Annual Research Report

2013

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

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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, Dr Luc Bonneau

May 2014

CONTEXT

2013 was a very difficult year for the PNG oil palm industry. Across the country the lower FFB yields and lower extraction rates combined with lower commodity prices and higher exchange rates (PGK vs USD) had a devastating impact on the revenue of the industry players: milling companies and smallhoders. From record production and revenue in 2011, two years in a row the industry experienced a decline (Table 1).

Table 1 FFB production (MT) by the oil palm industry donors to PNGOPRA between 2011 and 2014*

Year	Milling companies	Small holders + Outgrowers	Total	Versus 2011	Versus 2012	Versus 2013
2011	1,844,783	871,394	2,716,177	n/a	105%	116%
2012	1,702,393	887,981	2,584,748	95%	n/a	111%
2013	1,558,522	776,406	2,334,928	86%	90%	n/a
2014*	1,852,055	889,683	2,741,738	101%	106%	117%

**2014 FFB budget*

However, at time of writing (April 2014 production) the situation looks much better. The FFB budget although comparable to 2011 production look to be in good track: -3.1% for milling companies and -9.5% for smallholders which convert into -5.1% against budget to date for the whole industry. Associated with a serious drop in the exchange rate and an increase in CPO and PKO price the industry is much healthier financially than the last couple of years. All actors expect that 2014 will be a year of rebound and expect to close the gap to 2014 budget and may be establish a new record for PNG.

However, an El Niño climatic event is announced to commence in few weeks. To date it is impossible to forecast the short term and long term impact on production of such event as the scientific community remain shared on the regions that might be impacted. At best, perimeters of our association members in PNG and operations in SI are mostly spared while a moderate event occurs in the Indonesia Malaysia region which would curtail palm products production. From the first signs of drought the market would anticipate and take measures. As a result, inflation on the commodity prices related to oil palm could occur and remain if El Niño drought generates scarcity. A stronger El Niño could have a devastating impact on the global industry as in case of severe scarcity the end consumer might turn and change their practices to alternate vegetable oils.

Following the production level achieved in 2013 in comparison to 2012 there were no changes of voting rights neither in 2013 nor in 2014 (Table 1 & Table 2).

Table 2 FFB production in 2013 and voting right in 2014 per OPRA associate members

MEMBER	FFB Produced in 2013	VOTES Number	VOTES %
New Britain Palm Oil Limited	780,562	**9**	31.0
Smallholders (OPIC)	776,406	**9**	31.0
Kula Palm Oil Ltd (ex CTP (PNG) Ltd)	441,906	**6**	20.7
Hargy Oil Palms Pty Ltd	237,197	**3**	10.3
Ramu Agri-Industries Ltd	98,857	**1**	3.4
Acting Director of Research[1]	n/a	**1**	3.4
TOTAL	2,334,928	**29**	100

[1]*Section 28a of the Rules of the Association state that the Director holds one vote.*

However in 2013 the hectares in production have greatly reduced (Table 3) as result of faster replant taking place (Table 4 & Table 6) but mostly for the correction of hectares in the smallholder by the identification and removal of ghost blocks.

Table 3 Planted mature area (ha) in December 2013

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (NBPOL WNB)	**34,029**	**24,659**	540	**59,229**
Ponpondetta (NBPOL HOP Kula)	6,398	11,955	-	18,353
Milne Bay (NBPOL MBE Kula)	8,761	1,850	-	10,611
Poliamba (NBPOL POL Kula)	4,539	2,340	-	6,879
Ramu (NBPOL RAIL)	9,811	-	260	10,071
Bialla (SIPEF HOPL)	8,934	10,455	**1,876**	21,265
TOTAL	74,472	51,259	2,676	**128,407**

Table 4 Planted immature area (ha) in December 2013

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (NBPOL WNB)	2,919	**2,243**		**5,162**
Ponpondetta (NBPOL HOP Kula)	2,360	1,592		3,952
Milne Bay (NBPOL MBE Kula)	1,909	35		1,944
Poliamba (NBPOL POL Kula)	1,204	273		1,477
Ramu (NBPOL RAIL)	1,679		160	1,839
Bialla (SIPEF HOPL)	**3,453**	1,167	43	4,663
TOTAL	13,524	5,310	203	**19,037**

Nonetheless, the total hectares planted by the OPRA members at the end of 2013 reached 145,444 ha with 1,261 additional hectares planted (+0.9%). NBPOL West New Britain remains the biggest site and NBPOL Poliamba the smallest (Table 5).

Table 5 Total planted area (ha) in December 2013

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (NBPOL WNB)	**36,948**	**26,902**	**540**	**64,390**
Ponpondetta (NBPOL HOP Kula)	8,758	13,547		22,305
Milne Bay (NBPOL MBE Kula)	10,670	1,885		12,555
Poliamba (NBPOL POL Kula)	**5,743**	**2,613**		**8,356**
Ramu (NBPOL RAIL)	11,490		420	11,910
Bialla (SIPEF HOPL)	12,387	11,622	**1,919**	25,928
TOTAL	85,996	56,569	2,879	**145,444**

It is noted that SIPEF HOPL and NBPOL HOP have the highest proportion of their estate as immature exceeding 25% of the total area planted (Table 6).

Table 6 Proportion of immature palms in December 2013

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (NBPOL WNB)	7.90%	8.34%	0.00%	8.02%
Ponpondetta (NBPOL HOP Kula)	**26.95%**	**11.75%**		17.72%
Milne Bay (NBPOL MBE Kula)	17.89%	1.86%		15.48%
Poliamba (NBPOL POL Kula)	20.96%	10.45%		17.68%
Ramu (NBPOL RAIL)	14.61%		**38.10%**	15.44%
Bialla (SIPEF HOPL)	**27.88%**	10.04%	2.24%	**17.98%**
TOTAL	15.73%	9.39%	7.05%	**13.09%**

PNGOPRA continued to be 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 2013 was lower than the previous year at K5.54 million and is budgeted to be even lower in 2014 at K5,39 million.
The Association Member levies financed 96.9% of this expenditure while external grants were lower at 3.1% however with the opening of new project the share of the external grants has climbed up to a modest 7.6% in 2014 budget. The Member levy remains set at a rate of K2.00/tonne of FFB for all growers since the last increase in 2009. Levy of which PNGOPRA received K1.85/tonne of FFB the other share is allocated to the Palm Oil Council but remain administrated by PNGOPRA. In 2013, expenditure by PNGOPRA was distributed as follows: Agronomy research, 40.8%, up slightly from 39.4% in 2012, Entomology research, 22.2% (down from 23.5%), Plant Pathology research 12.1%, (down from 12.9%) with Management and centralized overheads at 24.9% up slightly from 24.1% in 2012. No budget was set for Socio-economics in 2013 despite the recruitment of staff in 2012. In 2014 expenditure budget was distributed as follows: Agronomy research, 40.8%, equal to 2013, Entomology research, 21% (down from 22.2%), Plant Pathology research 16.1%, (up from 12.1%) with Management and centralised overheads at 20.7% down from 24.9% last year, finally a small budget was set for Socio-economics (1.4%).

MAN POWER

In 2013 PNGOPRA has seen some major changes in its management with the departure and arrival of senior executives and research officers. Nonetheless, research projects carried on as defined by the 2012 SAC. Bill Page retired in UK at the end of February 2013 after 6 years as Head of Entomology and 3 years as Director of Research. Charles Dewhurst took over as Acting until 1st of July 2013 and subsequently retired on 1st of August 2013 after 6 years as Head of Entomology. Dr Luc Bonneau initially seconded to PNGOPRA in July 2012 was then retrieved by NBPOL OPRS to lead the Breeding Materials Department as of December 2012. He then was appointed Acting Director of Research from 1st of July 2013 but retained his HOD position in NBPOL OPRS. From August 2013 until early 2014, PNGOPRA went through structural change and reduction of staff. From 108 in August 2013 PNGOPRA now employs 79 permanent workers. Agronomy and Administration were the most affected while Entomology and Pathology remained almost unchanged. However the creation of the Socioeconomic and Small holder Research SSR out of Agronomy and Socioeconomic took place and comprise 14 permanent employees.

OPRA management wish to thank Pole Crompton former Administrator for 18 years, Charles Tringin former Head of IT for 3 years, Douglas Roger Head of Socioeconomics for 1 year , Winston Eremu Former Research officer for 18 years and Rachel Pipai Agronomy research officer for 11 years.

The distribution of employee age is presented in Figure 1 and Figure 2. The succession plan for is not a current issue. The executives benefit from a pool characterized by a young (<40) generation of executive scientists of which some are already leaders in their research sections. As for the non-executives, the numbers illustrate a large proportion of young workers/recorders and a population of more senior research supervisors. In addition, the overall sex ratio in PNGOPRA is 1/3rd female, 2/3rd male.

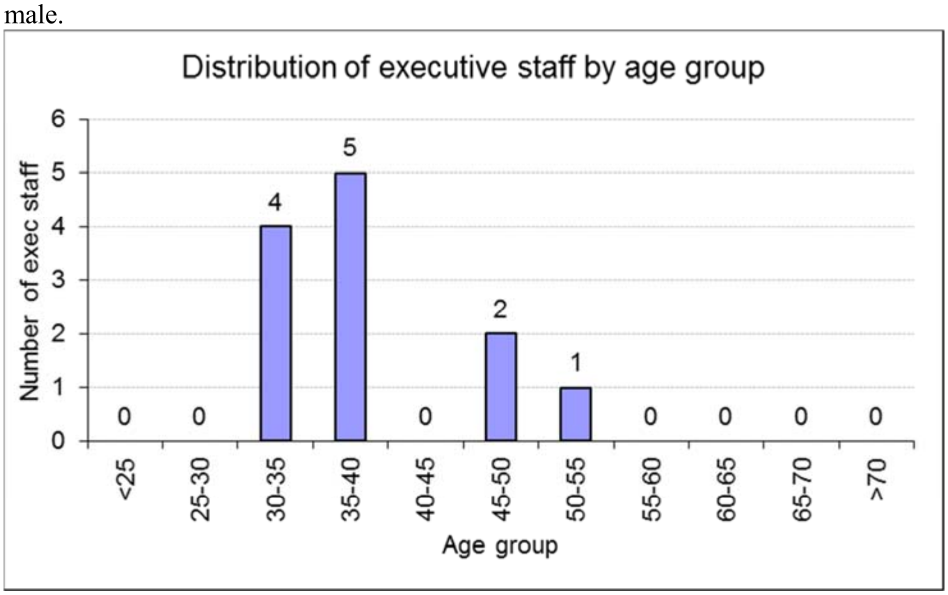

Figure 1 Distribution of the 12 executive staff employed by PNGOPRA per age group

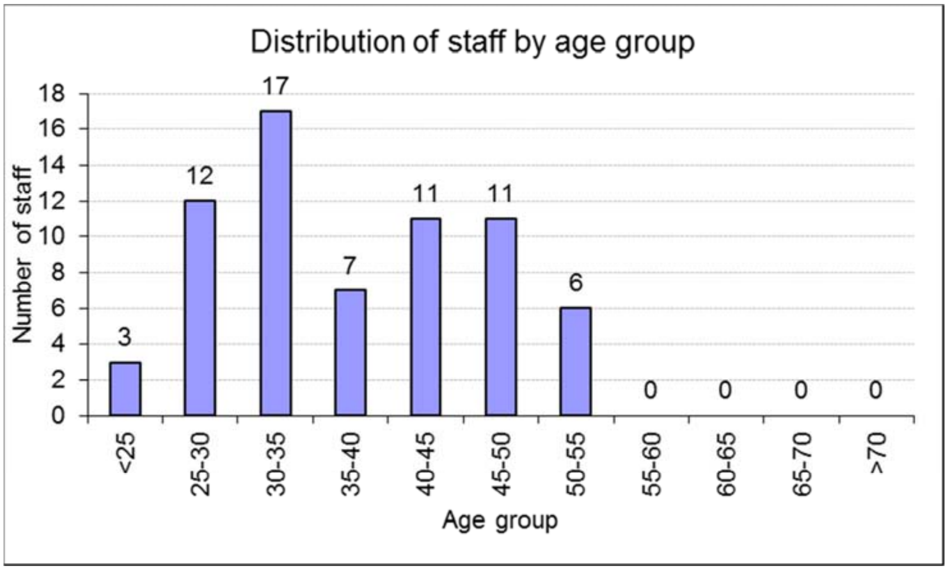

Figure 2 Distribution of the 67 non-executive staff employed by PNGOPRA per age group

RESEARCH IN 2013

In 2013 the research performed by PNGOPRA remains in the same lineage and spirit as previous years. Below each section head for Agronomy, Entomology, Plant Pathology and the Supervisor of Socioeconomics put together their respective section in the annual report.

There were a couple of very good prospects for the industry coming of the research in 2013 that will contribute significantly to the bottom lines ("People, Planet, Profit"):

- First in Entomology where the studies on the introduction of a new pesticide seeking a less toxic alternative to methamidophos for the control of leaf eating insects. Concluding studies indicate that Thiosultap commercialized and known as Dimehypo is as efficient if not more, equally expensive if not cheaper and less toxic than Metamidophos. Further studies 2014 shall confirm the validity of the above and we will drive the registration of Thiosultap as injectable into oil palm insecticide next to the Department of Environment and Conservation of PNG. We hope to phase out methamidophos of the oil palm system in PNG.

- Secondly, coming from Plant Pathology which communicated on the change of practice in sanitation of ganoderma infected plantation. In brief, as this is vastly explained in Oprative technical note 22 April 2014, sanitation must be performed as young as possible to retard the cumulative infected palm level of 5%. Once passed that threshold, census and removal of bracket may be performed but the infection is considered "out of control". However, two years before replant a complete census and sanitation rounds must resume lowering the level of inoculum in the field before replant takes place.

In addition, a SADP project housed between OPIC and PNGOPRA Entomology matured into a guideline to assess river qualities in WNB and Oro bay. The guide produced is of good quality although we fear that the industry might not buy in this method of assessing the general health of the oil palm and surrounding environment couple. SADP discontinued his funding towards this research in December 2012 and subsequently the entomologist involved in that project Brian Kiely was recruited in February 2014 by PNGOPRA. It is recommended that the members that wish to conduct water stream survey contact the entomology section for a refresher/initiation course.

As for the agronomy and socioeconomics, there is much routine work going on as well in traditional fertilizer designs and in household surveys with no noticeable findings. The aided projects have not matured but offer good analyses for the ACIAR sustainability of oil palm system in PNG which converted in three publications. The project on cover crop of Rachel Pipai (Resigned in December 2013) led to interesting science but no new practical recommendation to the industry.

1. AGRONOMY SECTION

HEAD OF SECTION I: DR. MUROM BANABAS

AGRONOMY 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 then communicate the information to the oil palm industry. In addition to optimising yield, activities are in place to determine the long term sustainability of the oil palm system.

The bulk of the work undertaken by the Agronomy team is 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). Trial types vary between the different areas and depend on where the gaps in knowledge are and differences in soil type. However the number of trials has generally been reduced in the NBPOL plantations while several new ones have started during the last 2-3 years in Hargy Oil Palm Plantations. The new trials are planted with consideration of probable progeny effects on the oil palm responses to fertilisers.

a) There are several experiments looking at the effects of different spacing arrangements on yield,
b) effect of reduced density by poisoning on yield and
c) yield monitoring and forecasting.

