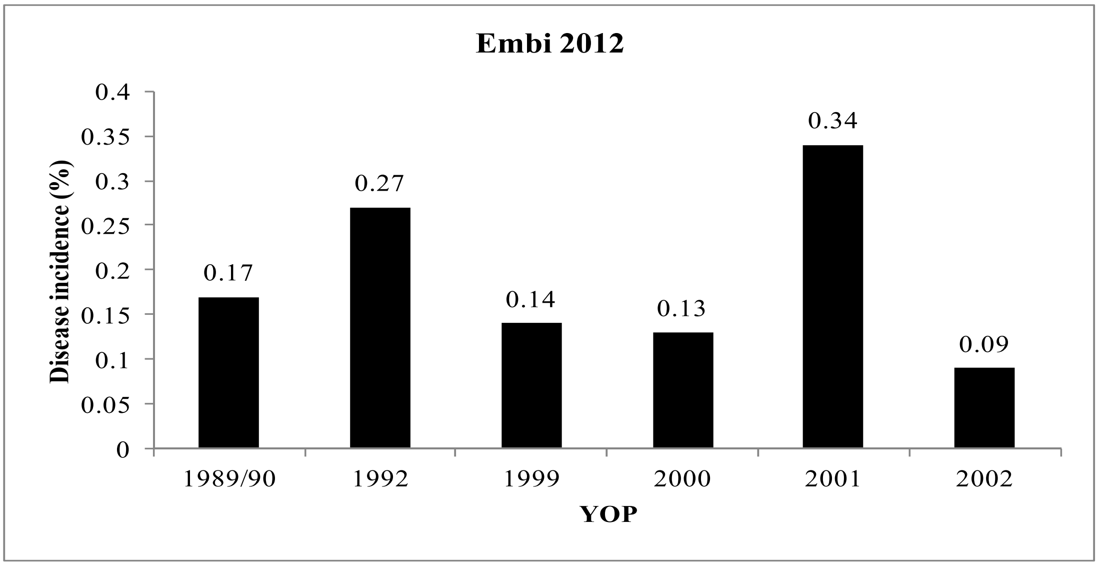


Figure 92. ***Ganoderma*** **disease incidences for surveyed blocks recorded in 2012 at Embi Estate, Higaturu Oil Palms Ltd. (Data supplied by TSD Section. Higaturu Oil Palms Ltd. YOP = year of planting.**

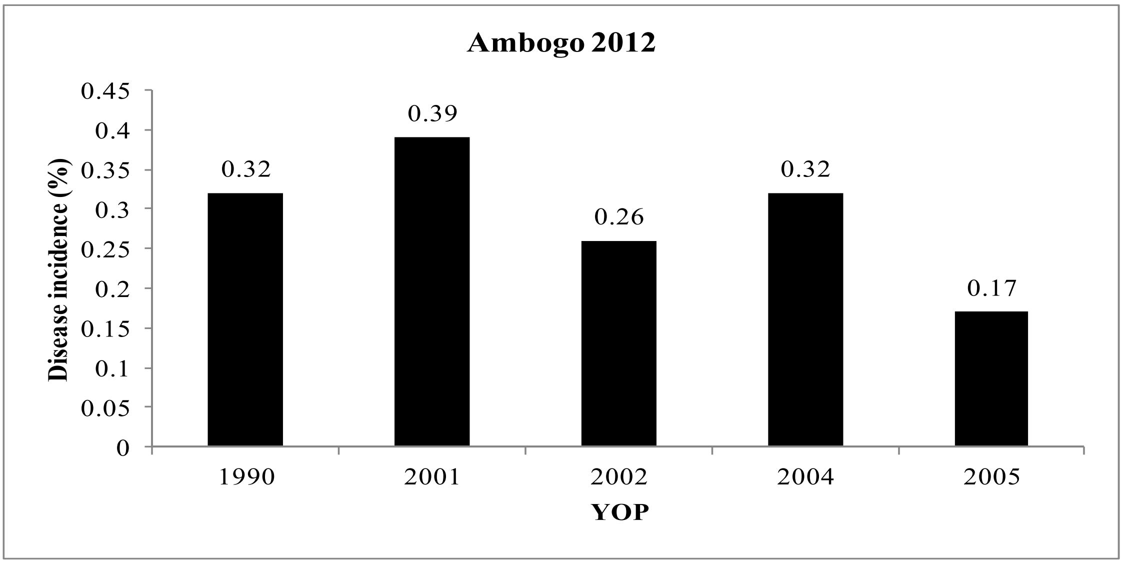


Figure 93. ***Ganoderma*** **disease incidences for surveyed blocks recorded in 2012 at Ambogo Estate, Higaturu Oil Palms Ltd.**
(YOP = year of planting).

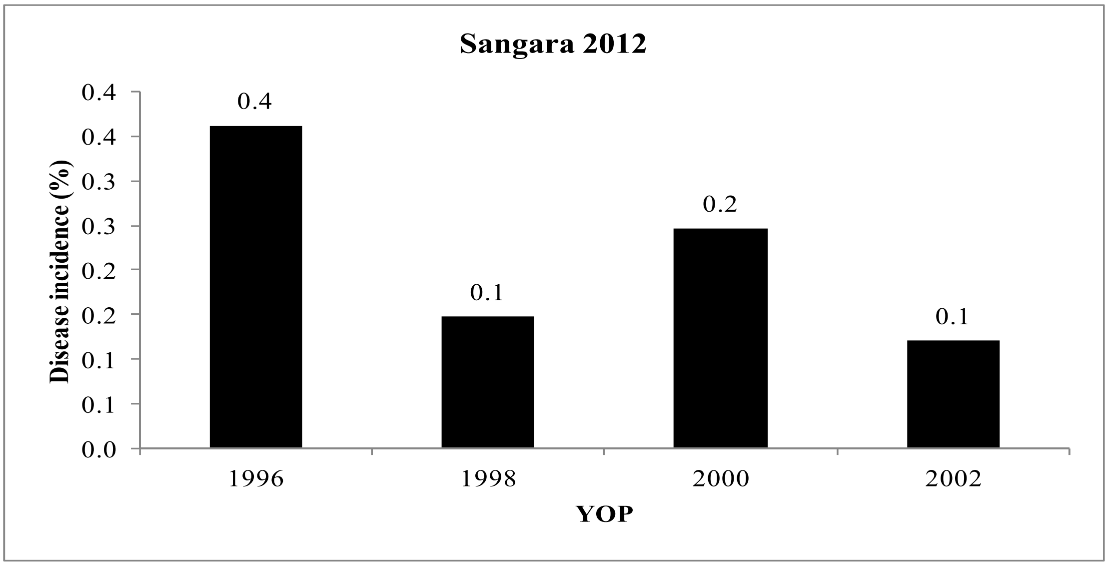


Figure 94. ***Ganoderma*** **disease incidences recorded in 2012 for Sangara Estate, Higaturu Oil Palms Ltd.**
(YOP = year of planting).

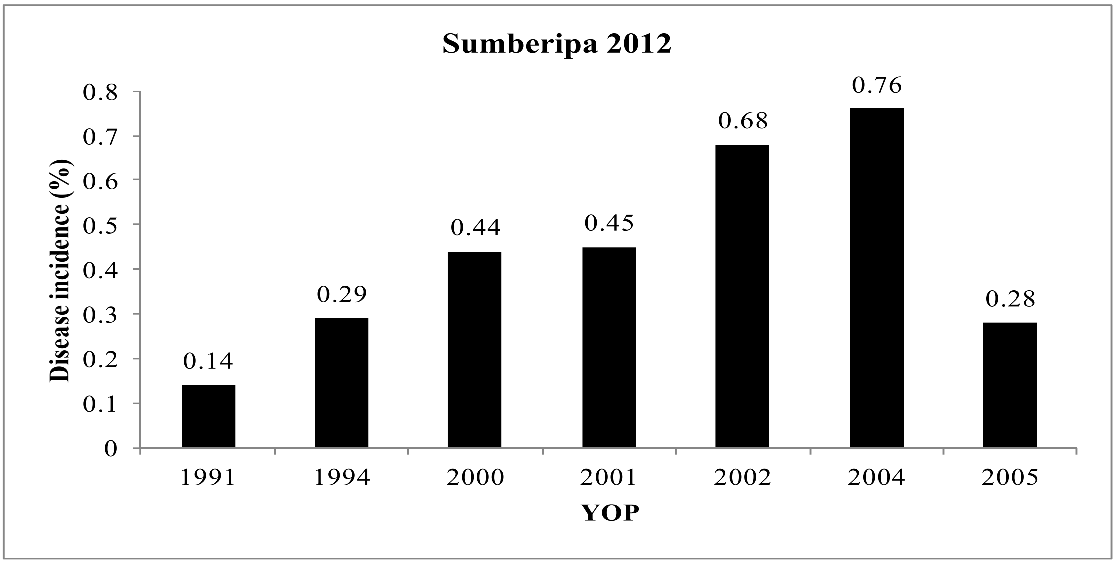


Figure 95. ***Ganoderma*** **disease incidences recorded in 2012 for Sumberipa Estate, Higaturu Oil Palms Ltd.**
(*YOP = year of planting*).