However the 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 donor funded projects, N Loss and Mg/Cation, were closed and have been (PNGOPRA Annual Reports, 2006 and 2008)reported. There was another donor funded project (ACIAR) that looked at sustainability of oil palm production in PNG that started May 2010 and was closed in 2013. As part of this project, Agronomist Rachel Pipai studied for her masters at University of Adelaide in Australia looking at nitrogen fixation by legume cover crops under the oil palm systems in PNG and submitted her thesis. A short brief of the work she did was reported in the 2012 report. Three papers published from the project are presented in Appendix 3. There were also two other projects that looked into food security in smallholder farming systems. These two projects were funded by AIGS (ARDSF project funded by AusAID) however winded up in April 2012. PNGOPRA and Curtin University commence studies into the food security project in 2014, and will be funded by ACIAR. Another short term study looked into quantifying the amount of dropped loose fruits from ripening bunches during the course of the ripening process.

There was increased involvement in smallholder related activities. There are smallholder fertiliser-demonstration blocks in Hoskins, food security activities have started and are continuing in Oro, Hargy and Poliamba. The collection of leaf tissues for analysis continued in Oro and Hargy and started in Hoskins. Work on fertiliser demonstration blocks in Milne Bay and Poliamba continued and two more new demonstration blocks were started in Poliamba, the aim here is to increase FFB yields in the smallholder sector from 10-15 t/ha/year to >25 t/ha/year. Preparation for a smallholder project looking at diversifying livelihoods of smallholders was initiated by NBPOL Sustainability Department and PNGOPRA was involved.

Across all sites, there was continued involvement with the industry in training. PNGOPRA was involved with OPIC in smallholder field days and radio broadcasts. Trainings were also carried out in the plantations on leaf sampling techniques.

ABBREVIATIONS

AMC	Ammonium chloride (NH4Cl)
AN	Ammonium nitrate (NH4NO3)
ANOVA	Analysis of variance (Statistical test used for factorial trials)
BA	Bunch ash (burnt EFB)
BNO	Number of bunches
cmolc/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, MgSO4)
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 ((NH4)2SO4)
SOP	Potassium sulphate (K2SO4)
TSP	Triple superphosphate (mostly calcium phosphate, CaHPO4)

Methods of soil chemical analysis done for the trials are presented in Table 7.

Table 7 Soil analytical methods used (Hill Laboratories, NZ)

Parameter	Method
Preparation	Air dried at 350C 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 K2PO4 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 NH4+
Organic S	0.02 M K2 PO4 extraction followed by ICP-OES for total S, then subtraction of sulphate-S
Sulphate-S	0.02 M K2PO4 extraction followed by ion chromatography
Hot water soluble B	0.01IM CaCI2 extraction, det. By ICP-OES
Organic matter	Dumas combustion. Calculated at 1.72 x total carbon

HARGY OIL PALM LIMITED

(Susan Tomda, Andy Ullian and Peter Mupa)

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

Trial 205 was initially established to provide information for fertilizer recommendations in the deep fertile soils at Hargy. The trial ceased at the end of 2012 however a number of plots were selected to monitor the rate of nutrient depletion after fertilizer application is stopped. This will provide information for fertilizer recommendations 3-4 years before replanting and also for the first 3 years after the replanting. After a year of no fertilizer addition, there was no effect on yield and leaf tissue nutrient contents. It was recommended the trial continued until replant.

Introduction

Trial 205 was initially established to investigate the response of oil palm to applications of EFB and nitrogen fertilisers, After the trial was closed in 2012, it was proposed that fertiliser treatments were to cease and a number of plots were to be monitored in 2013 and up until replant. This was to investigate the rate of nutrient depletion and use the information to assist fertiliser recommendations 3-4 years before and after the replant in this soil environment.
The background information is shown in Table 8 .

Table 8 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	21 years	Altitude	135 m asl
Treatments 1st applied	June 1997	Previous Land-use	Oil Palm
Progeny	Known*	Area under trial soil type (ha)	17.70
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

Materials and Method

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 factorialdesign, replicated three times resulting with 48 plots. The fertiliser treatments ceased at the end of 2012 and in 2013, 9 plots of different fertiliser combinations were chosen for monitoring (Table 9).

Table 9 Trial 205 Selected plots for monitoring with fertiliser treatment rates up to 2012

Plot	Fertilisers (kg/palm/year)			
	AN	TSP	KIE	EFB
6	2.3	0	0	0
11	4.6	0	3	0
12	4.6	3	0	0
13	4.6	3	3	0
16	4.6	3	0	230
25	4.6	0	3	230
43	4.6	0	0	230
45	4.6	0	0	0
46	4.6	3	3	230

Data Collection

Yield data, leaf sampling for nutrient analysis and vegetative measurements were carried out during the year (Appendix)

Results

FFB yield

FFB yields results from 2011 and 2012 which had fertilizer treatments applied and in 2013 after fertilizer treatments ceased at the end of 2012 are presented in Table 10. There was no clear indication of yield falling after a year of no fertilizer. For example in plot 6 with low AN, yield was 27.0 t/ha in 2013 compared to 26.4 and 25.9 t/ha in 2011 and 2012 respectively. On the other hand, plot 46 with all the fertilizers showed lower yield in 2013 than in 2011 and 2012.

Table 10 Trial 205 FFB yield in 2011, 2012 and 2013.

Plot	Fertiliser rates (kg/palm/year)				FFB yield (t/ha)		
	AN	TSP	KIE	EFB	2011	2012	2013
6	2.3	0	0	0	26.4	25.9	27
11	4.6	0	3	0	24.3	28.1	28
12	4.6	3	0	0	26.3	26.3	27.6
13	4.6	3	3	0	27.6	26.7	24.7
16	4.6	3	0	230	26.1	25	25.3
25	4.6	0	3	230	28.3	28.3	30.6
43	4.6	0	0	230	27.6	28.1	26.9
45	4.6	0	0	0	28.5	27.7	28.3
46	4.6	3	3	230	29	29	26.1
GM					27.1	27.2	27.2
Std dev					1.46	1.31	1.78
CV %					5.4	4.8	6.5

Effect of fertilizer treatments on leaf tissue nutrient concentration in 2013

The leaflet and rachis nutrient contents are presented in Table 11. Plots that received high AN rates had higher leaflet N and low rachis N contents compared to Plot 6 which received a low AN rate. However the same was not seen with TSP (effect on leaf P), Kieserite (effect on leaf Mg) and EFB (effect on leaf K), The differences in the contents of these nutrients cannot be explained by the different fertiliser rates received in the past years except for AN and N contents, On the whole, the analysed nutrients were above the critical levels except for leaflet Mg contents.

Table 11 Trial 205 Leaf tissue nutrient contents from selected monitored plots in 2013

Plot	Fertilisers (kg/palm/year)				Leaflets (% DM)				Rachis (% DM)		
	AN	TSP	KIE	EFB	N	P	K	Mg	N	P	K
6	2.3	0	0	0	2.37	0.136	0.61	0.17	0.68	0.121	1.42
11	4.6	0	3	0	2.47	0.138	0.67	0.22	0.42	0.069	1.74
12	4.6	3	0	0	2.45	0.14	0.65	0.21	0.38	0.08	1.7
13	4.6	3	3	0	2.53	0.142	0.67	0.24	0.47	0.063	1.38
16	4.6	3	0	230	2.52	0.145	0.71	0.22	0.39	0.084	1.54
25	4.6	0	3	230	2.46	0.141	0.65	0.16	0.41	0.063	1.7
43	4.6	0	0	230	2.51	0.141	0.69	0.18	0.41	0.074	1.78
45	4.6	0	0	0	2.52	0.143	0.61	0.18	0.37	0.072	1.74
46	4.6	3	3	230	2.57	0.143	0.65	0.25	0.35	0.056	1.38
Mean					2.49	0.141	0.66	0.2	0.43	0.08	1.6
Std dev					0.06	0	0.03	0.03	0.1	0.02	0.17
CV(%)					2.35	1.94	5.03	16.01	23.12	23.85	10.47

Conclusion

Yield and leaf tissue nutrients were not affected a year after fertiliser was stopped in well fertilised plantations on deep fertile soils, It is recommended for this trial to continue until replant.

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

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

Factorial fertiliser trials in WNB have not shown any consistent responses to N fertiliser since the 1980’s. The reasons given for this lack of response were that fertilisers were either moving from one plot to the other or were taken up from the neighboring plots via the oil palm extensive root system. This trial was designed to have fertiliser treatments systematically arranged to minimise effects of nutrient movements and or taken up by neighboring palms. Trial 211 trial was started in 2001 on 3 year old palms at Navo volcanic ash soils to generate information annually to assist fertiliser recommendations for palms in Navo area. AN significantly increased yield and yield components, most leaf tissue nutrient contents and LAI and dry matter production in 2013. Depending on the palm oil price and cost of production, the recommended N fertiliser rate is between 0.75 and 1.00 kg N/palm/year.It is recommended this trial continue.

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 incontrol plots were generally higher than it would be expected. It was suspected that fertiliser may bemoving from plot to plot and or nutrients were poached from the neighboring plots. Large plots, guard rows and trenches between plots were introduced to avoid movement of nutrients between plots, but a lack of or inconsistent response persisted for duration of these trials. 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 generate fertiliser response information for fertiliser recommendations in Navo Plantation and neighboring plantations on similar soil types. Trial background information is presented in Table 12.

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	15 years	Altitude	164 m asl
Treatments 1st applied	Nov 2001	Previous Land-use	Sago and forest
Progeny	Unknown	Area under trial soil type	37.16 ha
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

Methods

Experimental Design and Treatments

This trial was established at Navo Plantation in 2001. The systematic design had 9 rates of N replicated 8 times, resulting in 72 plots. For each replicate, 9 treatments were systematically allocated to 72 plots. The rates applied increase from 0 to 2kg N/palm with 0.25kg N/palm increments (Table 13). The trial was designed such that in each adjacent replicate block the N rates increase or decrease systematically. Each plot consisted of 4 rows of recorded palms with 13 palms each resulting in 52 palms/plot.

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

Table 13 Trial 211 Nitrogen treatments and rates in kg/palm/year

N Fertiliser Code	N0	N1	N2	N3	N4	N5	N6	N7	N8
Ammonium Nitrate	0	0.74	1.48	2.22	2.96	3.7	4.44	5.18	5.92
N rate (equivalent)	0	0.25	0.5	0.75	1	1.25	1.5	1.75	2

Data Collection

Yield recording, physiological growth measurements and leaf tissue sampling were done as per the standard trial management SOP (Appendix)

Statistical Analysis

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

Results

Effects of treatments on FFB yield and its components

N fertiliser treatment had a significant effect ($p<0.001$) on FFB and its components in 2013 and the combined 2011-2013 period (Table 14). FFB yield increased with N rate from 27.4 at nil N to a maximum of 36.9 t/ha/year in 2013. Yield also increased with N rate in 2011-2013 (Table 14). Effect of N fertilizer was consistent on FFB yield and its components since 2004 (Figure 3).

Table 14 Trial 211 main effects of N rate treatments on FFB, yield (t/ha), bunch number (b/ha) and single (SBW) (kg/bunch) for 2013 and 2011-2013

		2013			2011-2013		
N rate (kg/palm)	Equivalent AN rate (kg/palm)	FFB yield (t/ha)	BHA	SBW (kg)	FFB yield (t/ha)	BHA	SBW (kg)
0.00	0.00	**27.4**	**1301**	**21.0**	**28.2**	**1321**	**21.3**
0.25	0.74	**30.1**	**1372**	**21.9**	**31.2**	**1404**	**22.2**
0.50	1.48	**31.0**	**1375**	**22.6**	**32.7**	**1435**	**22.8**
0.75	2.22	**32.9**	**1432**	**23.0**	**35.0**	**1507**	**23.2**
1.00	2.96	**34.9**	**1505**	**23.2**	**36.5**	**1564**	**23.4**
1.25	3.7	**35.6**	**1509**	**23.6**	**37.5**	**1573**	**23.8**
1.50	4.44	**36.1**	**1558**	**23.2**	**37.1**	**1586**	**23.4**
1.75	5.18	**36.9**	**1584**	**23.3**	**38.6**	**1627**	**23.7**
2.00	5.92	**35.3**	**1528**	**23.1**	**37.3**	**1593**	**23.4**
L.S.D $_{0.05}$		*2.73*	*121.3*	*0.89*	*2.74*	*95.9*	*0.81*
Significance		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
GM		33.4	1463	22.8	34.9	1512	23.0
CV%		8.2	8.3	3.9	7.9	6.3	3.5

P values <0.05 are in bold

Yield response over time

There were significant responses to effects of the N treatments over time (2004-2013) with yield performing above 30t/ha (Figure 3). Since 2002, the nil N fertilized continued to produce the lowest yield though greater than 25 t/ha/year while fertilized plots retained yields at greater than 30 t/ha/year. The yield gaps between the different N fertilizer rates also widened with time.

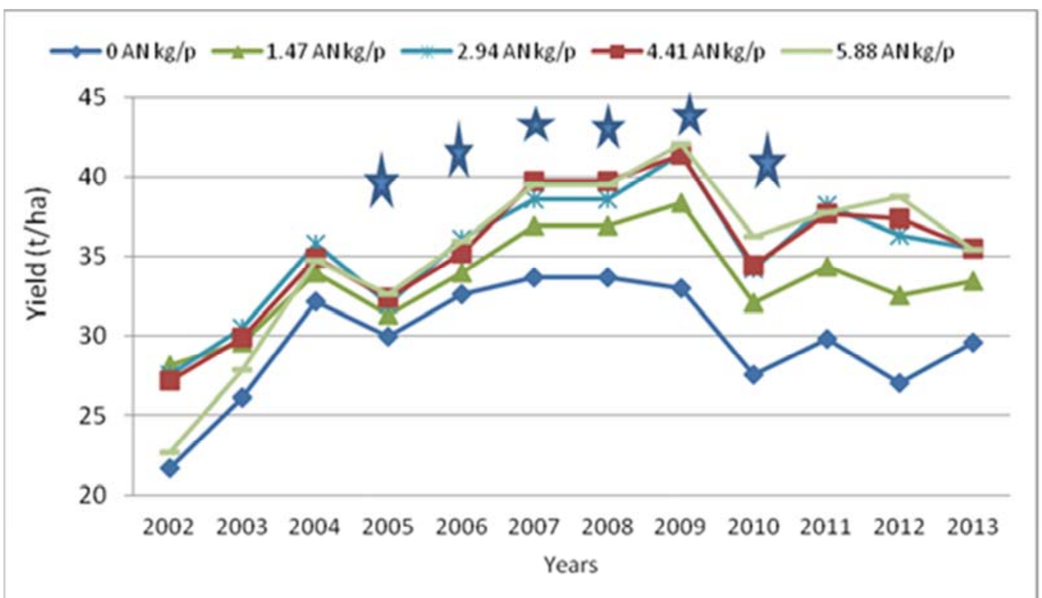

Figure 3 Trial 211 Yield trend from 2002 to 2013 for 5 rates of N (kg/palm) with higher rate of 1.47 AN kg /palm – 5.88kg AN/palm maintaining above 30t/ha after 5 years of maturity (2004). Years with a star indicate a significant difference between treatments. Note: in 2004 the palms were 6 years old.

The relationship between average FFB yield for 2011 to 2013 and N rates is presented in Figure 4. The R squared of 0.98 suggested a very strong quadratic relationship between N rate FFB yield. At zero N, yield was 28.2 t/ha/year, which was high for many oil palm growing environment. A negative coefficient of the quadratic component of the curve implied yield response decreased with N rates,. The flat nature of the curve implied that at higher rates, a unit change in N rate would not really affect the response to N. The flat nature of the curve implied that the soil was inherently fertile however could also imply that another factor was limiting response to AN.

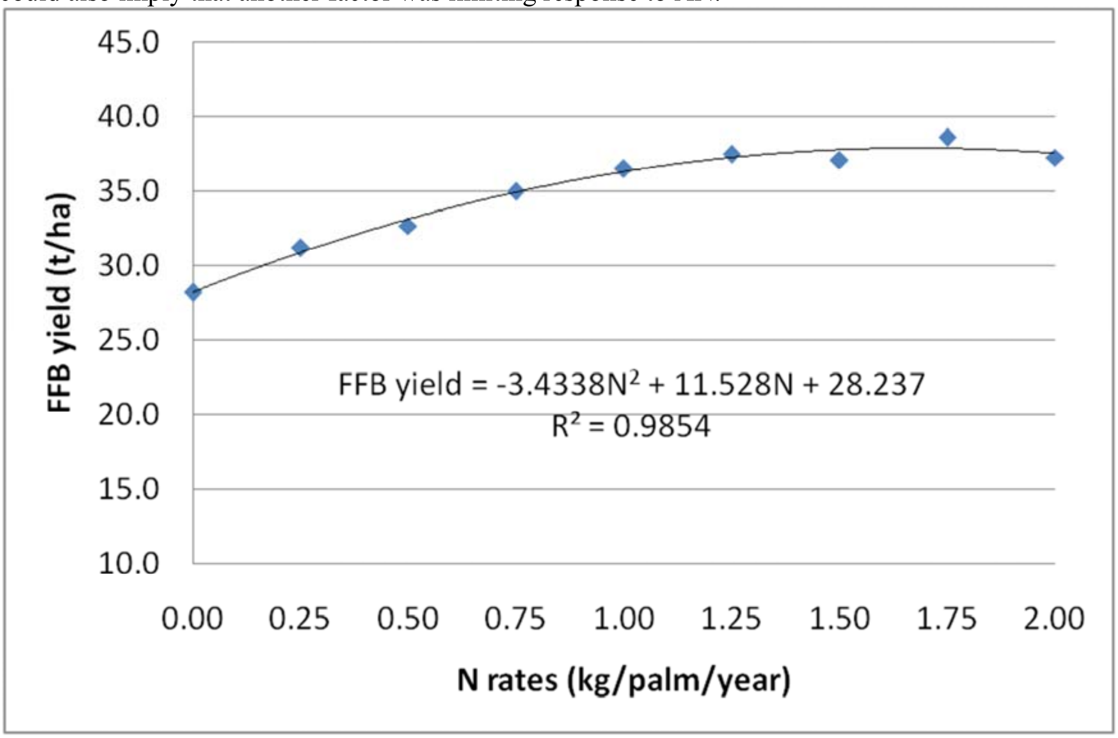

Figure 4 Trial 211 N rates and FFB yield response curve for 2011-2013

Effects of treatments on leaf tissue nutrient concentrations

The effect of N fertilizer on leaf tissue nutrient contents in 2013 is presented in. AN increased leaflet N ($p<0.001$), P ($p<0.001$), and rachis N ($p=0.008$) contents. However AN also decreased leaflet Mg ($p<0.001$), B ($p=0.04$) and rachis P ($p=0.05$) contents.

Table 15 Trial 211 effects of N rate treatments on leaf tissue nutrient (% DM except B mg/kg) concentrations in 2013

N rates	Equivalent AN rates	Leaflet nutrient contents (% DM)					Rachis nutrient contents (% DM)		
		N	P	K	Mg	B	N	P	K
0.00	0.00	**2.18**	**0.130**	**0.67**	**0.23**	**20**	**0.30**	**0.100**	**2.04**
0.25	0.74	**2.2**	**0.131**	**0.68**	**0.21**	**20**	**0.29**	**0.110**	**2.13**
0.50	1.48	**2.29**	**0.133**	**0.69**	**0.18**	**19**	**0.29**	**0.090**	**1.97**
0.75	2.22	**2.34**	**0.136**	**0.69**	**0.17**	**18**	**0.29**	**0.080**	**1.95**
1.00	2.96	**2.41**	**0.137**	**0.7**	**0.16**	**18**	**0.30**	**0.080**	**1.93**
1.25	3.70	**2.45**	**0.139**	**0.71**	**0.16**	**18**	**0.31**	**0.080**	**2.00**
1.50	4.44	**2.44**	**0.139**	**0.71**	**0.16**	**18**	**0.32**	**0.080**	**2.02**
1.75	5.18	**2.49**	**0.141**	**0.71**	**0.16**	**19**	**0.32**	**0.090**	**1.93**
2.00	5.92	**2.51**	**0.142**	**0.72**	**0.16**	**18**	**0.33**	**0.080**	**1.92**
L.S.D $_{0.05}$		*0.05*	*0.004*	*0.04*	*0.02*	*1.67*	*0.027*	*0.021*	*0.21*
Significance		p<0.001	p<0.001	p=0.22	p<0.001	p=0.04	p=0.008	p=0.054	p=0.55
GM		2.37	0.136	0.70	0.17	19	0.31	0.09	1.90
SE		0.05	0.04	0.04	0.02	1.66	0.027	0.021	0.21
CV %		2.1	3.6	5.4	11.2	8.9	8.8	23.7	10.5

P values less than 0.05 are in bold

Response curve between N fertilizer rates and leaflet N contents

The response curve for N rates and leaflet N contents is presented inFigure 5. The N content was averaged for 2009 to 2013 to minimize year to year variations. There was a very strong quadratic relationship between N rates and leaflet N contents with an R2 of 0.94. Leaflet N content was below 2,35 % DM at 0.75 kg N/palm/year. The curve flattened after about 1.00 kg N/palm/year and leaflet N content was at 2.40 % DM. Increase in N rate after 1.0 kg N/palm/year caused smaller increase in N content.

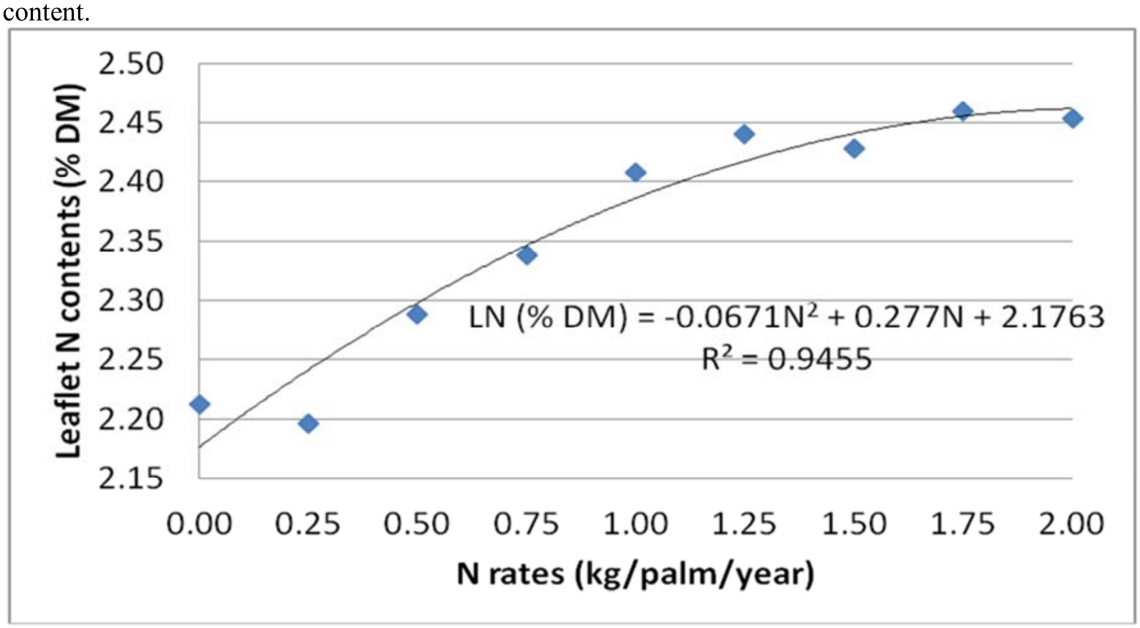

Figure 5 Trial 211 Relationship between N rates and leaflet N content averaged for 2009 to 2013.

Fertiliser effects on vegetative growth parameters in 2013

Effect of AN of physiological growth parameters are presented in with the abbreviations at the bottom of the table. AN significantly increased FA, LAI, FDM, BDM TDM and VDM (Table 16). For instance, FA increased from 11.2 m^2 in nil fertilized plot up to 13.2 m^2 at 2 kg N rate. The significant increase in FA and LAI resulted in significant increases in the dry matter production parameters. Of the TDM, half the dry matter was BDM with BI values close to 0.50.

Table 16 Trial 211 main effects of N treatments on vegetative growth parameters in 2013

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**	**BI**
0.00	0.00	40.0	32.3	23.7	**11.2**	**4.2**	**11.8**	**14.5**	**29.2**	**14.7**	**0.50**
0.25	0.74	38.3	32.2	24.7	**12.3**	**4.6**	**11.7**	**15.9**	**30.6**	**14.8**	**0.52**
0.50	1.48	43.4	32.2	25.7	**12.5**	**4.6**	**13.8**	**16.3**	**33.4**	**17.1**	**0.49**
0.75	2.22	43.9	33.6	25.8	**13.9**	**5.4**	**13.9**	**17.3**	**34.6**	**17.4**	**0.50**
1.00	2.96	45.5	33.2	25.5	**14.3**	**5.5**	**14.2**	**18.4**	**36.2**	**17.8**	**0.51**
1.25	3.70	43.6	33.5	25.5	**13.7**	**5.3**	**14.4**	**18.8**	**36.9**	**18.1**	**0.52**
1.50	4.44	44.7	34.3	25.8	**13.6**	**5.4**	**13.8**	**19**	**36.4**	**17.4**	**0.52**
1.75	5.18	48.9	33.8	25.2	**13.9**	**5.4**	**14.3**	**19.5**	**37.6**	**18.1**	**0.49**
2.00	5.92	50.0	34.2	26.5	**13.2**	**5.2**	**15.9**	**18.7**	**38.4**	**19.7**	**0.50**
L.S.D $_{0.05}$					*1.28*	*0.58*	*2.36*	*1.42*	*3.54*	*2.69*	*0.033*
Significance		p=0.09	p=0.038	p=0.169	**p<0.001**	**p<0.001**	**p=0.02**	**p<0.001**	**p<0.001**	**p=0.01**	**p=0.402**
GM		44.1	33.3	25.5	13.2	5.1	13.7	17.6	34.8	14.6	**0.5**
SE		6.646	1.603	1.886	1.28	0.583	2.363	1.417	3.55	2.691	**0.033**
CV %		15.2	4.8	7.4	9.7	11.6	17.2	8.1	10.2	15.6	**6.6**

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)

In Figure 6, the relationship between N rates and LAI is presented. The curve plateaued after 0.75 kg N/palm/year. The optimum rate for LAI to be above 5.0 was at 0.75 kg/palm/year.

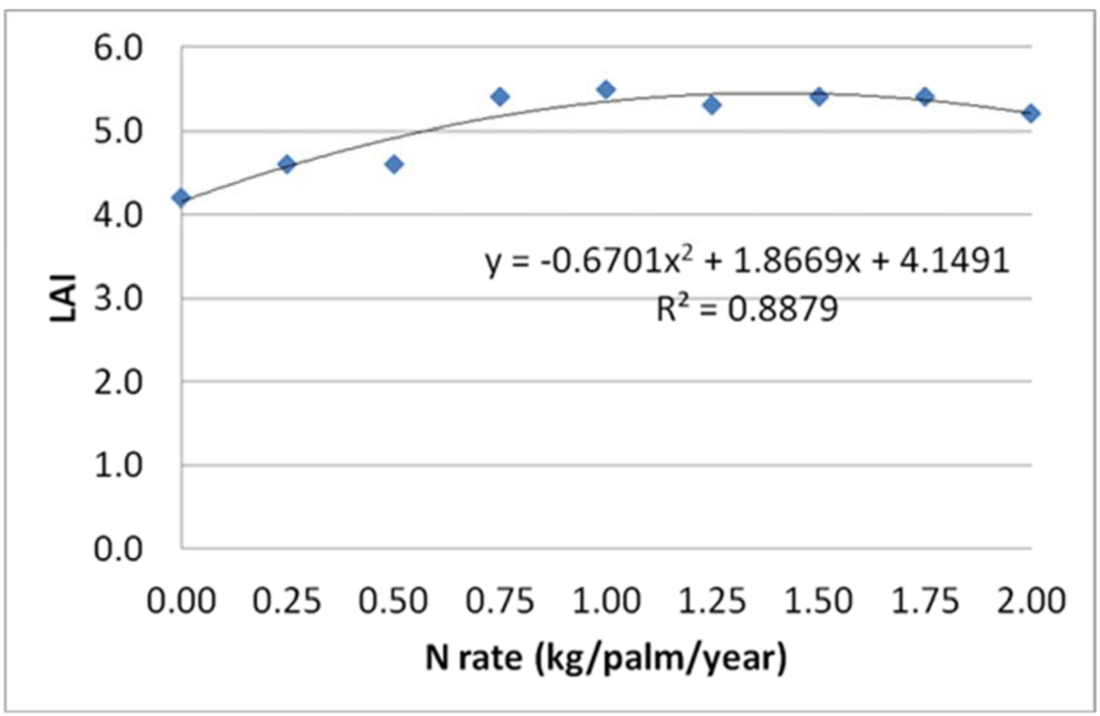

Figure 6 Trial 211 Relationship between N rate and LAI in 2013

Conclusion

The optimum N rate for FFB production at Navo is between 0.75 and 1.0 kg N/palm/year which is 2-3 kg AN. It is recommended that rates for fertilizers in this environment on annual basis is within these

2 rates depending the palm oil prices and other related cost of production. Rates lower than 2 kg AN/palm could lower leaflet N contents to fall below 2.35 % DM and reduce yield in subsequent years while rates greater than 3 kg AN will result in small or no yield benefit. It was recommended this trial continue.

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

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

Factorial fertiliser trials in WNB have not shown any consistent responses to N fertiliser since the 1980's. The reasons given for this lack of response were that fertilisers were either moving from one plot to the other or were taken up from the neighbouring plots via the oil palm extensive root system. This trial was designed to have fertiliser treatments systematically arranged to minimise effects of nutrient movements and or taken up by neighbouring palms. Trial 212 trial was started in 2002 on 6 year old palms at Hargy volcanic ash soils to generate information annually to assist fertiliser recommendations for palms in Hargy area. AN significantly increased yield and yield components, most leaf tissue nutrient contents and LAI and dry matter production in 2013. Depending on the palm oil price and cost of production, the recommended N fertiliser rate is between 0.75 and 1.00 kg N/palm/year. It was recommended this trial to be closed

Introduction

This trial was established for the same reasons as were for Trial 211 at Navo Plantation, however Trial 212 was set up to provide information for fertilizer recommendations at Hargy Plantation. Trial information is presented in Table 17.

Table 17 Trial 212 Background Information

Trial number	212	Company	Hargy Oil Palms Ltd.
Estate	Hargy	Block No.	Area 8, Blocks 10 & 11
Planting Density	140 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Free draining
Date planted	Feb 1996	Topography	Moderate slope
Age after planting	17 years	Altitude	103 m asl
Treatments started	2002	Previous Land use	Oil palm
Progeny	Unknown	Area under trial soil type (ha)	18.08
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

Materials and methods

Experimental Design and Treatments

The trial design is similar to Trial 211 however in Trial 212 there are 2 rows of 15 core palms each (30 palms/plot) which are recorded and one guard row palm at both ends (3-4 guard row palms in a plot). All data collection, fertilizer applications and data analysis were similar to Trial 211.