New Britain Palm Oil Ltd.

Monthly monitoring of disease levels in Fields E4 and E5 at Numundo Plantation continued in 2012 (Figure 96). Field E5 averaged 30 new infections per month and the Field E4 mean was 25 new infections per month in 2012. The higher infection numbers in Field E5 could have been due the non-removal (at our request) of infected palms within the yield trial area. This was necessary in order to monitor the survival and production profile of diseased (*Ganoderma*) palms.

Cumulative disease progress from 2000 to 2012 for these two blocks is shown in Figure 97.

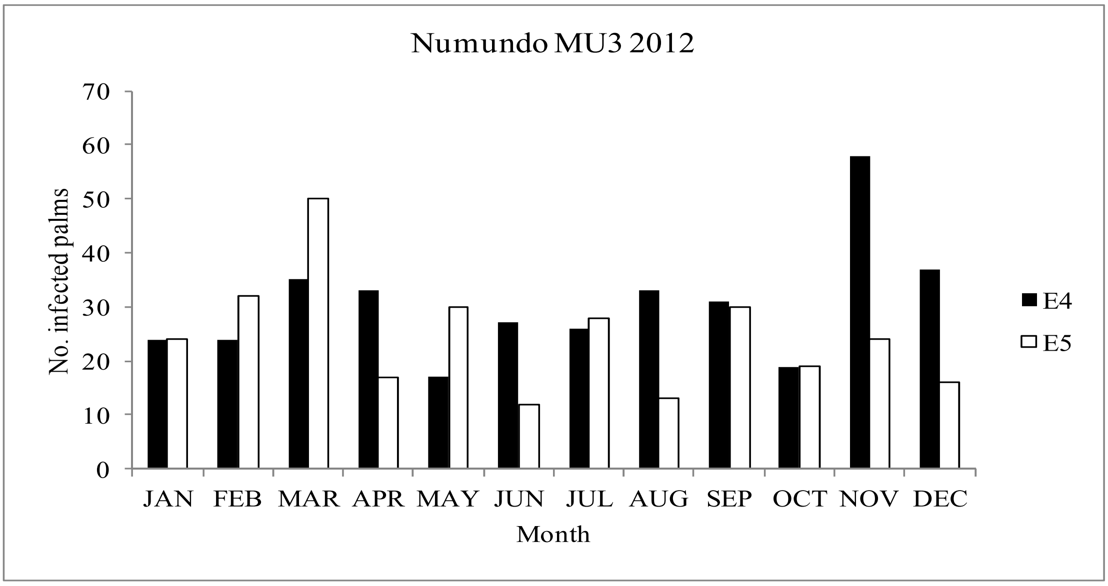


Figure 96. Total (*Ganoderma* and suspect) infections recorded monthly in Fields E4 and E5, Numundo Plantation, New Britain Palm Oil Ltd. in 2012.

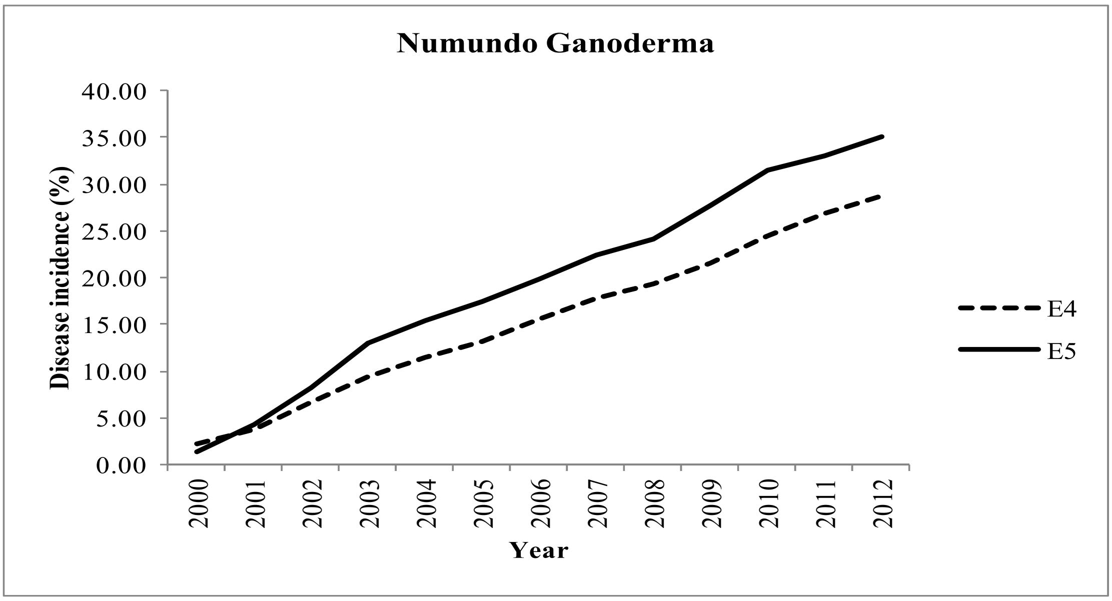


Figure 97. Disease progress curves for the fields E4 and E5 at Numundo Plantation, New Britain Palm Oil Ltd. from 2000-2012.

Monitoring the effects of disease on production in selected blocks

The apparent yield increase for Numundo MU3 in 2012 is interesting (Figure 98). A sharp increase of over 70kg per palm was recorded for 2012 although disease levels are over 30%. One explanation for this increase would be that fields were not fully harvested in 2011. Comparative data from the yield trial at Numundo Field E5 was not available at the time of writing. It's possible however that the bulk of the crop contributing to the yield increase originated from Field E4 in which case the data cannot be compared with trial production data.

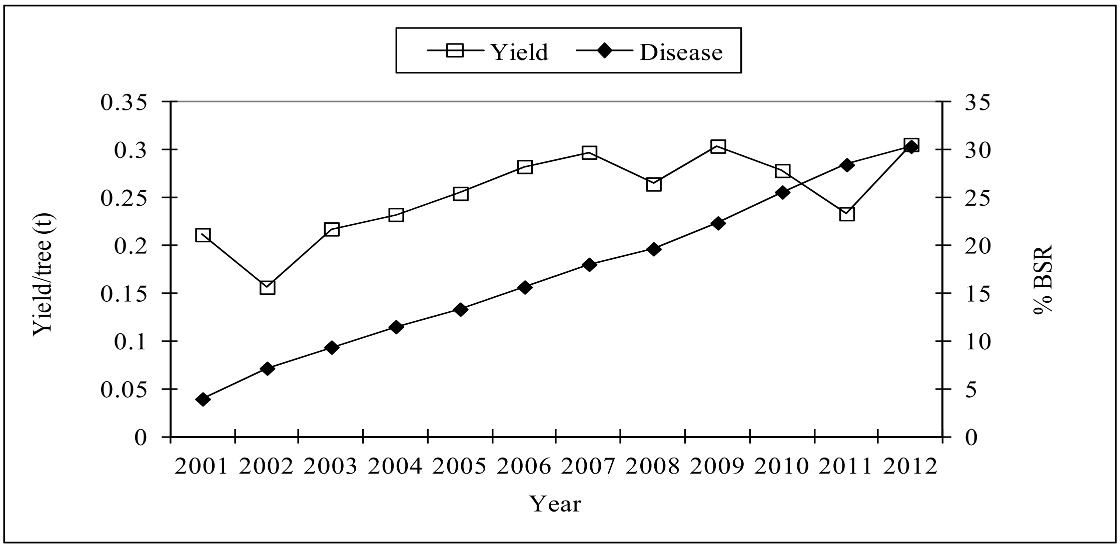


Figure 98. Yield for MU3 (Field E4 and E5) at Numundo Plantation, NBPOL from 2001-2012. (Data provided by Dami OPRS).

Yield studies on ganoderma-infected palms

Yield recording for this trial commenced in December 2010 and ceased in January 2013 due to the high incidence of Ganoderma within the trial. Data for the 2-year trial were still being edited and analysed at the time of writing, and have therefore not been included in this report.