Results

Effects of treatment on FFB yield and its components

AN significantly increased FFB yield and yield components in 2013 and 2011-2013 except for bunch numbers in 2013 (Table 18). FFB yield increased from 26 t/ha in nil N fertilised plots up to a maximum of 30.6 t/ha at 1.5 kg N/palm/year fertilised plots in 2013. A similar significant increase in yield response was seen for the average 2011-2013 yields as well.

Table 18 Trial 212 main effects of N treatments on FFB yield (t/ha) for 2013 and 2011-2013

		2013			2011-2013		
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	0.00	**26.0**	1110	**23.5**	**26.5**	**1139**	**23.3**
0.25	0.74	**26.4**	1098	**24.0**	**26.1**	**1101**	**23.8**
0.50	1.48	**29.3**	1177	**25.0**	**29.0**	**1172**	**24.7**
0.75	2.22	**29.8**	1158	**25.9**	**29.4**	**1159**	**25.4**
1.00	2.96	**29.6**	1110	**25.8**	**29.6**	**1137**	**26.1**
1.25	3.70	**30.2**	1149	**26.0**	**30.7**	**1202**	**25.6**
1.50	4.44	**30.6**	1165	**25.7**	**31.9**	**1238**	**25.8**
1.75	5.18	**30.5**	1191	**26.1**	**31.0**	**1202**	**25.9**
2.00	5.92	**29.6**	1170	**25.3**	**31.5**	**1242**	**25.4**
L.S.D $_{0.05}$		*2.63*	*114.6*	*1.35*	*2.16*	*92.6*	*1.14*
Significance		p=0.003	p=0.802	p<0.001	p<0.001	p=0.05	p<0.001
GM		29.1	1154	25.3	29.5	1177	25.1
SE		2.63	114.7	1.35	2.16	92.7	1.14
CV %		9.0	9.9	5.4	7.3	7.9	4.6

P values <0.05 are shown in bold

The relationship between N rates and averaged FFB yield data for 2011-2013 is shown in Figure 7. There was a strong relationship between N rates and FFB yield with an R2 of 0.91. However the curve was relatively flat and yield increase after 0.50 kg N/ha/year was comparatively small.

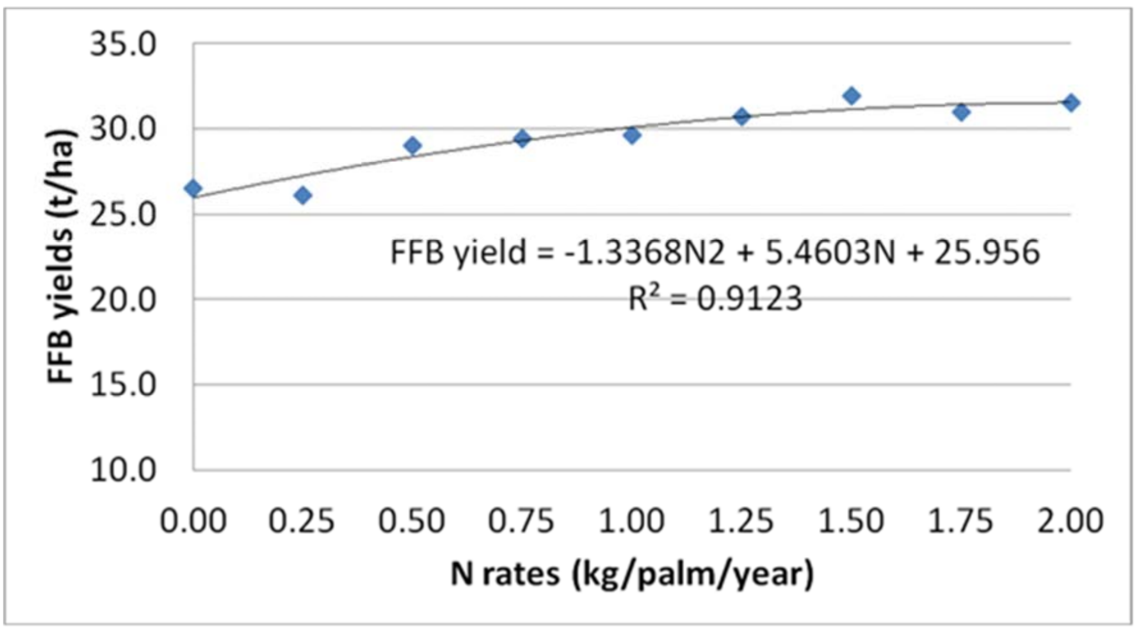

Figure 7 Trial 212 FFB yield response curve with N rates for 2011-2013

Yield response over time

Yield responses to AN rates started two years after the trial commenced in 2002. The yield gap between nil fertilized and fertilized plot widened but generally remained parallel throughout the duration of the trial (Figure 8).

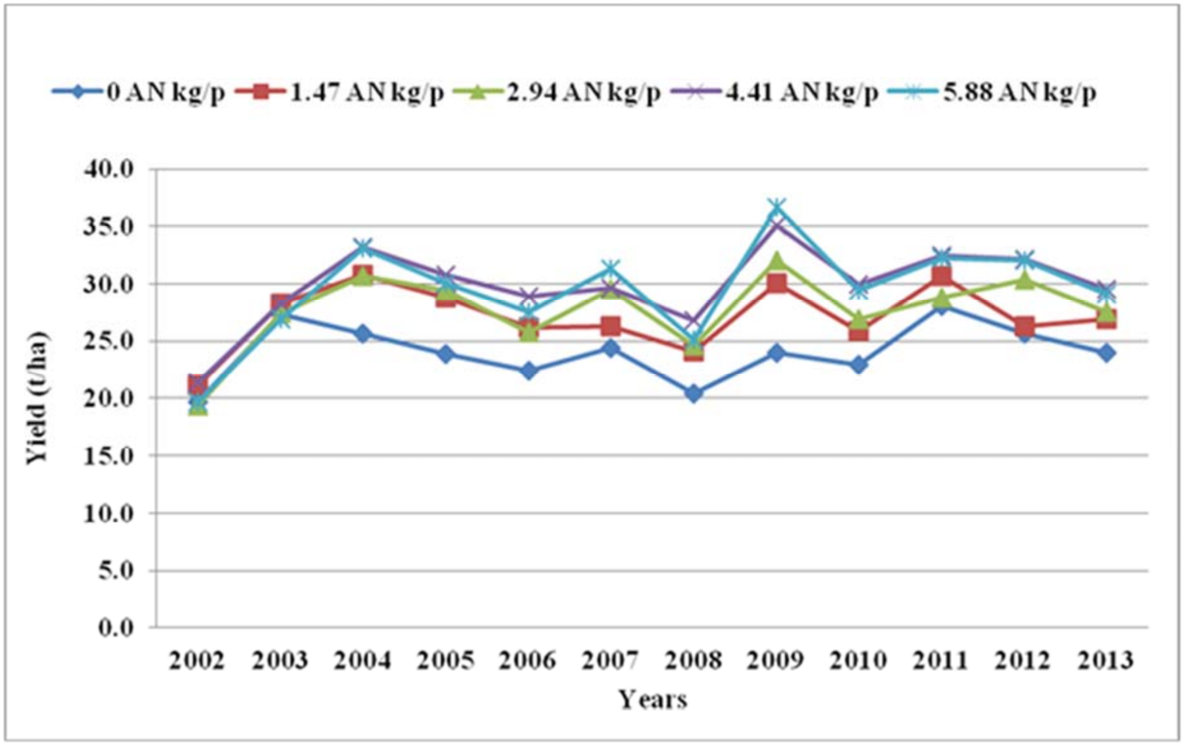

Figure 8 Trial 212 Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in 2002

Effects of fertiliser treatments on vegetative parameters

In 2013, AN increased BDM (p=0.004) and TDM (p=0.02) but did not affect the other physiological growth parameters (Table 19). This contrast to Trial 211 which showed most of the parameters being increased by AN.

Table 19 Trial 212 main effects of treatments on vegetative growth parameters in 2013

N rate	Equiv. AN rate	Radiation Interception					Dry Matter Production (t/ha/year)				
(kg/palm/year)		PCS	GF	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
0.00	0.00	46.4	33	21	14.2	6.6	14.5	**14.0**	**33.9**	17.7	0.46
0.25	0.74	46.5	34	20	14.2	6.9	14.0	**14.3**	**31.7**	17.2	0.44
0.50	1.48	49.6	34	21	15.2	7.3	14.8	**15.9**	**31.4**	18.2	0.45
0.75	2.22	51.2	35	20	15.4	7.4	15.5	**16.0**	**34.2**	19.0	0.47
1.00	2.96	51.7	35	20	14.9	7.3	15.6	**15.7**	**35.0**	19.0	0.46
1.25	3.70	48.3	35	21	14.4	7.1	14.8	**16.0**	**34.7**	18.2	0.47
1.50	4.44	49.3	34	20	14.8	6.8	14.7	**16.0**	**34.2**	18.1	0.47
1.75	5.18	50.2	35	21	14.7	7.3	15.4	**16.8**	**34.0**	18.9	0.46
2.00	5.92	52.0	35	21	14.4	7.1	15.8	**15.6**	**35.0**	19.2	0.45
L.S.D $_{0.05}$								*1.51*	*2.504*		
Significance		NS	NS	NS	NS	NS	NS	0.04	0.02	NS	NS
GM		49.7	34	21	14.7	7.1	15	15.5	33.9	18.4	0.46
SE		4.286	1.672	1.836	1.206	0.603	1.871	1.508	2.506	2.066	0.039
CV %		8.7	4.9	9.0	8.2	8.5	12.5	9.7	7.4	11.2	8.4

Significant effects (p<0.05) are highlighted in bold.
PCS = Petiole cross-section of the rachis (cm2); GF = number of green fronds (fronds per palm); FP = annual frond production (new fronds/year); FA = Frond Area (m2); 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).

Conclusion

The optimum N rate for FFB production at Hargy is between 0.5 and 0.75 kg N/palm/year which is 1.5-2.2 kg AN. It is recommended that rates for fertilizers in this environment on annual basis is 1.5 kg AN/palm/year but adjusted with results of leaf tissue results from the LSU. This trial was recommended for closure towards the end of 2013.

Trial 214: Phosphorous (TSP) Fertiliser Placement Trial on Volcanic soils, Hargy Plantation

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

The soils at Hargy have very high P retention capacity due to high allophonic clay mineral content. This affects P availablitiy in the soils for crop uptake which can be a limiting factor to crop production in Hargy soils. The trial was established in Hargy (Area 4) to identify the best P rate and placement option which will be used for fertiliser management on these very high P retention soils. Todate there was no response to the treatments. The reason for no response was probably due to soil clay minerals retaining phosphate ions . Therefore in 2012, TSP rates were doubled in 2012 with the view to saturate the clay mineral surfaces and make excess P available for uptake. It was recommended the trial continue.

Introduction

The trial was originally set up as a Magnesium trial in 2007, however 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.

The soils at Hargy have high contents of allophanic clay minerals which result in soils having greater than 90% P retention values. The topsoil at the site contained 6 – 8 % allophane (high) and the subsoil around 12 % (very high). The allophane binds phosphate, making it unavailable for plant uptake.).Organic matter form complexes with clay minerals and reduce P retention capacity of soils. The purpose of this trial was to see if P is applied onto the frond piles where organic matter content is high, will enable palms to take up P. This compared with applying P in the weeded circle which have less organic matter input. The TSP rates were doubled in 2012 with the view that earlier rates were low and were retained by the soils.

The initial work on pre-treatment data and soil samples were collected in 2007. The application of treatment fertilisers was done in October 2008. Trial background information is provided inTable 20.

Table 20 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	19 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 in charge	Susan Tomda

Materials and Methods

Experimental design and Treatment

The trial has a structure treatment of 5 levels of TSP fertiliser applied in zones (WC- weeded circle and FP- frond pile) around the palms in each plot (Table 21). Treatment fertilisers are applied in split application every year. The TSP rates were doubled in 2012. 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 21 Trial 214 fertiliser treatments and placement information. In brackets are rates from 2007 to 2011

		Details				
Levels		1	2	3	4	5
Rates (kg/palm/year) and Placement		0.0 (0.0) Nil	2.0 (1.0) WC	2.0 (1.0) FP	4.0 (2,0) WC	4.0 (2.0) FP

Trial management, data collection and analysis

Refer to Appendix

Results

TSP rates and placement did not affect yield and yield components in both 2013 and 2011-2013 (Table 22). Effect of TSP on yield was insignificant since 2008 however data not presented here. The effect of treatments on physiological growth parameters were also insignificant in 2013 and are not presented here as well.

Table 22 Trial 214 main effects of AN on yield and yield components in 2013 and 2011-2013

Treatment levels	P rates and placement (kg/palm/yr)	2013 Yield (t/ha)	2013 BHA	2013 SBW (kg)	2011-2013 Yield (t/ha)	2011-2013 BHA	2011-2013 SBW (kg)
1	0 – Control	27.2	1170	23.2	24.2	1013	23.9
2	2 – WC	25.5	1076	23.8	25.0	1029	24.4
3	2 – FP	27.5	1201	22.8	25.0	1057	23.6
4	4 – WC	25.2	1063	23.7	25.0	1009	24.9
5	4 – FP	26.1	1186	22.0	25.6	1097	23.4
Significance		ns	ns	ns	ns	ns	ns
GM		26.3	1139	23.1	25	1041	24
SE		4.2	162.8	1.36	3.23	114.988	1.44
CV %		16.0	14.0	6.0	13.0	11.0	6.0

Conclusion

The responses to TSP fertilizer would be expected in the next several years after the high TSP rates saturate the soil mineral surfaces and become available for crop uptake. The high allophane content appears to be holding onto the P. It was recommended the trial continue with the increased TSP rates.

Trial 216: N x P x K Trial on Volcanic soils at Barema Plantation

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

The soils at Barema are inherently very low in fertility because it is formed on old river bed. It is characterized by sand and river gravel and has low nutrient retention capacity. The trial started in 2013 with a composite design to develop fertilizer response curves for fertilizer management decisions on this particular soil type. It is still premature for any responses to be seen and it is recommended the trial continue.

Introduction

Soils in Barema Plantations are different from rest of the areas in Bialla. The soils are formed on aold river bed. The inherent soil fertility of the old river bed soil is very low and with the coarse nature of the materials,nutrients are highly prone to leaching.The soils are suitable for oil palm production however, the soil has little or no capacity to hold onto applied nutrients.Because of the poor native fertility of this soil type it is also likely that oil palm would be highly responsive to applied nutrients. A composite designed trial was proposed for the site to provide information for fertilizer recommendations in this soil type. Trial information is presented inTable 23.

The trial was set out in March 2009 where unknown progenies of 2 year olds were growing in the field. 24 plots were marked out and the 16 core palms were removed and replaced with four known commercial progeny palms (Dami Bunch Reference: 0710226N; 0791065N; 0791195C and 0709668C). Yield recording started in December 2012 and commenced fertiliser treatments in March 2013.

Table 23 Trial 216 background information

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	4 years	Altitude	40 m asl
Recording Started Treatment started	Dec 2012 May 2015	Previous Land-use	Forest
Progeny	Known*	Area under trial soil type (ha)	10.7
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

Materials and Methods

Experimental Design and Treatment

Four known Dami progenies were identified and /selected on yield performance (and planted randomly in each plot. A total of 50 plots were planted and 24 were selected for the trial. Each plot has 16 monitored palms with 20 guard palms, giving a total of 36 palms per plot.

The N P K trial was set up as a 3 x 3x 3 Central Composite arrangement, resulting in 24 treatments (randomly allocated into three blocks (Table 24). Palms that were not in plots but were in the same block were termed perimeter palms, and were fertilized according to plantation practice. The trial area received a basal application of borate at 50 g/palm/year in the initial plantings.

The first treatment commenced in May 2013 with basal application of fertiliser. Due to availability of AC as form of Nitrogen used by Hargy Plantation, equivalent rate of AN was used instead. The treatments were split into two applications per year. In 2013, a basal application of Borate (0.150 kg/palm) was applied.

Table 24 Trial 216 fertiliser levels and rates

Fertiliser treatment	Fertiliser requirement in kg /palm/year				
	Level 1	Level 2	Level 3	Level 4	Level 5
N (as AN)	0.77	1.68	3.06	4.44	5.35
K (as MOP)	0.00	1.00	2.50	4.00	5.00
P (as TSP)	0.00	0.40	1.00	1.60	2.00

Data Collection

Field trial management, data collection and quality standards are referred to in the Appendix 1.

Statistical Analysis

Linear multiple regression is used to analyze the yearly influence of fertiliser N, P and K on yield and the other measured parameters. In the regression equation (Equation 1), yield is the dependent variable, and the N, P and K fertilisers are the independent variables. The equation used is:

$$Yield = a + bN + cN2 + dK + eK2 + fP + gP2 + hN.K + iN.P + jK.P + kN.K.P$$

Equation 1Multiple linear regression for N, P and K to determine the dependent variable i.e.yield

where a, b, c, d, e, f, g, h, i, j and k are the parameters determined from the regression analysis. The terms, h, i, j and k represent the linear by linear interaction between N, K and P fertilisers.

Results

Effects of treatments and FFB yield and its components

2013 was the first year of fertiliser treatment applications and yield recording. Analysed data did not show any significance responses.

Conclusion

2013 was the first year of fertiliser treatment and data collection and therefore it was early to expect any responses to fertiliser treatments. It was recommended the trial continue.

NEW BRITAIN PALM OIL LIMITED, WEST NEW BRITAIN

Steven Nake and Paul Simin

Trial 139: Palm Spacing Trial, Kumbango

RSPO 4.2, 4.3, 8.1

Summary

Use of machinery for infield FFBevacuation, fertilizer applications and EFB spreading is desired with increasing costs of labour. Use of machines within the field have the potential of disturbing the soil physical properties and eventually reducing yield in the long term. This trial of varying avenue widths at a constant palm density of 128 palms/ha was established to investigate effects of the different spacing and avenue widths on yield. In 2013, there was not effect of treatments on yield, leaf nutrients contents and physiological growth parameters. The implications here is that palms can be planted at wider avenues to allow machines to be used and will not affect yield. The trial was recommended for closure.

Introduction

Mechanical removal of infield FFB, fertiliser spreading and EFB spreading 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. This trial was set up with the aim to investigate if the planting arrangements of palms are changed while retaining the density to allow mechanization will affect yield. Background information for the trial is shown in Table 25.

Table 25 Trial 139 Background information

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	13	Altitude	19 m asl
Recording Started	Jan 2003	Previous Landuse	Oil Palm
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Unknown	Agronomist in charge	Steven Nake

Materials and Methods

There were 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 remained constant at 128 palms per hectare. The three spacing treatments are shown in Table 26. Leaf sampling, frond marking and vegetative measurements were being done on every 5th palm per recorded row per plot. Basal fertilisers applied in 2013: AN 2.0 kg/palm, TSP 0.5kg/palm, MOP 2kg/palm and Boron 0.15kg/palm.

Table 26 Trial 139 Spacing treatments information

Treatment	Spacing (m)	Density (palms/ha)	Width (m) Avenue	Inter-row
1	9.5x9.5x9.5 (Standard)	128	8.2	8.2
2	9.0x9.0x9.0 (Intermediate)	128	9.5	7.8
3	8.6x8.6x8.6 (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. Yield recording, leaf tissue sampling and vegetative measurements were done as per field operations procedures shown in Appendix 1.

Results

Spacing treatment effect on yield in 2013

The spacing treatment did not show significant differences ($p>0.05$) in on the FFB yield and yield components in 2013 (Table 27). The FFB yields in the Intermediate and Wide avenue spacings were slightly lower in yield and number of bunches per hectare than in the standard spacing (but not statistically different). A similar yield response trend was observed since 2003 (Figure 9).

Table 27 Trial 139 main effects of avenue widths on yield, bunch number and single bunch weight in 2013

Avenue width	Yield t/ha	Bunch number per hectare	Single bunch weight (kg/bunch)
Standard	26.5 (29.3)	1133 (1269)	24.0 (24.7)
Intermediate	25.4 (28.4)	1059 (1185)	24.5 (23.7)
Wide	25.0 (27.8)	1060 (1188)	24.2 (23.8)
Significance	ns	ns	ns
Mean	25.7	1084	24.2
CV%	4.2	2.7	2.5

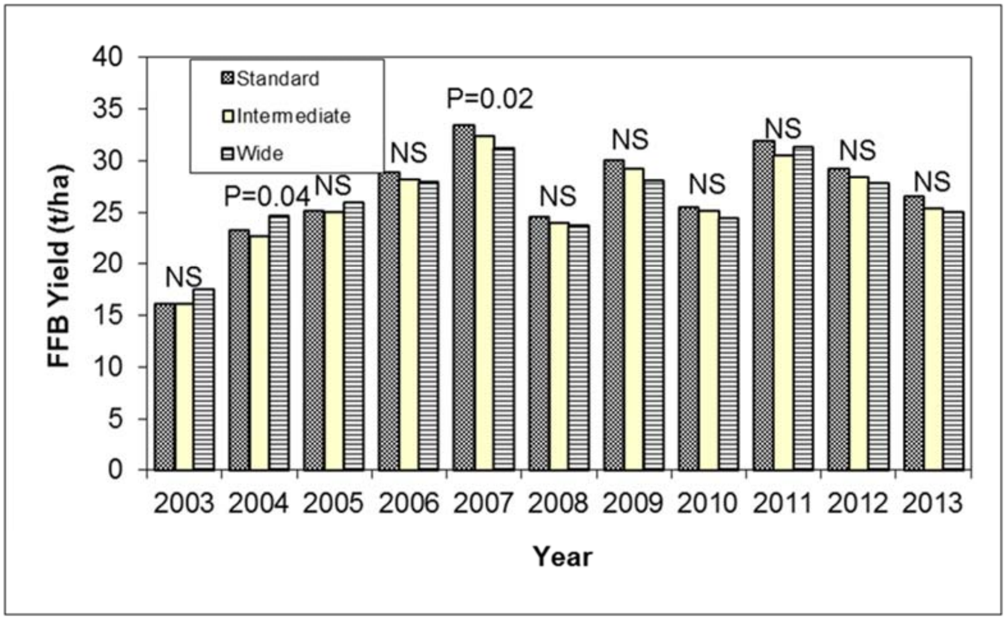

Figure 9 Trial 139 the effect of avenue widths on yield (keeping planting density the same), 2003-2013.

Spacing treatment effect on tissue nutrient levels

The spacing treatments did not have any effect on both the leaflet and rachis nutrient contents levels except for rachis N (Table 28). Irrespective of the spacing treatments, leaflet N, Mg and B were slightly below the adequate levels, whereas leaflet K was within the adequate level.

Table 28Trial 139 leaflet and rachis nutrient contents for the three different avenue widths in 2013

Avenue Width	Leaflet nutrient concentration (% DM except B in mg/kg))					Rachis nutrient concentration (% DM)		
	N	P	K	Mg	B	N	P	K
Standard	2.42	0.148	0.66	0.18	14.6	**0.3**	0.1	1.49
Intermediate	2.45	0.148	0.68	0.18	14.3	**0.31**	0.1	1.73
Wide	2.47	0.153	0.7	0.18	13.6	**0.33**	0.1	1.65
Adequate level:	2.5	0.145	0.65	0.2	15	**0.32**	0.1	1.5
Significance:	NS	NS	NS	NS	NS	p=0.05	NS	NS
CV %	1.7	1.9	5.6	3.7	8.5	3.2	10.5	6.5

Spacing treatment effects on vegetative growth parameters

The spacing treatments did not have any significant effect on the growth parameters in 2013 (Table 29). This may be due to the fact that the palms have matured and the canopy cover is more or less the same between the three spacing treatments (different avenue widths).

Table 29 Trial 139 effects of the three different avenue widths on physiological growth parameters in 2013

	HT (cm)	HI (cm)	PCS (cm^2)	Radiation interception				Dry matter production (t/ha)			
				FA	GF	FP	LAI	FDM	BDM	TDM	VDM
Means	904	93.8	50.6	13.4	38	25	6.5	17.1	13.5	33.9	20.5
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV%	1.9	19.5	4.7	2.7	2	1	4.4	5.1	3.2	3.3	4.8

HT = Height; HI = Height increment(cm); PCS = Petiole cross-section of the rachis (cm2); FA = Frond Area (m2); 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)

Conclusion

Palms can be planted at wider avenue widths and at recommended planting density to allow for infield mechanization with no significant effect on FFB yield. The trial was recommended for closure.

Trial 150: Smallholder fertilizer trial/BMP demonstration blocks (WNB)

RSPO 4.2, 4.3, 4.5, 4.6, 4.8, 8.1

Summary

The smallholder sector makes up 42 % of the oil palm industry however crop production is often low. The potential of increasing yields in the smallholder blocks will have a major impact in the farmers' lives and the economics of the community. The smallholder demonstration blocks were established to demonstrate importance of fertilizers and best agronomic practices which will result in high yields. The different fertilizer management practices was not important in increasing yields rather proper upkeep and regular harvest was important in getting high yields. It was recommended the demonstration blocks continued but as an extension format.

Introduction

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 proved yields of 30 – 35 t/ha were 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 available 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 to demonstrate best management practices with smallholders (extension) and to develop criteria for fertiliser decisions with smallholders (research). The demonstration block or on farm trials were established to show importance of fertilizers and best management practices to farmers to increase their oil palm yields.

Materials and Methods

Site Details

Trial 150 consisted of 17 (initially 26) smallholder blocks from the Hoskins Project Site. The distribution of the trial blocks under each division are shown in (
Table 30).
The blocks initially were low producing with poor sanitation (management) and obvious N deficiency on the oil palm e.g. pale leaflet colour, small frond area, smaller PCS, erected fronds (with less small

and less number of bunches). The blocks were identified by OPIC and confirmed by PNGOPRA upon site inspection.

Table 30 Trial 150 list of selected smallholder blocks used for study in 2013

No	Block No.	LSS/VOP	Division	Year Planted	Year trial started
1	92	Koimumu	Siki	1994	2011
2	138	Waisisi, CRP	Siki	1999	2009
3	209	Tabairikau	Siki	1999	2011
4	1055	Siki, Sect 2	Siki		Dec-13
5	165	Buluma	Kavui	2000	2011
6	126	Mai	Kavui	1998	2011
7	1637	Kavui Sect 11	Kavui	1983	2011
8	1719	Kavui Sect 7	Kavui	1998	2009
9	8	Gaongo	Kavui	1985	2011
10	1169	Buvusi Sect 5	Buvusi	1997	2010
11	1186	Buvusi Sect 6	Buvusi	1997	2009
12	980	Sarakolok Sect 6	Nahavio	1998	2009
13	114	Ubae VOP	Salelubu	2000	2009
14	16	Kukula VOP	Salelubu	1998	2009
15	921	Mamota, Sect 8B	Salelubu	1991	2009
16	26	Marapu VOP	Salelubu	2001	2009
17	458	Silanga	Salelubu	2004	2011

Experimental design and treatments

The trial layout is shown in Figure 10. The trial block consisted of 4 rows of each treatment, total of 12 rows. Only ten 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) were also fertilised with the standard rate (2 kg AN/palm/year).

Fertiliser treatments:
- Treatment 1 - (current block fertiliser practice)
- Treatment 2 - recommended rate [2kg Ammonium nitrate (AN) /palm]
- Treatment 3 - Recommended plus [3 kg Ammonium nitrate (AN)/palm + 1kg Muriate of potash (MOP)/palm]

Yield recording, leaf tissue sampling, vegetative measurements and monthly field standard assessments were done as per Appendix 1.

Results

Treatment effects on yield and its components on individual blocks in 2013.

The fertilizer treatments did not have any significant effects ($p>0.05$) on the FFB yields in 2013 (Table 31). Despite that, the yields, bunches per hectare and the single bunch weights were increased in 2013. Yields on average have increased to over 20 t/ha since the inception of this work in 2009 (5 years). Similarly the number of bunches have gone over 1000 bunches/ha/year.

The individual block production (FFB yield) in Figure 10 also shows no effect of fertilizer treatments on FFB yield and yield components. However, 75% of the trialed blocks had yields greater than 20 t/ha in 2013 (Table 31).

Table 31 Trial 150 effects of fertiliser treatments on yield and its component in 2012 and 2013.

Fertiliser Treatments	2012			2013		
	Yield (t/ha)	BHA	SBW (kg)	Yield (t/ha)	BHA	SBW (kg)
1	19.1	1019	19.3	21.2	1096	19.6
2	20.1	1053	19.6	19.6	1055	19.8
3	20.1	1069	19.6	20.8	1072	19.8
GM	19.8	1047	19.5	20.5	1074	19.7
Significance	ns	ns	ns	ns	ns	ns
CV %	38.1	37.6	20.4	13.6	11.5	6.3

Note: Data for blocks 138 and 209 not included in the analysis

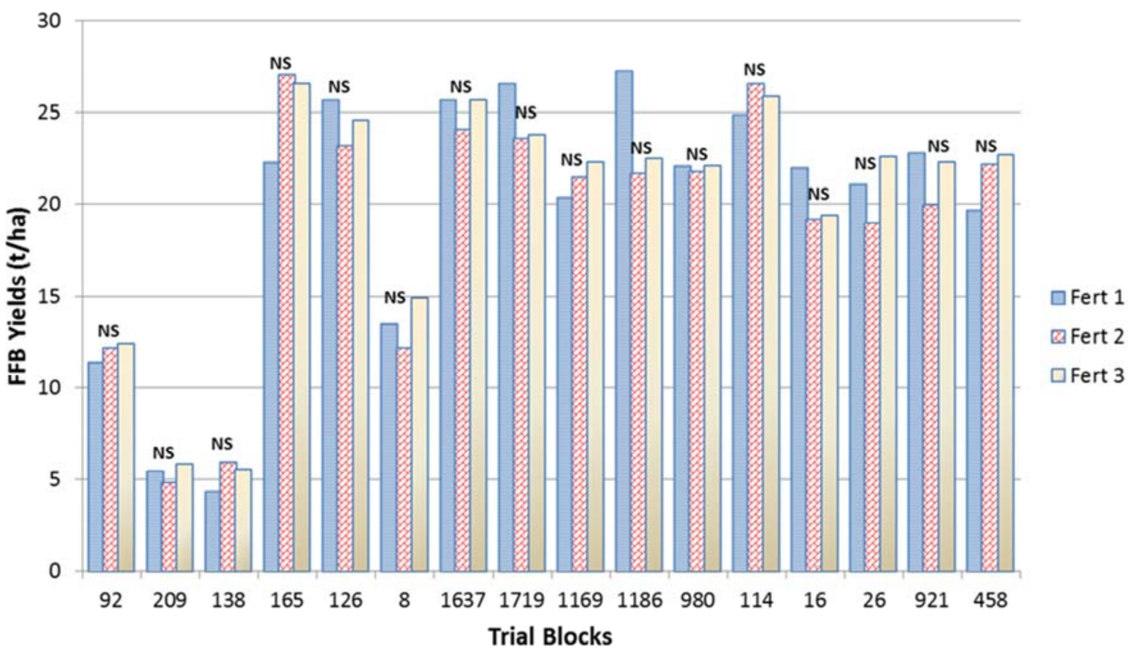

Figure 10 Trial 150 fertiliser treatment effects on individual block yields in 2013

Treatment effects on tissue nutrient concentration (% DM)

Leaflet and rachis nutrient contents did not respond significantly (p>0.05) to the fertilizer treatments in 2013 (Table 32). Leaflet N contents were below the adequate level of 2.45%. Similarly, leaflet Mg was slightly below the adequate level. Rachis N and P were also below the adequate range.