A new trial is planned in the adjacent F fields at Numundo Plantation where disease levels are below the threshold of 20%.

Biological control of Ganoderma with Trichoderma spp.

Laboratory production of the biocontrol agent continued in 2012 for use in nursery trials and VOP training demonstrations. Investigations on the possibility of commercial production are continuing.

Screening for Ganoderma resistance sucesptibility

Including the ACIAR *Ganoderma* Project PC-2007/039 “The control of basal stem rot caused by *Ganoderma* in Solomon Islands”

Nursery screening of Dami progenies in GPPOL trials

No testing was carried out in 2012, as seed was not available from Dami OPRS for screening.

Field trials- Solomon Islands

Genetic testing of trial progenies

The screening of progenies with the 18 SSR markers which was developed in 2011r was completed in 2012. A rapid method of DNA extraction was developed to allow faster screening of the trial palms and a paper entitled “*A safe high through-put DNA extraction method developed for oil palm microsatellite analysis is suitable for other angiosperms”* has been drafted for publication in a suitable journal. Analysis of all the palms in the two trials at GPPOL is nearing completion, and a paper entitled “*Microsatellite markers for analysis of genetic diversity in Dami oil palm populations”* was drafted for publication.

Phenotypic data collection

Bunch and flower counts and palm status recordings were continued in 2012. There was no significant difference (P<0.001) in the mean number of bunches in each of the Trials in 2012 (Figure 99). Figure 100 and Figure 101show the mean bunch production on a monthly basis over a 12month period (Jan-Dec 2012) for each of the progeny in Trials 1 and 2. Progeny ranking by bunch production was generally consistent in each of the Trials and mean monthly bunch production in both trials was around 1.5 bunches per month.

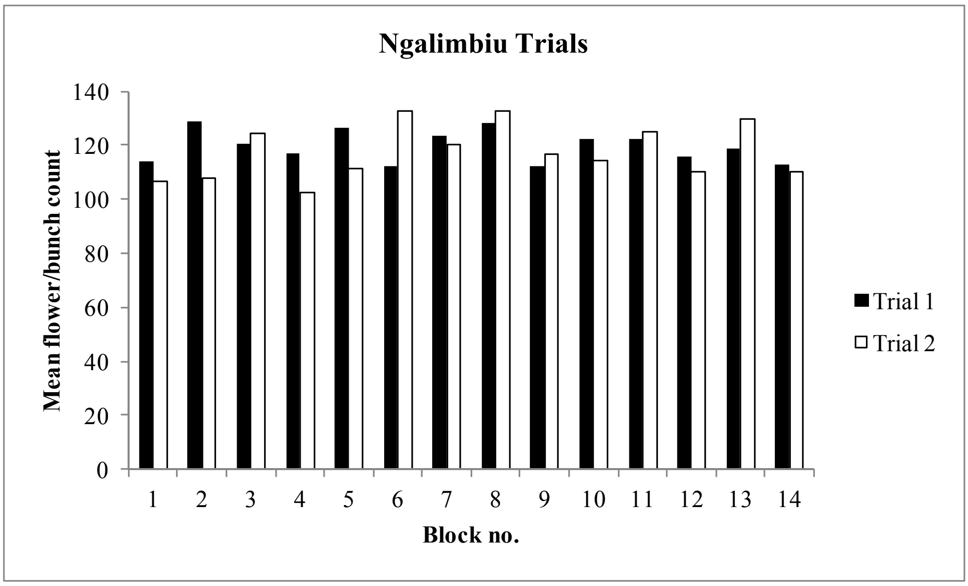


Figure 99. Bunch production in Ngalimbiu progeny trial blocks in Fields 12 (Trial 1) and Field 13 (Trial 2) over a 12-month period from January to December 2012.

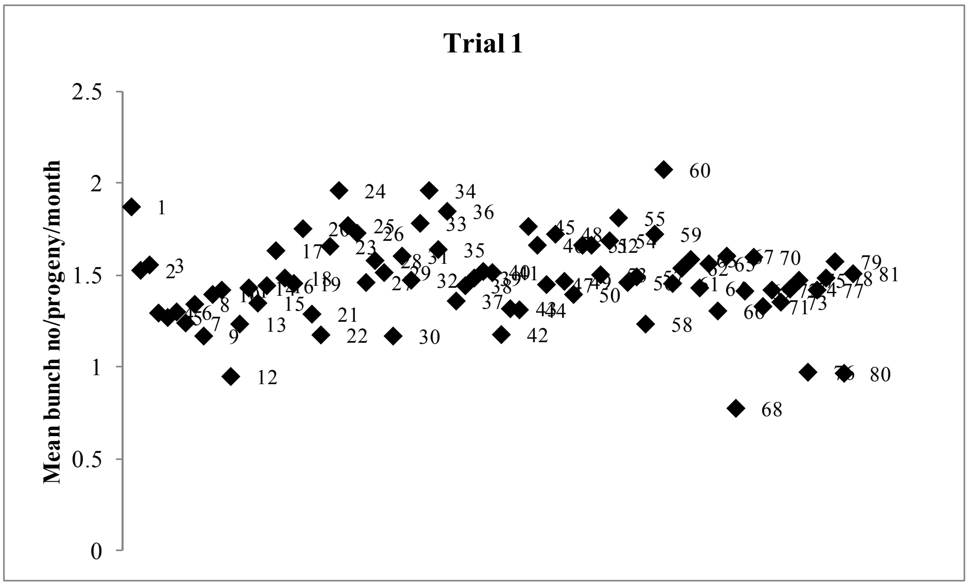


Figure 100. Mean monthly bunch numbers (14 Blocks) produced by different progenies (numbers) in Trial 1 (Field 12) Ngalimbiu Plantation, GPPOL for 2012.

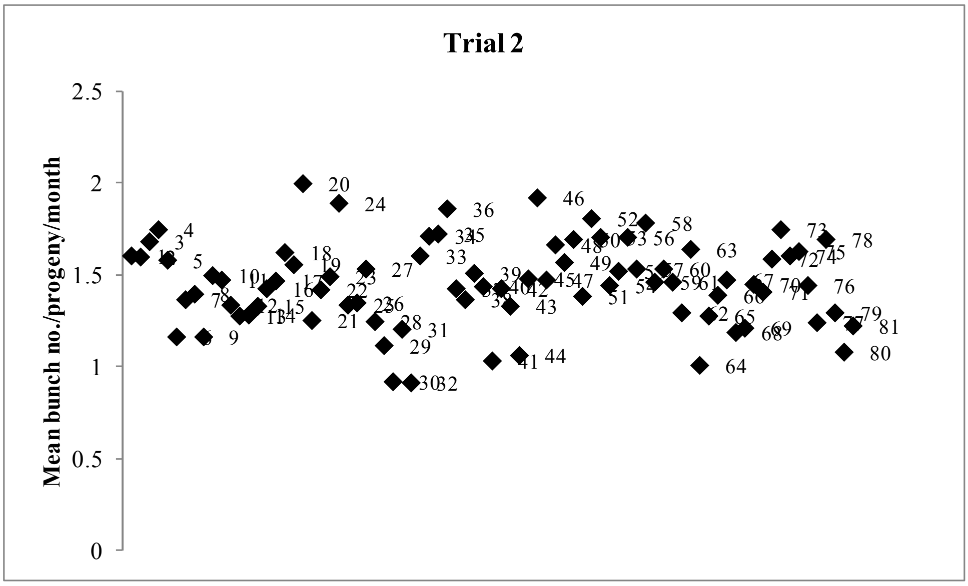


Figure 101. Mean monthly bunch numbers (14 Blocks) per month produced by progenies (numbers) in Trial 2 (Field 13) Ngalimbiu Plantation, GPPOL for 2012

BOGIA COCONUT SYNDROME

Testing of coconut and insect samples

Coconut samples collected from various Provinces in PNG were received by the Plant Pathology Laboratory in Milne Bay. These samples were processed and DNA extracted. Samples were tested for phytoplamsas using a nested PCR assay. Positive samples were sent to New Zealand for sequencing to confirm the identity of the phytoplasma.

BCS vector study- ACIAR funded

Plants and insects were also sampled in August 2012 to test for phytoplasmas. Insect samples collected (by entomologists, were returned to the Plant Pathology Laboratory in Milne Bay where they were subsequently tested by nested PCR for phytoplasmas. A selection of the positive samples were sent to New Zealand for sequencing.
A total of 575 insect and plant samples were processed and tested for the phytoplasma associated with BCS (Table 121)

Table 121. Number of plant and insect samples received and analysed in 2012 for BCS testing.

Plants	Insects
318	257

PUBLICATION, CONFERENCES AND TRAVEL

The Australasian Mycological Society Conference was attended in October 2012 by C. Pilotti and a poster was presented at the MPOB/IOPRI Pest and Disease Conference in Bandung Indonesia in December 2012.

Travel

Travel was undertaken by the Head of Plant Pathology (HoPP) for plantation site visits, ACIAR projects activities and conferences (Table 122).

Table 122. Travel undertaken by HoPP in 2012.

Month	Plantation/Visit
January	Madang (BCS work)
January	NBPOL
March	GPPOL
April	Madang (BCS work)
April	RAIL
June	Poliamba Ltd
August	Madang (BCS sampling at Furan)
September-October	GPPOL
October	Australasian Mycological Conference, Cairns
October	NBPOL, SAC Meeting
November	Poliamba Ltd
December	PORIM/IOPRI OP Pest &Disease Conference, Bandung

OTHER ACTIVITIES

Project administration
General administration and submission of annual reports for ACIAR Ganoderma Project were accomplished.

LPC meetings
The Head of Plant Pathology attended LPC meetings held monthly throughout the year in Milne Bay.

Disease reports
The number of disease reports received and attended to in 2012 by staff in Milne Bay and West New Britain are shown in Figure 102. All reports were investigated and recommendations made.

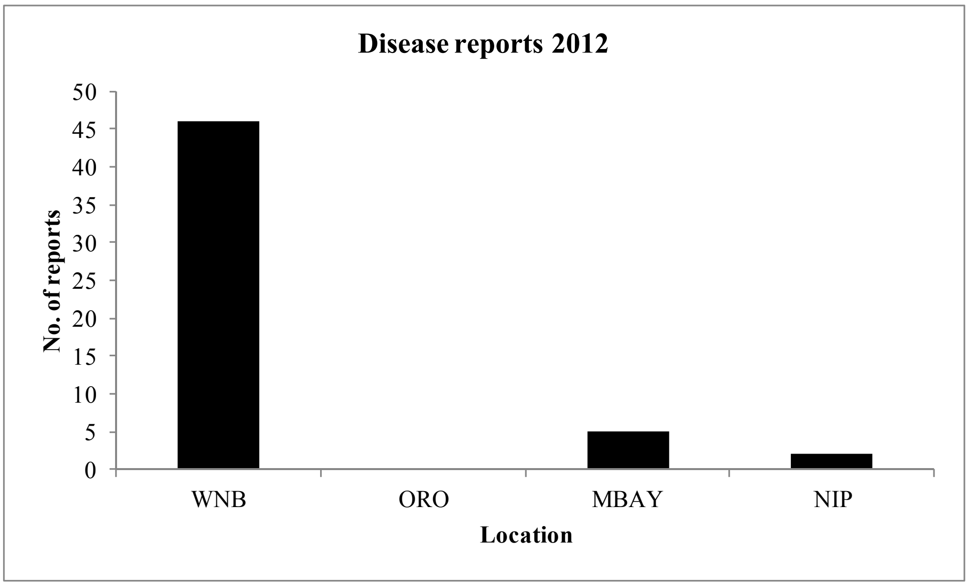


Figure 102. Disease reports received by the Plant Pathology section from OPIC and plantations in 2012.

Training
Most training activities in 2012 were field-based for OPIC and plantations. A summary is provided in Figure 103.

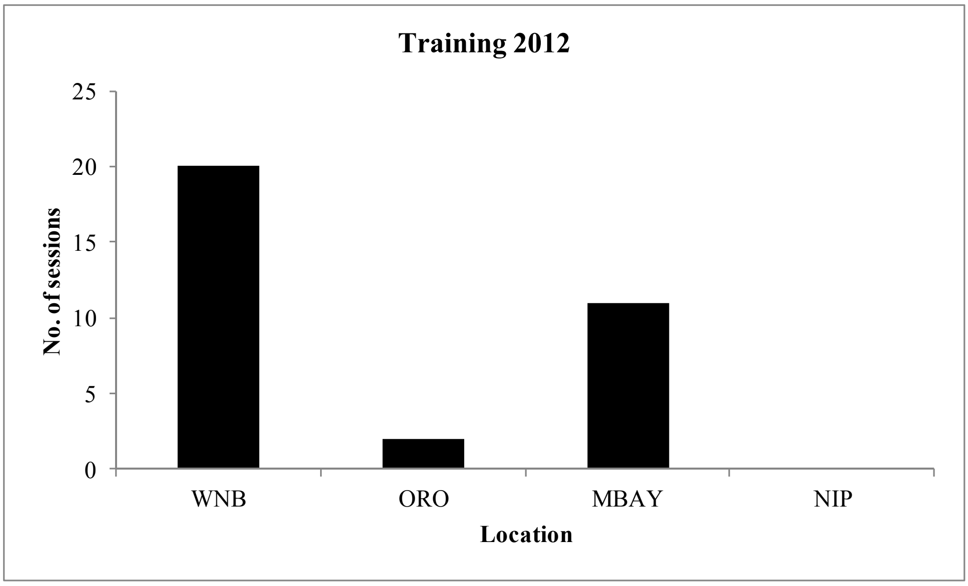


Figure 103. Disease training and awareness sessions held throughout 2012 for OPIC and plantations by the Plant Pathology Section.

Acknowledgements
The support of ACIAR with the *Ganoderma* resistance/susceptibility work is acknowledged. Survey data supplied by the plantations is also appreciated.

4. SOCIO-ECONOMICS SECTION

HEAD OF SECTION IV: DOUGLAS ROGER

with Emmanuel Germis and Merolyn Koia

INTRODUCTION

In 2012 the socioeconomics section continued work on several projects and has maintained its close links with other PNG National Agricultural Research Institutes, industry partners, and external organisations, particularly Curtin University in Australia. Smallholder socio-economic research currently has several components including:

- Examining the socio-economic factors affecting productivity among smallholders.
- Improving smallholder agronomic and farm management strategies.
- Understanding smallholder livelihood strategies and their influence on smallholder production.
- Analysing recent socio-agronomic changes occurring among smallholder households.
- Monitoring and evaluating smallholder interventions.
- Examining land tenure issues (e.g. developments on customary land).
- Food security.

The focus on smallholder research is becoming more important with the rapidly changing socio-demographic context of smallholder production (population growth, generational change, food security and the growing threat of HIV/AIDS), the high rates of under-harvesting amongst smallholders, land tenure disputes and compliance with RSPO principles and criteria. These may affect patterns of production, income distribution, farmer decision-making, and the overall quality of life. These can have further indirect effects on social attitudes and norms.

In 2012 the socioeconomics research team worked on the following projects and activities:

Commercial sector/smallholder partnerships for improving incomes in the oil palm and cocoa industries in Papua New Guinea. ACIAR Project ASEM/2006/127 (in collaboration with Curtin University)

This project was completed at the end of 2012. The aim of the project was to raise smallholder productivity and incomes in the oil palm and cocoa sectors through identifying, refining and promoting effective strategies for commercial sector partnerships with smallholders.

As part of this project, attention was given to identifying the main land tenure issues affecting smallholder production of oil palm on leasehold land (the land settlement schemes) and customary land (VOP and CRP blocks). Land conflicts take many forms in the oil palm industry, from the large compensation claims demanded by customary landowners for land alienated for land settlement schemes (LSS) and estate plantations to land ownership disputes between and within households. Land disputes are critical production issues because they can take oil palm stands out of production for extended periods thereby reducing smallholder productivity and growers' capacity for loan repayments. In addition, the types of land tenure arrangements sometimes influence smallholder productivity, attitudes to replanting and infill, investment levels in farm inputs and other assets, production strategies of smallholders, the livelihood strategies pursued by smallholders and the welfare and quality of life of smallholder families.

A final report from the project will be completed in 2013 which will provide an overview of the main land tenure issues in the smallholder sector and will cover the following four areas:

- Types of land tenure governing smallholder oil palm.
- Land tenure conflicts on oil palm land settlement scheme blocks.
- Land tenure conflicts on customary land, especially on customary rights purchase blocks (CRPs)
- Clan Land Usage Agreements (CLUAs).

A significant part of the project was a close examination of the factors giving rise to disputes over CRP blocks, especially in the Hoskins region. The research found that the current procedures for dealing with new oil palm plantings on CRPs and the existing Clan Land Usage Agreements (CLUA) did not provide adequate land tenure security for the outsider 'purchasing' or leasing land; nor did it ensure that all members of the landowning group agreed to, or benefited from, these land transactions. In most cases, the sales were not in accordance with customary law. Section 81 of the Land Act prohibits the sale of customary land except to citizens of PNG in accordance with customary law. Thus, unless the sale of the land can be shown to be in accordance with customary law then the sale is illegal. An illegal sale is not compliant with RSPO criteria. Therefore, the research reviewed current practices relating to the establishment of CRPs. The socio-economic team worked closely with OPIC and consulted widely with customary landowners and migrants acquiring land in Hoskins, Bialla and Popondetta to develop a new Clan Land Usage Land Agreement (CLUA).