Table 32 Trial 150 leaf tissue nutrient contents (% DM) in 2012 and 2013

Treatments	Leaflets (%DM)				Rachis (% DM)		
	N	P	K	Mg	N	P	K
1	2.18	0.136	0.69	0.17	0.27	0.07	1.27
2	2.18	0.137	0.7	0.18	0.26	0.07	1.28
3	2.21	0.139	0.68	0.17	0.27	0.07	1.33
GM	2.19	0.138	0.68	0.18	0.26	0.07	1.3
Min	1.92	0.126	0.58	0.12	0.22	0.03	0.9
Max	2.36	0.41	0.84	0.61	0.32	0.17	1.63
CV %	2.5	2.6	4.8	10.2	9.9	16.4	10.2
Adequate levels	2.45	0.145	0.65	0.2	0.32	0.1	1.2

Treatment effects on physiological parameters

Bunch dry matter (BDM) continued to respond significantly ($P<0.05$) to the treatments in 2013 while the rest of the physiological parameters were not significantly affected (Table 33). In 2013, the frond length extended to over 600 cm with an average PCS of 39.9 cm^2. Number of green fronds was maintained at 36, a result of regular pruning. An average of 23.8 new fronds was produced in 2013 (one in every 15 days).

Table 33 Trial 150 effects of the fertiliser treatments on vegetative growth parameters in 2013

	Llen	PCS	Radiation interception				Dry matter production (t/ha)			
	(cm)	(cm^2)	FA	GF	FP	LAI	FDM	BDM	TDM	VDM
GM	613	39.9	11.8	36	23.8	4.8	12.1	**15.7**	30.8	15.2
Significance	ns	ns	ns	ns	ns	ns	ns	p=0.004	ns	ns
L.s.d $_{0.05}$	-	-	-	-	-	-	-	*0.89*	-	-
CV%	31.4	16.8	16.0	9.9	9.5	22.7	20.9	36.3	23.8	19.7

Llen = Leaf length (cm); PCS = Petiole cross-section of the rachis (cm2); FA = Frond Area (m2); 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)

Block standard assessment

At the end of each month, block assessments are compiled for every individual trial blocks as per Appendix 2. The scores are averaged for the month and year for reporting. The average scores for the current 17 trial blocks in 2013 are presented Table 34. Generally the block standards have improved over the last 4 years, though the average score for 2013 was 2.6, that is two points less than 2012.

Table 34 Trial 150 block assessments average scores from 2009 to 2013

Criteria used for scoring block assessment	2009 a	2009 b	2011	2012	2013
Palm Nutrient Deficiency	1.0	1.0	2.4	2.6	2.4
Block Standard	3.0	3.0	3.0	3.0	2.9
Frond stack	1.5	3.0	2.5	2.9	2.9
Ganoderma	3.0	3.0	3.0	3.0	3.0
Ground cover-deficiency	2.0	2.0	2.6	2.7	2.8
Harvest standard	2.7	2.5	2.8	2.9	1.2
Harvest paths	1.0	2.9	3.0	3.0	3.0
Insect Damage	2.3	2.3	2.9	2.9	2.9
LCP	2.9	2.9	2.9	2.9	3.0
Pruning <7years	1.0	2.8	2.8	N/A	2.0
Pruning >7years	1.0	2.9	2.9	2.4	2.4
Rat Damage	3.0	3.0	3.0	3.0	2.9
Trunk weeds/ferns	2.1	2.1	2.1	2.8	2.9
Trunk weeds/woods/vines	2.2	2.2	2.2	2.8	2.7
Weeded circle	1.0	2.5	3.0	2.9	2.4
Weed-ground cover	1.2	2.8	2.7	2.7	2.5
Average	1.9	2.6	2.7	2.8	2.6
Min	1.0	1.0	2.1	2.4	1.2
Max	3.0	3.0	3.0	3.0	3.0

a=before work started and b=after work started

Conclusion

The different practices of fertilizer application did not matter in producing high yields but it was the proper block up keep and regular harvest that contributed to getting high yields. It was recommended the demonstration blocks continue but as demonstration blocks for extension services.

Trial 151: Smallholder Oil Palm/Food Crop Intercropping Demo Block, Buvusi (WNB)

RSPO 4.2, 4.3, 5.1, 6.1, 8.1

Summary

Food crops production is an important part of the smallholder farming system. Food crops are produced for own use, for sale for cash income and for cultural/religious activities. With increase in pressure on available land due to increased population, food security within many farming families is threatened. Intercropping oil palm planted at altered avenue widths with food crops was an option that is studied to see if the intercropping will sustain both food crops and oil palm with time. Major food crops could be produced twice in a year while peanut grown as a rotation crop has the benefit of high income per kg. Pests and stealing were also major impeding factors affecting food crop yields. Oil palm crop is not measured and will be done in 2014. It was recommended this trial continued.

Introduction

The background information for this trial is similar to Trial 337 at Sangara and Biru in Table 73 and Table 74 respectively for smallholder oil palm/food crop intercropping at Popondetta.

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 32). An area of1.5 ha of the total area (2 ha) under replant was planted with oil palm at the spacing of 9.75 m x 9.75 m (120 palms/ha) (Figure 12), while only 0.5 ha was reserved for intercropping with food crops. The food crops were planted in 2 replicates of 8 plots. Each plot was 8m x 8m (16 m2 or 0.0016 ha). The list of the food crops planted in the trial plots are shown inTable 35.

Table 35 Trial 151, Block background 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
Pattern	Triangular		
Date planted	July 2011		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2011 (Food crops)		

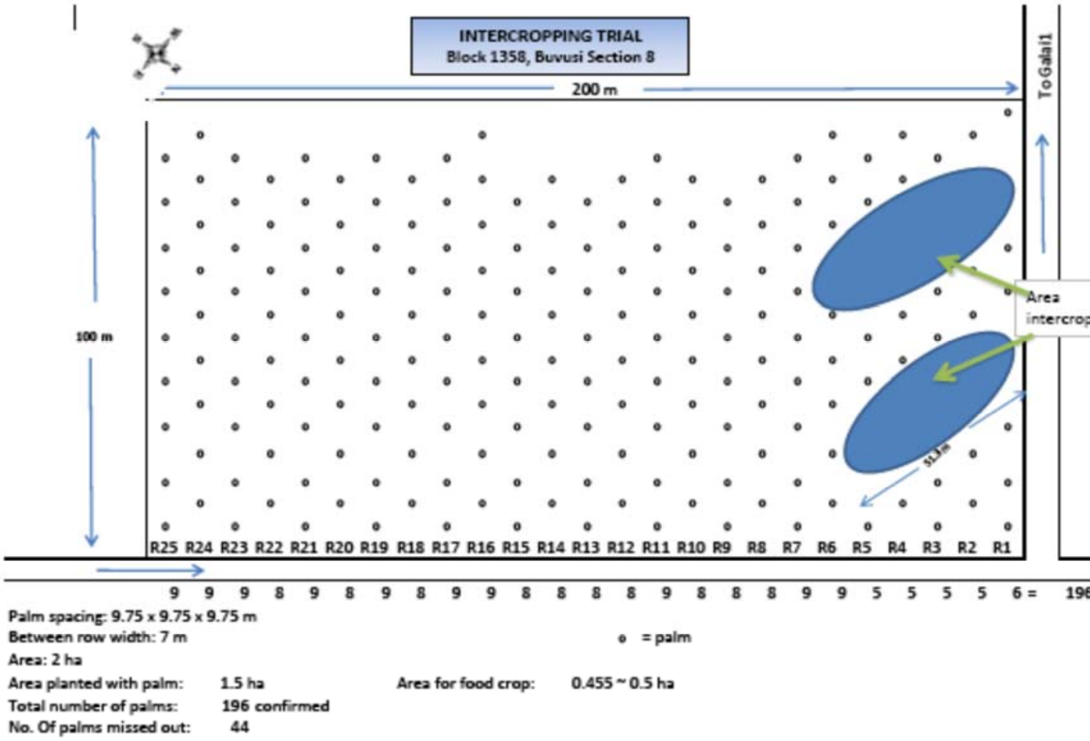

Figure 11 Trial 151 Trial map of the intercropping trial, Block 1358 at Buvusi section 8, Hoskins Project

Materials and Methods

Design and analysis

There was no strict statistical design for this experiment. The oil palm block was divided into 2 parts. One portion was 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 were collected and dry matter production determined. The measurements were carried out to determine nutrient movement in and out of the smallholder blocks. Soil samples were also taken 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 at 200g/palm) was applied to all the young palms in October 2013. Slashing was done around the young palms and circles were maintained both in the intercropped and full palm stand oil palms. The garden plots were maintained throughout the year.

Results

Food garden

The harvested food crop yields data is presented in Table 36. In 2013, the intercropping trial recorded only 5 harvests, while two complete plots of corn and one entire plot for kaukau were eaten by pests (birds and rats) and stolen (Table 38). From the 5 harvests, the yields were much lower than the 2012 yields of the same crop. Singapore taro was not planted in 2013, but did not perform well hence it was replaced with winged bean. However, the winged beans were also eaten by birds and no yield data was collected (Table 38).

Market surveys were conducted at the main and roadside markets to determine the current selling price of 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 37). The same table also shows the market value (Kina) for the crops if all were to be sold at the market. Of the crops, peanut was the most valued crop with K4.40/kg. A crop rotation system with peanut will be useful for cash income.

Pest (especially birds and rats) and theft (by human) were two main factors that affected the potential crop yields from the plots (Table 38). Corns, peanuts and beans were normally eaten by the parrots while kaukau was normally stolen by people or eaten up by pigs before maturity.

Table 36 Trial 151 total food crop yield from crop harvested from the intercropping trial in 2013

Food crop	Total Quantity harvested in 2013 (kg)	Number of Harvests
Kaukau	44.4	2
Taro	85.5	1
Peanut	20.5	1
Corn	3.2	1

Table 37 Trial 151 food crop harvested crops and money value from intercropped component of the block

Food Crop	Harvest		Value	Total value
	Date	Quantity (kg)	(Kina/kg)	(Kina)
Kaukau	19/02/2013	44.40	1.30	57.72
Taro	23/03/2013	85.50	1.50	128.25
Kaukau	13/05/2013	52.90	1.33	70.40
Peanut	19/10/2013	20.50	4.40	88.00
Corn	1/11/2013	3.20	2.00	6.60
Total				350.97

Table 38 Trial 151 estimated yield loss from the intercropping trial

Food crop	Date	Amount of crop loss	Cause of crop loss
Taro	23/03/2013	1 taro stolen	Theft
Kaukau	13/05/2013	1 full plot	Theft and pigs
Peanut	19/10/2013	¾ of the plot	Eaten up by rats and birds
Corn	23/12/2013	2 full plots	Corn eaten up by rats and birds
Winged bean	19/07/2013	1 plot	Flowers and seed/pods eaten by birds

Oil palm

In 2013, oil palm physiological growth parameters were measured between the two systems i.e. full stand of oil palm versus intercropping oil palm with food garden. Yield recording on the oil palm will commence in January 2014. In this report, only the results of physiological parameters are presented and discussed.

The different physiological parameters measured on the young palms grown under the full oil palm stand (control) and the palms intercropped with food garden presented in Table 39. The frond length and the number of green fronds on the palms were significantly different ($p<0.05$) between the two systems. The frond length of palms intercropped with food garden were much higher than the palms in the full stand. In contrast, more green fronds were recorded from palms in the full stand compared to the palms intercropped with food garden. The difference was due to palms intercropped with food crops being well maintained while working on food crops.

The foliar nutrient levels are shown in Table 39. Leaflet N, P and S and rachis N, P and K in both treatments were low (below the adequate level). The rest of the other foliar nutrients were within the adequate range.

Table 39 Trial 151 physiological parameters of oil palm measured from full oil palm stand and oil palm intercropped with food crops

Treatment	PCS	FL	GF	FP	FA	LAI
Oil palm full stand	8.3	**234.1**	**39**	27	2.4	1.2
Intercropped oil palm	8.8	**266.3**	**33**	25	2.7	0.7
Mean	8.5	250.2	36	26	2.5	0.95
Significance	ns	p=0.037	p=0.010	ns	ns	ns
L.s.d $_{0.05}$	-	*30.2*	*3.8*	-	-	-
CV%	19.9	14.3	12.6	25.8	20.2	28

Significant effects (p<0.05) are shown in bold.
FL = frond length (cm), PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index

Table 40 Trial 151 leaf tissue nutrient contents of oil palm measured from full oil palm stand and oil palm intercropped with food crops

Treatment	Leaflet (% DM) (B in mg/kg)						Rachis (% DM)		
	N	P	K	Mg	B	S	N	P	K
Oil Palm Full stand	2.20	0.142	0.71	0.27	10	0.18	0.27	0.053	1.10
Intercropped Oil Palm	2.19	0.142	0.71	0.20	8	0.17	0.26	0.043	1.14
Mean	2.20	0.142	0.71	0.24	9	0.18	0.27	0.048	1.12
Adequate levels	2.50	0.145	0.65	0.20	15		0.32	0.100	1.5

Conclusion

Food crops can be grown within oil palm stands at immature phase however pests and theft contributed to reduced yields. Rowing of food crops also encouraged maintain of oil palm at immature phase. are a concern in the food crops production. Growing of single food crop in garden plots appeared to have attracted pests. Oil palm yield data have not commenced because palms are still young. Data collection from oil palm yield would be expected in 2014 and it was recommended the demonstration block continued.

NBPOL, KULA GROUP, POPONDETTA

Winston Eremu and Graham Bonga

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

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

There was little leaf P contents responses to P fertilizers in past trials on Higaturu Volcanic Ash soils. However the leaf P contents had been falling with time to below critical levels. This trial was set up on the matured oil palm plantings 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 with differing N status in the matured palms. In 2013, Urea significantly increased yield and leaflet N contents while TSP only increased rachis P contents. Nitrogen fertilizer (minimum 460 g N/palm/year) is recommended for Higaturu soils while P fertilizers can be adjusted to replace exported P in yield. It was recommended this trial continue.

Introduction

There was little response to P fertilisers in previous trials at Higaturu. However leaf tissue P contents had been falling over the years. This could limit N uptake and FFB yield responses to N supply over time. The supply of N 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 it was decided to start a new trial with a wide range of P supply rates with different levels of N fertilizers to determine the critical levels of P in the Popondetta soils. This trial would provide a better understanding of the relation between N and P nutrition and provide information for fertilizer recommendation especially with respect to leaf and rachis nutrient levels. Background information for Trial 334 is presented in Table 41.