The new CLUA template is available from PNGOPRA and OPIC. It is a detailed agreement outlining the rights of both the CRP growers and the land-owning group. The new CLUA ensures there is **transparency** in the process of informally leasing land to non-clan members.

The final part of the project focussed on conducting awareness of the new CLUA. In 2012 the socio-economic team, in collaboration with OPIC, conducted awareness on the new CLUA for CRP blocks at Waisisi in the Hoskins Project area. Sixty-one growers attended the awareness programme, comprising of CRP growers, clan and land-owning members and Siki based OPIC officers. The awareness emphasised the requirement that all signatories for the new CLUA must be appointed by the majority of clan members, villagers or the community as a whole and that signatories must serve for a fixed period of time to avoid unnecessarily changes. Land owners were made aware that they have options to decide on the leasing period: that is whether the lease will be renewed after one planting cycle. The renewal of the lease term will depend on community consultation. The rules and responsibilities of both landowners and CRP block holders under the CLUA were stressed and the consequences of breaching the terms of the CLUA were explained. The outcome of this awareness was the signing of the new CLUAs on developed blocks, developing blocks and newly prepared blocks. Awareness activities will continue in 2013.

SADP Smallholder Engagement Strategy (in collaboration with Curtin University)

In 2012 the socio-economic section completed the second phase of a research project within the support framework of the Smallholder Agricultural Development Project (SADP). The findings from the first phase of the project have been reported in Koczberski, G. Ryan, S. Germis, E and Curry, G.N. (2012). *Developing a Smallholder Engagement Strategy for OPIC. Stakeholder Consultation Workshop Report.* This report has been circulated to industry stakeholders. The objective of the SADP Smallholder Engagement Strategy Project is to determine the most effective and appropriate extension methodologies to apply in SADP project areas. The overall aim of the project is to produce a Smallholder Engagement Strategy for OPIC that will lead to more effective and efficient delivery of extension services.

As part of the project the socio-economic section conducted questionnaire surveys and interviews with over 340 land settlement scheme (LSS) and village oil palm (VOP) smallholder households at Hoskins, Bialla and Popondetta.

The household surveys collected data on the major topics of:

- Block ownership
- Production strategies
- Household demographics
- Attitudes toward extension and impressions of the effectiveness of OPIC extension
- Education levels and household educational strategies
- Household income sources
- Block management

Particular attention was given to investigating the education levels on smallholder blocks and attitudes towards OPIC extension.

Education Levels on the LSS blocks

(taken from Ryan, Koczberski, Germis and Curry. Draft**: Smallholder Education Strategies Report).** School education levels of adults residing on LSS blocks are higher than the national average. Adults aged 25 years or older have completed on average 6.9 years of school education compared with the national average of 4.3 years (Table 123). These levels of education are high in comparison with poorer provinces in PNG, but are still low considering that the average adult on an LSS block will not finish primary school (Grade 8). Table 123 shows, for both males and females, that second and third generation smallholders have completed more schooling than first generation smallholders. Thus, the children born on the LSSs are better educated than their parents; many of the parents were subsistence gardeners prior to settling on the LSSs. This general improvement in education levels is in line with national trends that show higher literacy rates amongst youth (15–24 years) than adults (ADB, 2012; UNESCO, 2011).

Of LSS primary school aged children between the ages of 6 and 13 years, approximately 71% were attending school at the time of the surveys (Table 124). This is comparable with the national net enrolment rate of approximately 70%, but low in comparison with other nations in the Asia-Pacific region. Perhaps, surprisingly, there are slightly more primary school aged girls than boys attending school.

Whilst attendance levels at primary school are reasonable, retention rates in secondary school are poor. The difficulty of retaining students into secondary school in PNG is reflected in the proportion of LSS adults completing various school grades (Figure 104). The largest proportion of both males and females on LSS blocks finish school after completing Grades 6 or 10.

Approximately 47% of both male and female students have completed their schooling by the end of Grade 6 and 88% by Grade 10. Under the previous education system[2], primary school finished at Grade 6 and junior secondary at Grade 10 creating 'two major bottlenecks' within the system and a high drop-out rate at the end of primary school (Connell, 1997; UNESCO, 2000). This is reflected in the LSS education data.

[2] *In 1995 the PNG education system delayed the finish of primary school to Grade 8. Students now complete three years of elementary school before going to primary school which runs from Grade 3 to 8 (Gibson & Fatai, 2006).*

Table 123. Mean years of schooling* for LSS residents in 2012 aged 25 years and older.

	Number of LSS residents	LSS Mean (years)	PNG national average (years)
1st generation male	189	7.0	
1st generation female	165	5.9	
2nd and 3rd generation male	158	7.7	
2nd and 3rd generation female	125	6.7	
Total	637	6.9	4.3**

* *Mean years of schooling is part of the United Nation Human Development Index (HDI) to assess the average number of years of education of adults, using an age bracket of people aged 25 years and older.*
**Source: UNDP, Human Development Report 2011b*

Table 124. LSS children aged 6-13 years currently attending primary school.

	Number of LSS children	Per cent of LSS children	PNG net enrolment rate
Male	119	69.7	n.a.
Female	102	73.5	n.a.
Total	221	71.5	69.47*

**Source: PNG Department of Education 2009.*

The high dropout rate at Grades 6 and 10 is, in part, due to families being unable to afford the increase in school fees after these grades. Over 50% of households with school age children reported difficulties sending at least some of their children to school. Of the households experiencing difficulty, 82% reported trouble paying school fees as the main constraint. The financial burden for some families sending children to school in PNG is well documented (e.g., Connell, 1997; ADB, 2012; PNGINA, 2012). In 2012 the government introduced the 'tuition fee free education policy[3]', but it remains to be seen what the impact will be on LSS resident education levels.

[3] *In 2012 the government implemented a policy to provide free education from elementary preparation to Grade 10 and a 75% reduction of costs for Grades 11 and 12. However, at the time of data collection, numerous delays meant only some schools had received education subsidies. In addition, many schools were still charging project fees to cover various school costs. Therefore, only a small number of households had children enrolled in tuition-free schools.*

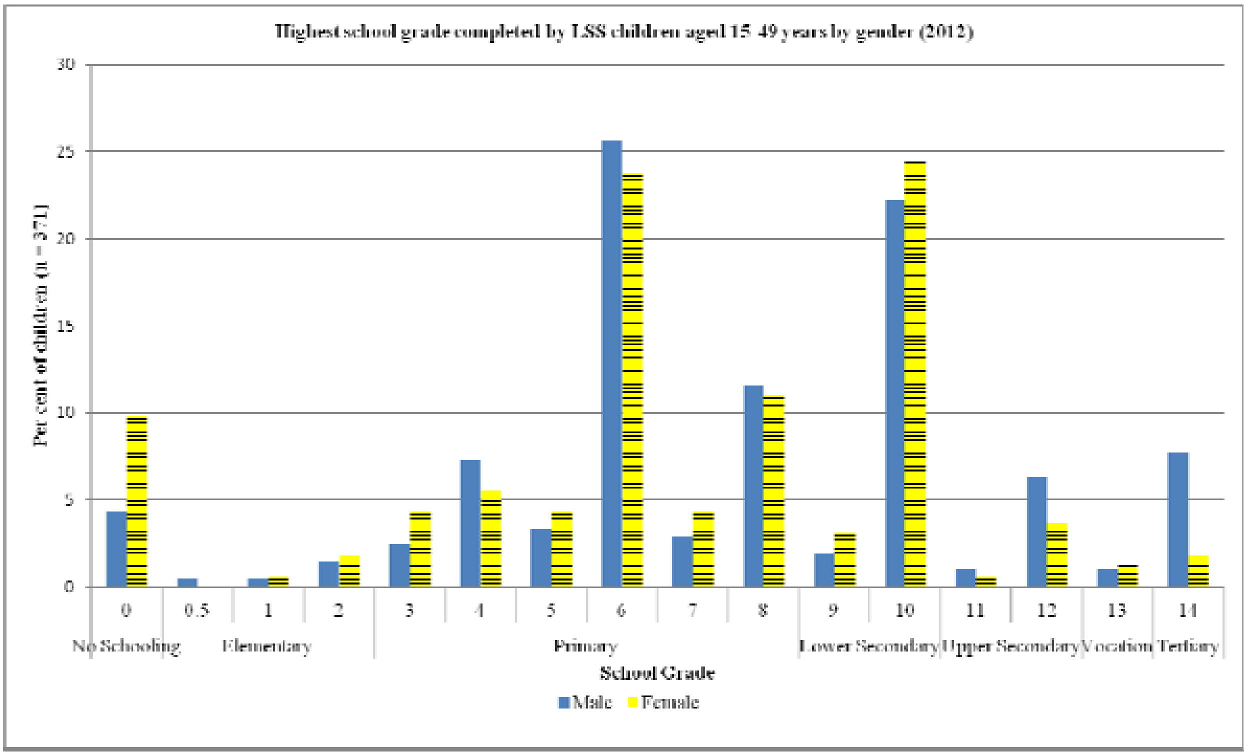


Figure 104. Highest school grade completed by LSS children aged 15-49 years by gender (2012).

Gender is an important factor influencing educational opportunities of boys and girls. As highlighted in Figure 104, there is a significant difference between the highest education level attained by males and females in the categories of those with no schooling and those educated at tertiary level. Almost 10% of female children have no formal education compared with approximately 4% of male children, and approximately 8% of male children complete tertiary level education compared with just 2% of females. In addition, female adults on the LSS blocks have on average approximately one year less of education than male adults (Table 123). This discrepancy between male and female education is likely due to a number of factors including the high opportunity cost of girls going to school (girls tend to do more unpaid household chores and help with younger siblings than boys) and the general pro-son bias on the LSS blocks which is systematic of wider discrimination against girls within Melanesian culture (Gannicott & Avalos, 1994). Research also indicates that there is a tendency for parents to invest in sons rather than daughters at a tertiary level because of security concerns over having to travel to education institutions far from home (Hill & King, 1991; Connell, 1997; PNGINA 2012).

Given the large family size on the LSS (there is on average 4.3 children per family on the LSS blocks which is comparable with the national total fertility rate of 4 children per family, UNICEF 2010), and the financial burden of school fees, the research shows a relationship between children's birth order and education levels. Two distinct patterns are observed. Second and third born children have on average higher education levels that the first-born child. This is perhaps due to older children who have left school helping pay the school fees of their younger siblings. In addition, children born after the fifth born child have significantly lower education levels than their elder siblings, even though the majority of parents claimed that they do not discriminate between which children they send to school. In large families the tenth born child has almost three years less of schooling than the highest achieving third born child, highlighting the difficulty for large families to accumulate enough savings to send all their children to school. Interview data suggest some households stagger their children's school enrolments until they have saved enough money. The consequence of this is that later birth order children are older when they begin school. The average age of a Grade 1 child on the LSS blocks is approximately 8 years, meaning that by Grade 8, children are 15 years old: an age at which some girls marry or become pregnant and boys start looking for work. This pattern may also partly explain the large drop in the number of girls moving to Grade 9 (Figure 104).

In summary, the average education level of adults on the LSS blocks is higher than the national average, but poor school retention rates mean that the majority of LSS children do not finish primary school. Moreover, the research found that a greater proportion of female adults than male adults on the LSS blocks have no education, and females are less likely than males to be tertiary educated. Gender, age, family size, education of the household head and household status were found to be key determinants affecting education levels of LSS smallholders. Education is a key component of rural development and there is a positive correlation between people's education levels and their technical efficiency, as educated farmers show a greater ability to adopt new agricultural practices and technologies than farmers with low education levels (Azhar, 1991; Asfaw & Admassie, 2004; De Muro & Burchi, 2007). Research also clearly shows that in non-monetary terms, the education of women is known to be one of the most effective measures for reducing inter-generational poverty.

Field days and extension messages

Field days are the main avenue used by OPIC to conduct training and awareness among smallholders. Over half of smallholders surveyed thought that field days were useful, although 42% had no opinion because in most cases they did not attend field days (Table 125). Smallholders were asked about their attendance at field days in the past twelve months. Only one third of LSS smallholders surveyed said they regularly attended field days. The main reasons given for not attending a field day in the last twelve months were that field days were not regularly held, they had other commitments, they were not responsible for making decisions on the block, or other people on the blocks attended instead of them (Table 126). In interviews with smallholders many complained that the extension messages presented at field days have remained virtually unchanged for many years, and many felt that field days needed to incorporate new topics and new ways of disseminating information to growers (see below).

Table 125. Smallholders' views on the usefulness of OPIC field days (n = 270).

	Per cent of LSS households
Useful	56.7
Not useful	1.1
No opinion	42.2
Total	100

Importantly, a significant proportion of smallholders stated that they have so little input into block management decisions that they could see no reason to attend field days. Smallholders not attending field days are largely apathetic towards extension and have few opinions about how to improve extension delivery. For these smallholders their engagement with oil palm is largely restricted to harvesting the palms for an income: they are not especially interested in improving farming techniques through attending field days. Some of these smallholders are regularly employed by neighbouring blocks to do harvesting and collect loose fruit, and occasionally to undertake block upkeep, sanitation and fertiliser application. Forty-one per cent of smallholders not attending field days said they did not attend because they were either uninterested as they were not responsible for decision-making, or other people from the block attended, mostly the male head of the primary household (manager of the block) or someone more senior or male (Table 126). Those not attending field days were typically women, younger growers and those belonging to secondary households; they tended to view attendance at field days as the responsibility of the male block 'owner'/leaseholder. Only a small proportion of smallholders reported not going to field days because of literacy problems; these smallholders were all elderly women.

Field days are typically a male dominated activity and many women did not see field days as something they should attend. Only 18% of women had attended a field day in the past twelve months. Given that field days are the main extension approach used by OPIC to train and disseminate information to growers, it is of concern that large numbers of smallholders, especially women and hired labourers, are not regularly attending field days. Overall, few people living on a block attended field days, despite their involvement in production.

According to those attending field days (largely block managers or block manager's sons), 87% claimed they translated extension messages for other block residents when they returned to the block. Thus, the success of extension messages being circulated within blocks relies heavily on the communication between the primary household and other block residents. This finding suggests that it would be valuable if OPIC were to consider effective ways to assist with the dissemination of the information learnt by those attending field days to other block residents involved in oil palm production. For example, there is potential for the use of new communication technologies, such as DVDs to communicate extension messages to growers who are not attending field days and who are only receiving second hand extension information.

Table 126. Reasons smallholders did not attend OPIC field days (n = 142).

	Per cent of LSS households
No field days conducted	27
Had other commitments	16
Uninterested as not responsible for block management decisions	13
'Manager'/head of the block attends	12
Only men attend	9
Does not receive messages about when field days are conducted	8
Brother/s attend	5
Thinks it's a waste of time/outdated information	3
Elderly/poor health	2
Other people on the block attend	2
Illiterate	1
Other	2
Total	100

Over 50% of smallholders said that extension messages were understandable. However, approximately 36% of smallholders did not have an opinion on the effectiveness of extension messages because they did not attend field days or meetings. Topics that smallholders learnt about at field days are listed in Table 127. The most common topics are general block management/maintenance, pest and disease control and fertiliser application. Whilst smallholders found these topics to be important (Figure 105), many wanted other topics to be included in field days, such as financial management. Smallholders were asked what topics they would like to see included in field days and over 90% of them thought budgeting, banking and business training were important or very important topics for field days (Figure 105). These topics reflect the desire of smallholders to improve their savings, financial literacy and business skills to strengthen household economic security. Although topics on financial management are not directly related to oil palm, the inabilities to accumulate savings and develop secure livelihoods are critical production issues: improvement in well-being and economic security are strong incentives for smallholders to invest their time and labour in oil palm production.

OPIC officers themselves do not have the skills and training to conduct extension on all of the above topics and are aware that if field days were to incorporate other topics such as financial literacy the participation of other stakeholders would be required at field days. Representatives from PNGOPRA, the Health Department, Department of Primary Industry, local NGOs, women's groups, Police Department and banks and credit unions are among some of the stakeholders that should be more closely involved in OPIC field days.

Table 127. Topics addressed at OPIC field days (n = 139).

	Per cent of households
Block management	37
Pest and disease control	37
Fertiliser application	35
Block sanitation	17
FFB quality control	14
Herbicide safety	9
Pruning techniques	9
Harvesting techniques	8
RSPO planting standards	8
Budgeting	7
Family planning	7
HIV awareness	6
Other	18

Thus, one important way to attract smallholders to field days is to introduce new topics that are important to smallholders and which have a bearing on smallholder productivity. OPIC officers also acknowledged that the content and mode of delivery of field days have not adjusted to address the changing needs and circumstances of smallholders and believed that the narrow emphasis on oil palm topics (e.g. fertiliser application and block maintenance) was no longer appropriate given the rapidly changing socio-cultural, economic and demographic environment of smallholders. Field days could be made much more attractive to smallholders if a broader perspective were taken to improve smallholder livelihoods, food security and the quality of life and well-being of smallholders.