Table 41 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 42). Fertiliser applications started in 2007. Every palm within the trial field received basal applications of 1 kg Kieserite, 2 kg MOP per palm as basal. Yield recording, leaf tissue sampling and vegetative measurements are described in Appendix 1.

Table 42 Trial 334 fertiliser treatments and levels

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 its components in 2013 but affected only yield and SBW in 2011-2013 (Table 43). At Urea level 1 (460 gN/palm/year), FFB yield was greater than 30 t/ha in both 2013 and 2011-2013 periods and there was no increase in yield after level 2 (Table 44). The significance in yield response to TSP cannot be explained because there was no trend. The mean FFB yield was 34.4t/ha in 2013.

Table 43 Trial 334 effects (p values) of treatments on FFB yield and its components in 2013 and 2011-2013

Source	2013			2011-2013		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	**<0.001**	**0.013**	**0.016**	**0.002**	0.172	**0.027**
TSP	**0.017**	**0.025**	0.417	0.166	0.25	0.531
Urea.x TSP	0.496	0.882	0.215	0.703	0.815	0.884
CV %	8.4	10.2	4.4	6.5	7.7	4.0

Table 44 Trial 334 main effects of treatments on FFB yield (t/ha) in 2013 and combined harvest for 2011-2013

Treatments	2013			2011-2013		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea 1	**31.8**	**1345**	**23.6**	**33.6**	1518	**22.2**
Urea 2	**35.6**	**1514**	**23.5**	**36.4**	1600	**22.8**
Urea 3	**35.7**	**1456**	**24.6**	**36.4**	1579	**23.2**
L.S.D $_{0.05}$	***2.164***	***109.8***	***0.795***	***1.719***		***0.689***
TSP 1	**33.6**	**1378**	24.4	35.3	1534	23.1
TSP 2	**34.0**	**1451**	23.5	35.1	1582	22.3
TSP 3	**32.7**	**1457**	24.1	34.2	1507	22.8
TSP 4	**37.5**	**1582**	23.8	37.0	1631	22.8
TSP 5	**34.0**	**1422**	24	35.7	1577	22.7
L.S.D $_{0.05}$	***1.026***	***1.417***				
GM	34.4	1438	23.9	35.5	1566	22.8
SE	2.893	146.7	1.063	2.298	120.3	0.918
CV %	8.4	10.2	4.4	6.5	7.7	4.0

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 in 2013 (p=0.496 and average yield data from 2011to 2013 (p=0.703) (Table 43). The highest yield of 41.0 t/ha was obtained at Urea-2 and TSP-4 levels (Table 45).

Table 45 Trial 334 effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2013. The interaction was not significant (p=0.496)

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	31.7	31.2	28.8	33.6	33.5
Urea-2	34.3	34.4	33.7	41	34.4
Urea-3	34.9	36.7	35.5	37.8	34.1
Grand mean	34.6				

Effects of Urea and TSP treatments on leaf nutrient concentrations

Urea had significant effects on leaflet N, Ca and Cl, and rachis N and P contents (Table 46 andTable 47). TSP significantly increased P contents in the rachis. There was some indication of interaction of Urea x TSP on rachis P (p=0.051) and K (p=0.042) contents. All leaflet and rachis nutrient concentrations were above their respective critical levels.

Table 46 Trial 334 effects (p values) of treatments on frond 17 nutrient concentrations 2013. p values <0.05 are indicated in bold

Source	Leaflet nutrient contents								Rachis nutrient contents			
	Ash	N	P	K	Mg	B	Ca	Cl	Ash	N	P	K
Urea	0.24	**<0.001**	0.09	0.338	0.839	0.167	**0.039**	**0.001**	0.298	**0.043**	**<0.001**	0.585
TSP	0.805	0.82	0.138	0.906	0.068	0.441	0.353	0.19	0.051	0.601	**<0.001**	0.144
Urea.TSP	0.772	0.563	0.168	0.923	0.38	0.437	0.461	0.457	0.065	0.314	0.053	**0.042**
CV%	3.6	2.5	2.4	5.8	7.2	8	6.7	6.2	7.6	8.8	11.4	9.2

Table 47 Trial 334 main effects of treatments on leaf tissue nutrient concentrations in 2013.

Treatments	Leaflet nutrient contents (% DM except B in mg/kg)								Rachis nutrient contents (% DM)			
	Ash	N	P	K	Mg	B	Ca	Cl	Ash	N	P	K
Urea-1	14.7	**2.33**	0.148	0.68	0.22	18	**0.82**	**0.49**	7.0	**0.38**	**0.260**	2.14
Urea-2	14.9	**2.41**	0.15	0.68	0.21	17	**0.79**	**0.52**	7.2	**0.40**	**0.210**	2.20
Urea-3	14.6	**2.51**	0.151	0.7	0.22	17	**0.76**	**0.54**	7.2	**0.41**	**0.180**	2.22
l.s.d $_{0.05}$		*0.046*					*0.04*	*0.02*		*0.026*	*0.018*	
TSP-1	14.8	2.42	0.15	0.68	0.2	18	0.81	0.5	6.8	0.39	**0.200**	2.13
TSP-2	14.9	2.41	0.149	0.7	0.22	17	0.76	0.53	7.0	0.40	**0.200**	2.13
TSP-3	14.6	2.41	0.149	0.69	0.21	17	0.78	0.52	7.1	0.38	**0.200**	2.12
TSP-4	14.7	2.40	0.15	0.68	0.22	17	0.8	0.5	7.2	0.40	**0.230**	2.21
TSP-5	14.8	2.44	0.153	0.68	0.22	17	0.8	0.52	7.6	0.41	**0.260**	2.37
l.s.d $_{0.05}$											*0.024*	
GM	14.7	2.42	0.15	0.69	0.22	17	0.79	0.52	7.1	0.39	0.22	2.18
SE	0.525	0.061	0.004	0.04	0.015	1.399	0.052	0.032	0.542	0.035	0.025	0.201
CV %	3.6	2.5	2.4	5.8	7.2	8	6.7	6.2	7.6	8.8	11.4	9.2

Effects with p<0.05 are shown in bold.

Effects of fertiliser treatments on vegetative parameters

Urea significantly affected PCS, FP, LAI and all dry matter production components (Table 48 and Table 49). The measured parameters were significantly increased. On the other hand, TSP only affected BDM production, BI was also affected but the effect as not clear.

Table 48 Trial 334 effects (p values) of treatments on nutrient concentrations 2013

Source				Radiation interception			Dry matter production				
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Urea	0.512	0.711	**0.022**	**0.003**	0.444	**0.03**	**<0.001**	**0.006**	**<0.001**	**<0.001**	0.492
TSP	0.89	0.935	0.532	0.353	0.76	0.277	0.38	**0.026**	0.317	0.507	**0.023**
Urea x TSP	0.145	0.403	0.702	**0.025**	0.644	0.557	0.305	0.513	0.255	0.272	0.734
CV %	2.3	26.2	6	3.3	4.9	5.8	8.1	8.6	5.6	6.4	5.5

Table 49 Trial 334 main effects of treatments on vegetative growth parameters in 2013

Treatments	FL	HI	PCS	Radiation interception FP	FA	LAI	Dry matter production (t/ha/yr) FDM	BDM	TDM	VDM	BI
Urea-1	675.1	80.4	**53.3**	**22.9**	14.2	**6.30**	**17.4**	**17.0**	**38.2**	**21.2**	0.44
Urea-2	677.3	79.0	**55.1**	**23.6**	14.5	**6.63**	**18.6**	**18.8**	**41.5**	**22.8**	0.45
Urea-3	670.7	74.5	**56.9**	**23.9**	14.4	**6.64**	**19.4**	**18.7**	**42.4**	**23.7**	0.44
l.s.d $_{0.05}$			*2.488*	*0.579*		*0.284*	*0.96*	*1.168*	*1.702*	*1.108*	
TSP-1	678.3	77	55.4	23.5	14.2	6.36	18.6	**17.8**	40.4	22.6	**0.4**
TSP-2	671.4	83.2	54.8	23.0	14.2	6.46	18.0	**18.1**	40.2	22.0	**0.5**
TSP-3	674.7	77.7	55.1	23.7	14.4	6.68	18.6	**17.2**	39.9	22.6	**0.4**
TSP-4	672.1	75.3	53.7	23.6	14.5	6.44	18.1	**19.7**	42.0	22.3	**0.5**
TSP-5	675.3	76.7	56.5	23.7	14.5	6.68	19.1	**17.8**	41.0	23.2	**0.4**
l.s.d $_{0.05}$								*1.507*			*0.024*
Grand mean	674.4	78	55.1	23.5	14.4	6.52	18.5	18.1	40.7	22.6	0.44
SE	15.7	20.4	3.326	0.774	1.138	0.38	1.284	1.561	2.275	1.442	0.024
CV %	2.3	26.2	6.0	3.3	4.9	5.8	6.9	8.6	5.6	6.4	5.5

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

FL = frond length (cm), FLI = Frond length increment (cm), PCS = Petiole cross-section (cm2); FP = annual frond production (new fronds/year); FA = Frond Area (m2); 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

Nitrogen is the major limiting nutrient in Higaturu soils and a minimum of 1 kg Urea (460 g N/palm/year) produces FFB yield greater than 30 t/ha/year. There was no clear response to TSP and it was recommended P requirements have to be calculated to replace exported P. It is recommended this trial continue.

Trial 335. Nitrogen x TSP Trial (Immature Phase) on Outwash Plains Soils, Ambogo Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

There was little leaf P contents responses to P fertilizers in past trials on Ambogo outwash plains sandy soils however the leaf P contents had been falling with time to below critical levels. This trial was set up on the immature oil palm plantings 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 with differing N status in the immature palms. In 2013, nitrogen fertilizer (minimum 460 g N/palm/year) was recommended for the Ambogo soils to produce greater than 30 t/ha/year. P fertilizers had to be adjusted to replace exported P in yield. It was recommended this trial continue.

Introduction

Fertiliser trials at Higaturu had not shown any FFB yield responses to P fertilizers over the years. However, leaf tissue P contents have been falling with time especially in the presence of high N rates. P could with time reduce responses to uptake of N fertilizers and affect FFB yield in the long term. This trial was established on newly planted palms of known progenies with different rates of P and N to determine the critical levels of N and P in the leaf tissues. This would provide information to fertilizer recommendations for the soils at Ambogo Estates. Trial background information is provided in Table 50.

Table 50 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".Yield data collection, leaf tissue sampling and vegetative measurements were done as per standard trial protocol referred to in Appendix 1.

Results and discussion

Yield and yield components

The effects of fertiliser on yield and its components are presented in Table 51 and Table 52. Urea had significant effect on FFB yield and its components ($p<0.001$) in 2013 and 2011-2013 (except BNO/ha). In 2013, FFB yield increase by 1.5 - 1.8 t/ha for every kg increase in Urea (Table 48). The average FFB yield was 38.6t/ha in 2013, an increase from 36 t/ha/year in 2012. TSP increased the number of bunches but the effect was not statistically significant.

Table 51 Trial 335 effects (p values) of treatments on FFB yield and its components in 2013

Source	2013			2011-2013		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea	**<0.001**	**<0.001**	**<.001**	**<0.001**	0.141	**<0.001**
TSP	0.164	0.229	0.419	0.192	0.14	0.925
Urea.x TSP	0.084	0.061	0.167	0.115	0.075	0.304
CV %	7.8	6.9	3.9	5.6	6	3.9

Table 52 Trial 335 main effects of treatments on FFB yield (t/ha) in 2013 and 2011-2013

Treatments	2013			2011-2013		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea-1	**35.7**	2850	**12.5**	**32.5**	3336	**9.9**
Urea-2	**37.2**	2836	**13.1**	**33.5**	3261	**10.5**
Urea-3	**42.8**	3075	**13.9**	**36.0**	3389	**10.8**
l.s.d $_{0.05}$	*1.923*		*0.33*	*1.219*		*0.259*
TSP-1	36.9	2826	13.1	33.0	3320	10.4
TSP-2	37.8	2989	13.1	33.8	3391	10.4
TSP-3	39.2	2925	13.4	34.1	3319	10.4
TSP-4	39.3	2946	13.3	34.4	3379	10.3
TSP-5	39.5	3018	13.1	34.9	3426	10.3
GM	38.6	2921	13.2	34.0	3329	10.3
SE	3.013	202.5	0.516	1.91	200.8	0.405
CV %	7.8	6.9	3.9	5.6	6	3.9

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of Urea x TSP however the highest yield of 44.6 t/ha was obtained at Urea-3 and TSP-2, and also at TSP 5 (Table 53).

Table 53 Trial 335 effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2013

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	36.5	36.4	36.6	33.8	35.3
Urea-2	34.8	35.2	36.5	40.8	38.7
Urea-3	39.4	41.9	44.6	43.2	44.6
Grand mean	38.6		Sed=2.130		

Effects of Urea and TSP treatments on leaf nutrient concentrations

Urea had significant effect on leaflet N, P, B, Ca and Cl, and rachis N, P and K. most of the leaflet and all of rachis nutrient concentrations (Table 54). Urea increased the mentioned nutrients except leaflet Mg, B and Ca, and rachis P contents. TSP only increased the rachis P contents. Urea x TSP had no interaction on all nutrient concentrations (Table 55).

Table 54 Trial 335 effects (p values) of treatments on frond 17 nutrient concentrations in 2013. p values <0.05 are indicated in bold

Source	Leaflets nutrient contents								Rachis nutrient contents			
	Ash	N	P	K	Mg	B	Ca	Cl	Ash	N	P	K
Urea	0..907	**<0.001**	**0.043**	0.186	0.372	**<0.001**	**0.037**	**<0.001**	**0.036**	**<0.001**	**<0.001**	**<0.001**
TSP	0.132	0.294	0.321	0.108	0.225	0.237	0.336	0.233	0.599	0.981	**0.025**	0.585
Urea.TSP	0.196	0.689	0.809	0.148	0.584	0.183	0.523	0.498	0.23	0.652	0.292	0.645
CV%	6.3	2.6	3.4	4.9	8.1	12.1	4.2	7.0	6.9	8.2	16.3	7.5

Table 55 Trial 335 main effects of treatments on F17 nutrient concentrations in 2013, 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	14.0	**2.35**	**0.148**	**0.78**	**0.25**	**26**	**0.88**	**0.46**	6.63	**0.31**	**0.267**	1.92
Urea-2	14.0	**2.44**	**0.151**	**0.76**	**0.25**	**27**	**0.88**	**0.49**	6.57	**0.32**	**0.199**	1.93
Urea-3	14.1	**2.54**	**0.152**	**0.78**	**0.24**	**23**	**0.86**	**0.53**	6.94	**0.35**	**0.176**	2.13
l.s.d $_{0.05}$		*0.04*	*0.003*	*0.024*	*0.013*	*1.95*	*0*	*0.022*		*0.017*	*0.022*	
TSP-1	13.6	2.45	0.147	0.79	0.26	27	0.87	0.48	6.66	0.32	**0.190**	2.02
TSP-2	13.9	2.44	0.151	0.79	0.25	24	0.87	0.50	6.87	0.33	**0.224**	2.03
TSP-3	14.0	2.41	0.15	0.78	0.23	25	0.86	0.48	6.67	0.33	**0.199**	1.95
TSP-4	14.4	2.46	0.151	0.76	0.25	26	0.88	0.51	6.77	0.32	**0.224**	2.01
TSP-5	14.3	2.46	0.151	0.76	0.24	25	0.88	0.49	6.58	0.33	**0.231**	1.96
l.s.d $_{0.05}$											*0.029*	
GM	14	2.44	0.15	0.78	0.25	25	0.87	0.49	6.71	0.33	0.214	2.00
SE	0.889	0.063	0.005	0.038	0.02	3.06	0.04	0.035	0.466	0.027	0.035	0.15
CV %	6.3	2.6	3.4	4.9	8.1	12.1	4.2	7.0	6.9	8.2	16.3	7.5

Effects of fertiliser treatments on vegetative parameters

Urea significantly increased all of the vegetative parameters except for height increment while TSP and Urea x TSP had no significant effect in 2013(Table 56 and Table 57). The change in BI from TSP cannot be explained. The increased vegetative growth parameters from Urea treatment translated to increased FFB yields and greater than 0.50 BI values.