Recommendations based on the findings of the smallholder household surveys will be outlined in a final report to be completed in 2013.

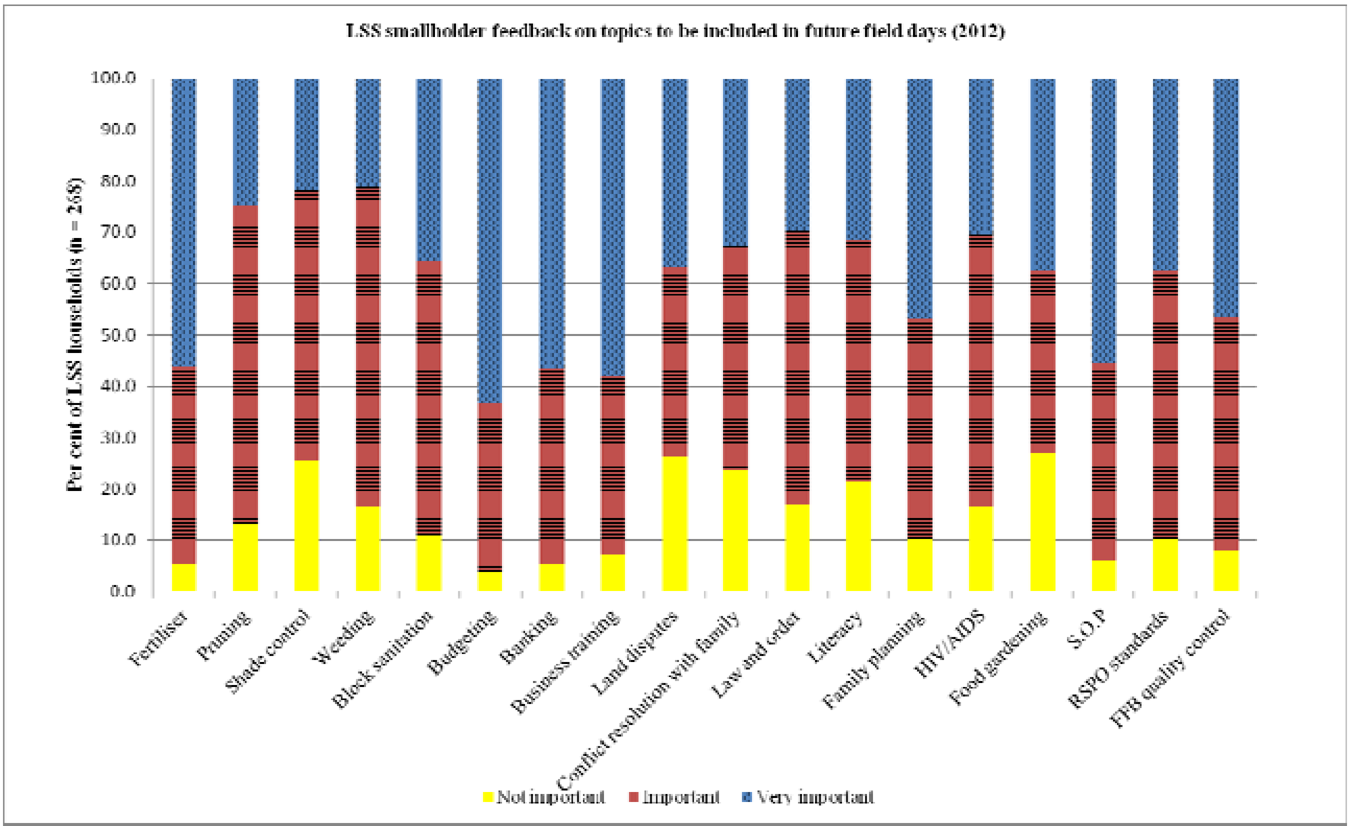


Figure 105. Smallholder feedback on topics to be included in future field days

Mobile Card Awareness

In 2012, four awareness programmes on the Mobile Card were conducted in the LSS subdivisions of Soi, Barema, Wilelo, and Tiauru and for the OPIC officers in Bialla project (Table 128). More than 200 copies of Mobile Card pamphlets were issued to smallholders during the awareness programme. To date, there are 201 LSS growers who have signed for the Mobile Card system in the Bialla Project.

Table 128. Mobile Card awareness

Bialla Sub-division	Number of Men	Number of Women	Total attendees
Soi (LSS)	41	5	46
Barema (LSS)	52	15	67
Tiauru (LSS)	15	4	19
Baubata (OPIC Officers)	20	Nil	20

Whilst conducting awareness, the following issues were identified:

- There was a decline in the number of smallholders applying for Mobile Cards.
- The transfer of OPIC officers to Bialla from the Hoskins project site has created a knowledge gap in the understanding of the Mobile Card concept, as the Mobile Card is used only in Bialla.
- There is a lack of understanding of the purpose of the Mobile Card system both by OPIC field officers and LSS oil palm growers. Low literacy levels of growers act as a barrier to understanding what is meant by percentage splits. Thus, further awareness training is necessary.
- Fluctuation of FFB price and particularly low prices, sometimes result in arguments between the Mobile Card worker and block owner. This is because when the price falls, Mobile Card workers feel they are not paid enough for their work in the block.

- The HOPL payment system continues to experience errors in payments to Mobile Card workers.

The following recommendations were made to OPIC, Bialla.

- Mobile Card workers must be above the age of 18 years and agree with the terms and conditions of the Mobile Card before signing the Mobile Card User Agreement Form. Bialla OPIC officers must ensure that both the Mobile Card worker and block owner understand the Mobile Card Agreement Form before signing to reduce the possibility of disagreement in the future.
- All Mobile Card Agreements must have a start and finish date to avoid employment misunderstandings. This will avoid situations where work by a Mobile Card worker continues after the contract expires, and payment is not made by the company payroll system.
- Mobile Card to be promoted on semi-abandoned VOP blocks.
- OPIC officers should assess LSS block holders before they sign up for a Mobile Card. A decision to sign up for Mobile Card must be collectively made by the LSS block owner and the Mobile Card User before signing the agreement form at the OPIC office.
- There is a need for further Mobile Card awareness training to improve understanding of the Mobile Card among all users. The Socio-economic Section can provide this service.
- Address the issue of the payment system within HOPL. The errors in payments are the main reason why Mobile Card contracts are not being renewed or taken up by smallholders.

Improving food security and marketing opportunities for women in smallholder cash crop production. Agricultural Innovative Grant Scheme (AIGS Project #9120)

In 2012, the socioeconomics section continued to work in collaboration with the agronomy section on food security trials on smallholder blocks. The trials are designed for densely populated LSS blocks that are facing land shortages. These trials address the growing concern that increasingly food gardens are being displaced from blocks to environmentally sensitive lands such as buffer zones, riparian habitats or to nearby state land or land belonging to customary landowners or the company. In the context of rising population and land shortages on the LSS, there is a need to develop sustainable production and farming systems to overcome these problems. One option is to look at innovative ways of utilising the limited amount of land available by intercropping oil palm with food crops. This project is currently investigating the optimal planting arrangements for oil palm to facilitate intercropping of food crops and fuel wood species for home consumption and sale at local markets while sustaining oil palm production.

Intercropping of oil palm and food crops will help ameliorate the land pressures from food gardening on marginal and environmentally sensitive areas like buffer zones. At the same time it would greatly improve women's access to land for food production, thereby contributing to food security and enhancing income opportunities. Intercropping trials are being conducted at Popondetta, Bialla and Hoskins. The socio-economic team is working closely with the agronomy section to monitor these trials.

As part of the project the socio-economic team, conducted market surveys in 2012 concentrating on sales of sweet potato, Chinese taro-tubers *Colocasia esculenta*, taro and peanuts. The market surveys were conducted at the following markets: Buluma, Buvussi, Galai, Kavui, Aling, Nahavio and Kimbe market in WNB. The main reasons for conducting the Food Security Market Surveys were:

- To measure or justify if yield loss from suspended oil palm trees in Food Security Trial in Smallholder oil palm block to food crop production can be compensated by the income from the sale and consumption of the cultivated food crops
- To monitor the trend in the market prices of food crops in relation to monthly FFB prices
- To justify if Food Security is of or a major concern in LSS blocks and also other smallholder oil palm schemes

- To compare the prices of marketed goods/food crops against store goods
- To compare prices of goods at various locations in and around Kimbe town
- To compare sellers/suppliers gender, locality, ethnicity and how they do their marketing in terms of the quality and quantity of their produces
- To monitor and compare the supply and demand for certain foods cultivated and sold

Some preliminary survey results indicate that:

- More women undertake food crop marketing than men, and a high proportion of the vendors are from LSS blocks.
- The sale of sweet potato, Chinese taro, *Colocasia esculenta*, taro and peanuts provide women from the LSS with an alternative source of income to oil palm.
- With the exception of Chinese taro, the price of sweet potato, taro and peanuts are influenced by the location of the market. Prices in Kimbe town market were lower than those recorded at markets at Aling, Nahavio, Buvussi, Kavui and Buluma. The lower prices at Kimbe town market may be explained by the shorter hours of operation at Kimbe market. The official operating hours of the market is from 8 am to 4 pm, and sellers need to sell their produce during these times. Other unregulated (roadside) markets remain open as long as vendors are present.
- Eight peanut sellers surveyed at Kimbe market, purchased 50kg bags of peanuts from the Markham Valley in Lae and had them shipped to West New Britain where they were resold. According to sellers, this business earns them high profits.

Smallholder production database.
The Socio-economic section is currently collating smallholder production data from all project sites from 2005 onwards. For each project site, data have been collated on smallholder monthly and annual production and annual loose fruit production. The following data have also been collected from 2010 onwards for each project site: monthly and annual total smallholder production for LSS, VOP and CRP blocks, total number (and hectares) of LSS, VOP and CRP blocks, and monthly FFB prices. These data will be used to calculate annual smallholder income and yields per hectare for each smallholder group. Smallholder RSPO bonus scheme records will also be recorded in the smallholder data base, starting from 2012.

Bialla plantation worker study
This study was initiated in October 2012 on the request of HOPL to investigate what motivational factors contribute to high labour force productivity among plantation workers. In December, the socio-economic section conducted a survey among 70 plantation workers in Area 8 of HOPL. The respondents worked as harvesters, *mama lus frut* collectors, cleaners, security officers, plantation drivers, sprayers and field supervisors. Of those interviewed, most were plantation workers between the ages of 20 and 35.

A detailed report will be completed in 2013. Preliminary findings revealed the following factors workers identified as encouraging high labour performance and productivity:

- Good housing and access to water and electricity.
- Access to health facilities for the worker and his/her family.
- A supportive and fair working relationship between plantation workers and their supervisor. A good relationship was a very important factor in motivating workers to achieve high performance.
- Access to education for plantation worker’s children.
- Higher pay rates increases incentives to work hard.

Most of the plantation workers interviewed were from the Highlands and Momase Regions of Papua New Guinea and have come to Bialla to work for HOPL. The main “pull factors” for the migration of workers to Bialla is to find employment and to gain access to services, while the main "push factors" driving their migration from their villages included fear of sorcery, social conflicts, land shortages and a lack of income opportunities in their home areas.

Collaboration with OPIC

Apart from the projects conducted in collaboration with OPIC as part of the SADP extension strategy and the Mobile Card outlined above, the Socio-economic section continues to work closely with OPIC.

OPIC Radio Program

The *Monthly* OPIC radio program is used by OPIC as part of the organisation's extension approach to share information and resources with smallholders. Recordings are made by Radio West New Britain and are broadcast to growers in the evening. In 2012, the socio-economic Section gave two broadcasts: i) Food security and ii) Smallholder oil palm harvesting and income distribution strategies. The latter focussed on the increasing number of blocks adopting *Skelim Hecta*, and the production and income implications for smallholders. The radio presentations were converted from English to Tok Pisin, and audio files were made of the presentations together with typed transcripts.

Income Generating Opportunities

The Socio-economic Section is working with OPIC to identify and implement alternative income earning projects for oil palm smallholders in West New Britain. The project is partly supported through SADP. The aim of the project is to generate alternative incomes to improve the living standards of the large extended families living on the LSS blocks in Bialla and Hoskins. The socio-economic section's involvement has proved vital for identifying suitable income generating activities such as poultry, piggeries, the sale of high value food crops, hired labour and small business enterprises (e.g. trade stores).

In October 2012 a provincial level "Committee for Alternative Income Generating Opportunities on the Oil Palm Blocks" was formed to implement business plans for the oil palm block holders. The committee has representatives from OPIC, the milling companies, PNGOPRA, major banking institutions, women's groups, training organisations and the provincial government. The socio-economic section participated in developing the terms of reference for the committee. The committee acknowledges that indigenous socio-cultural and economic values can be a major hurdle in operating small businesses in village settings. This is because at the village level, notions of market competition are largely absent, and the generation of profits, necessary for business viability and expansion, are not seen as important as maintaining good social and kinship relationships. The PNG project team will work closely with this committee to identify opportunities for livelihood diversification and monitor their uptake and impact.

Mainstreaming of Cross Cutting Issues: HIV & AIDS into PNGOPRA Programmes

Emmanuel Germis, the Socio-economic supervisor represented the Section in an HIV/AIDS workplace training conducted by BAHA PNG at the Kimbe Bay Hotel in July 2012. The objective of the training was to equip the private sector with appropriate knowledge and skills on HIV and its consequences. Some of the topics covered in the training were: HIV facts, analysing risky behaviour, prevention of mother to child transmission, voluntary confidential counselling and testing, care and support for people in the work place, delivery of work place training, strategies for helping people with HIV in the work place, PNG work place policies, HIV/AIDS and company policy implementation, training techniques and skills.

Based on the training received, Emmanuel Germis conducted HIV/AIDS workplace training in Dami Research Station in August, which was attended by nine PNGOPRA officers. During the training, it was identified that talking about sex openly in public was a challenge because of Papua New Guinea's cultural taboos.

Community Activities
The Socio-economic team continues to participate in community activities that promote family well-being and safer communities. This year, efforts were put into the commemoration of World Food Day and World AIDS Day.

Towards the end of November and the beginning of December 2012, the socio-economic section organised activities to commemorate the World AIDS Day with assistance from the Nursing Sister from the Dami Plantation Clinic. Activities undertaken were: a float through Buluma and Kumbango oil mill. In the evening, a video titled '*em wrong bilong mi yet'* (it was my own fault), was staged at the Dami plantation sports field. This activity was funded by the Mosa Local Level Government. The activities were organised and implemented under the theme, zero-HIV new infection, zero-stigma and discrimination and zero-AIDS related deaths.

World Food Day
World Food Day (WFD) was proclaimed at an FAO Conference in 1979. In 1980, the observance of WFD was endorsed in consideration of the fact that "food is a requisite for human survival and well-being and a fundamental human necessity" (FAO 1980). The aim of the day is to heighten public awareness of the world food problem and strengthen solidarity in the struggle against hunger, malnutrition and poverty.

The event provided an opportunity for the Socio-economic Section to educate smallholder growers in the Bialla LSS subdivision of Tiauru, and Matililiu and Mataururu VOP's of the importance of food security. LSS and VOP small holder farmers were given information on current population pressures and the implications on land shortages and food security. A video and PowerPoint slides, based on the PNGOPRA food security trial at Kabaiya were also used during the presentation. Over 200 LSS and VOP smallholders as well as subsistence farmers who attended the World Food Day were advised about the importance of the work being conducted by PNGOPRA on food security.

References

G. Ryan, S. Germis, E and Curry, G.N. (2012). ***Developing a Smallholder Engagement Strategy for OPIC.*** *Stakeholder Consultation Workshop Report*. Curtin University and PNG Oil Palm Research Association.

Bourke M. (2012).**The role of agriculture in a national economy dominated by gas, petroleum and mineral exports**. *State Society and Governance. Australia: ANU.*

Curry G & Koczberski G. (2009). **Livelihood and Food Security Programme.** *CRC. Australia: Curtin University*.

Food and Agriculture Organization of the United Nations (1979). **Report of the Conference of FAO.** *Twentieth Session, Rome: Food and Agriculture Organization.*

Orrell.I. (2013). **Palm Oil Palm Industry Statistics-2012.** Palm Oil Council. *Papua New Guinea: Port Moresby.*

5. ROUND TABLE FOR SUSTAINABLE OIL PALM RSPO

RSPO Principles are regularly updated and those are available on Web Site:

http://www.rspo.org/file/PDF/RSPO_national%20interpretation/papua/PNG%20NIWG%20Indicators%20and%20Guidance%20for%20RSPO%20rev%2020080317%20(FINAL).pdf