Table 56 Trial 335 effects (p values) of fertiliser treatments on frond 17 nutrient concentrations 2013

Source				Radiation interception			Dry matter production				
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Urea	0.009	0.083	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.006**
TSP	0.216	0.665	0.419	0.7	0.89	0.737	0.359	0.143	0.128	0.257	0.532
Urea x TSP	0.361	0.958	0.355	0.823	0.373	0.254	0.441	0.167	0.086	0.196	0.788
CV %	2.5	9	3.8	2.9	4.1	4.8	4.7	8.2	5.8	4.4	3.6

Table 57 Trial 335 main effects of treatments on vegetative growth parameters in 2013

Treatments				Radiation interception			Dry matter production (t/ha/yr)				
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Urea-1	**546.7**	71.4	**28.6**	**25.5**	**9.0**	**4.64**	**10.8**	**18.4**	**32.3**	**14.0**	**0.57**
Urea-2	**551.3**	73.8	**28.9**	**26.8**	**9.2**	**4.86**	**11.4**	**19.1**	**33.9**	**14.8**	**0.56**
Urea-3	**560.7**	76.3	**30.0**	**27.3**	**9.6**	**5.04**	**12.1**	**20.2**	**38.1**	**15.9**	**0.58**
l.s.d $_{0.05}$	*8.89*		*0.715*	*0.497*	*0.153*	*0.15*	*0.341*	*1.036*	*1.282*	*0.417*	*0.013*
TSP-1	551.4	73.6	29.0	26.4	9.3	4.82	11.3	18.9	33.5	14.6	**0.56**
TSP-2	556.0	73.9	29.3	26.7	9.3	4.91	11.5	19.6	34.6	14.9	**0.57**
TSP-3	547.9	71.5	28.8	26.4	9.2	4.80	11.2	20.2	34.9	14.7	**0.58**
TSP-4	549.3	75.1	29.1	26.7	9.3	4.88	11.5	20.3	35.3	15.0	**0.58**
TSP-5	559.9	75.1	29.6	26.6	9.4	4.82	11.6	20.4	35.6	15.1	**0.57**
l.s.d $_{0.05}$											*0.017*
GM	552.9	73.3	29.2	26.5	9.3	4.85	11.4	19.9	34.8	14.9	0.57
SE	13.93	6.613	1.121	0.778	0.386	0.235	0.534	1.624	2.008	0.653	0.02
CV %	2.5	9.0	3.8	2.9	4.1	4.8	4.7	8.2	5.8	4.4	3.6

Significant effects ($p<0.05$) are shown in bold.
FL = frond length (cm), FLI = Frond length increment (cm), PCS = Petiole cross-section (cm2); FP = annual frond production (new fronds/year); FA = Frond Area (m2); 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

Nitrogen is the limiting nutrient in this particular Ambogo Soil type at Higaturu. A minimum of 460 g N/palm/year was required to produce yields more than 30 t/ha/year. However low N in the lowest N treated plots leaflets implied the rates have to be revised with time. Because of no clear responses to TSP treatments, P fertilizers should be adjusted to meet exported P only. It was recommended the trial continue.

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

(RSPO 4.2, 4.3, 8.1)

Summary

With increasing labour costs, use of machinery for infield crop removal and other field operations aim to be used commonly in the plantations. The effect of use of machinery on the soils and eventual crop production and sustainability of the system is unknown. The trial was established to look into different planting patterns and ways to mitigate effects on the environment to sustain crop yields over time. It was concluded that it was better to plant at a lower density of 128 palms per ha and sustain high yields. It was recommended the trial was closed.

Introduction

With the increasing costs of labour, the use of machinery is desired for crop evacuation, fertilizer application and spreading of EFB in the fields. Little is known about the impact that traffic has on the physical properties and long-term sustainability of the soils. 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 operations with minimal effect on the sustainability of the system.

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 inTable 58.

Table 58 Trial 331 back ground information

Trial number	331	Company	Kula Oil Palms
Estate	Ambogo	Block No.	Ambogo AA0050
Planting Density	See Table 2	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-02	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

Method

Design and treatments

Initially there were 6 treatments of different planting densities with equilateral triangular spacing (Table 56). 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.

Table 59 Trial 331 treatment allocations '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	9.5	7	128	8.2
2	135	9.25	7	135	8
3	143	9	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. Yield recording, leaf tissue sampling and vegetative measurements were done as per the standard protocol and outlined in Appendix 1.

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 2013 but affected 2011-2013 average yield (Table 60). Treatments 1, 2 and 3 (un-thinned) produced yields which were greater than thinned densities though not statistically significant in 2013, it was statistically significant for the 2011-2013 averaged data. The density of 128 palms unthinned produced the highest yield however it was not really different from densities 135 and 143 unthinned. However with the cumulative yield, palms planted at a density of 192 palms/ha and later thinned to 128 palms/ha yielded 10-20 t/ha more than the other 5 densities (Figure 12).

Table 60 Trial 331 main effects of treatments on FFB yield (t/ha) in 2013 and combined 2011-2013 (treatments which are significantly different at P<0.05 are presented in bold)

	2013			2011 – 2013		
Density Treatment	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
128	33.2	1460	22.9	**33.0**	**1553**	21.5
135	32.2	1461	22.2	**32.2**	**1585**	20.6
143	31.3	1422	22.2	**32.5**	**1586**	20.8
128(192)	31.1	1389	22.6	**31.6**	**1488**	21.5
135(203)	30.3	1348	22.7	**30.8**	**1458**	21.4
143(215)	30.5	1380	22.3	**30.5**	**1480**	20.9
l.s.d. $_{0.05}$				*1.589*	*89.6*	
p values	0.141	0.208	0.672	0.039	0.03	0.181
GM	31.4	1410	22.5	31.8	1325	21.1
SE	1.284	59.4	0.667	0.874	49.2	0.495
CV %	4.1	4.2	3.0	2.7	3.2	2.3

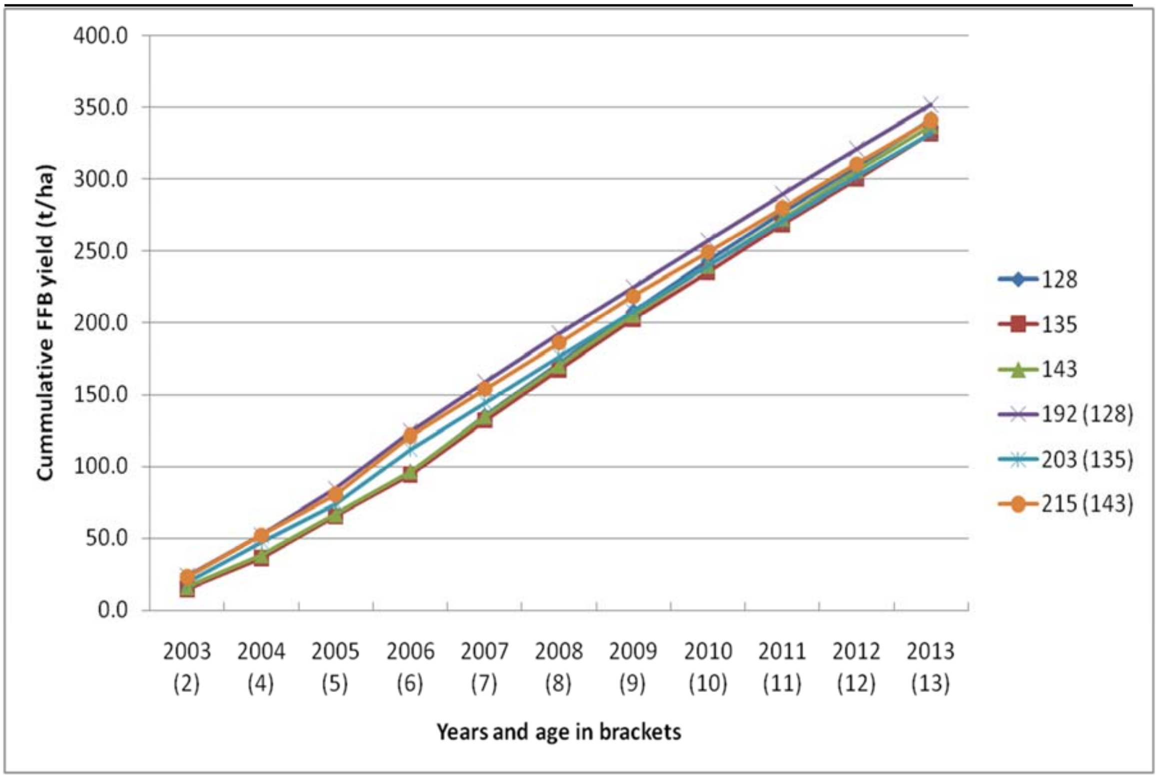

Figure 12 Trial 331: Cumulative FFB yield for the pre-thinning years (2003 and 2006) and the post-thinning year (2007 - 2013). The planting density in brackets refers to post-thinning

Leaf tissue nutrient concentrations

There was no difference in leaf tissue nutrient contents in 2013 except for leaflet P contents (Table 61). The leaflet P contents were higher in the thinned treatments than the high treatments. The nutrient concentrations were above their respective critical values for oil palm. The leaf nutrient contents were above sufficient contents and therefore were not limiting growth and yield production.

Table 61 Trial 331 main effects of treatments on F17 nutrient concentrations in 2013, in units of % dry matter, except for B (mg/kg)

Densities	Leaflet nutrient contents								Rachis nutrient contents			
	Ash	N	P	K	Mg	Ca	Cl	B	Ash	N	P	K
128	11.8	2.38	**0.146**	0.71	0.25	0.78	0.55	16	6.86	0.383	0.205	2.12
135	12.1	2.44	**0.147**	0.72	0.24	0.79	0.57	17	6.89	0.41	0.216	2.23
143	12	2.37	**0.149**	0.72	0.24	0.85	0.56	18	7.74	0.423	0.216	2.38
128 (192)	12.2	2.37	**0.151**	0.76	0.23	0.79	0.57	17	6.9	0.39	0.213	2.3
135 (203)	11.8	2.36	**0.15**	0.75	0.25	0.83	0.54	18	7.91	0.453	0.227	2.56
143 (215)	11.9	2.38	**0.152**	0.75	0.24	0.8	0.54	18	7.74	0.443	0.237	2.38
p value	0.525	0.562	0.044	0.644	0.892	0.57	0.387	0.923	0.288	0.269	0.299	0.184
GM	12	2.38	0.148	0.74	0.24	0.81	0.55	17	7.34	0.417	0.219	2.33
SE	0.349	0.053	0.0022	0.0453	0.0155	0.0507	0.0202	2.646	0.723	0.0396	0.0165	0.186
CV%	2.9	2.2	1.5	6.2	6.4	6.3	3.6	15.1	9.9	9.5	7.5	8

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

Conclusion

In the long term it was better to plant at a lower density of 128 palms/ha and retain the density without thinning. However where machines ware intended to be used, palms should be planted at altered spacing with wider avenues but at 128 palms per ha and not thinned later. It was recommended the trial closed.

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

Past trial in Milne Bay soils have identified N and K as being the most limiting nutrients in Milne Bay alluvial soils. The trial was set up to determine the best option of K fertilizer placement in the Milne Bay high K fixation soils. There was no preferred zone for K placement however effect of where potential leaching could occur should be considered during fertilizer applications. It was decided the trial closed.

Introduction

Nitrogen and potassium are the two major limiting nutrient in the Milne Bay Soils. Past trials (Trials 502 and 504) have identified these nutrients as the most limiting nutrient in this particular environment. The soils have a high K fixing capacity which makes K temporarily unavailable and not meet the short term requirements of crops. There were some indications that even with high amounts of K applied, uptake was not optimum and 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. Use of mechanical spreaders for spreading MOP (and other fertilizers) will be used in the future and this was included as a treatment (simulated mechanical spreading by throwing the fertiliser throughout the plot). This trial was established to identify the best placement of K so that K readily becomes available for uptake. Site details are presented inTable 62.

Table 62Trial 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	13	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).

The trial consisted of 16 plots with one rate of K (MOP at 7.5 kg/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 12 kg/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 2013 and 2011-2013 are presented inTable 63. 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 2013. Though statistically not significant, yield in the plots that received MOP at the edge of the weeded circle was greater than the other treatments. Mean FFB yield was 24.6 t/ha in 2013, and this fell from 30.9 t/ha in 2012.

Table 63 Trial 517 main effects of fertiliser placement treatments on FFB yield (t/ha) and its components for 2013 and 2011 to 2013 (three years averaged data). P values less than 0.05 are presented in bold

Treatments	2013			2011-2013		
	Yield (t/ha)	BN (bunches/ha)	SBW (kg)	Yield (t/ha)	BN (bunches/ha)	SBW (kg)
Nil fertilizer	22.7	1036	**21.6**	25.5	1243	**20.6**
Highest MOP rate	23.0	1004	**22.9**	27.2	1266	**21.6**
Edge of weeded circle	26.8	1201	**22.2**	28.6	1298	**22.1**
Weeded circle	24.5	1049	**23.4**	26.3	1206	**22.0**
Broadcast	23.9	1089	**21.0**	27.4	1280	**21.2**
Frond tips and piles	23.4	1082	**20.8**	27.9	1344	**20.6**
L.s.d $_{0.05}$			*1.48*			*1.14*
P values	0.205	0.278	0.009	0.16	0.212	0.041
GM	24.6	1105	21.9	27.5	1282	21.5
SE	2.261	110.5	0.96	1.33	87.1	0.74
C.V.%	9.2	10	4.4	4.8	6.8	3.4

Conclusion

MOP fertilisers can be placed any where under matured palms and would not affect yield. However throughfall and stemflow from rainfall will need to be taken into consideration as common sense and practice to minimize possible losses. It was recommended for the trial to close.

Trial 516: New NxK trial at Maiwara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

Summary

Nitrogen and K are very important in Milne Bay Soils. Large factorial trials had shown the importance of these two nutrients and this particular trial was established to determine the optimum N and K fertilizer rates for yields with various combinations. The results were inconclusive in 2013 because FFB yields fell by 26 %, which distorted the response curve by flattening it. It was recommended the trial continue.

Introduction

Nitrogen and potassium are major nutrients required in Milne Bay soils for high yields. Previous experiments were large factorial trials (Trials 502, 504 and 511) that looked at various combinations of not only N and K but also other nutrients with and without EFB. Trial 516, a uniform precision rotatable central composite trial design was established for generating fertiliser response surfaces. For a 2-factor (k = 2) central composite design, the treatments consist of (a) 2k (= 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:

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

Equation 2 multiple linear regression of N and K on dependent variable - yield

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.

This trial was established to determine the optimum N and K rates for alluvial soils in Milne Bay and provide additional information for fertilizer recommendations. Site details are presented in Table 64.

Table 64 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	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: 0.5 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.

The trial consisted of 13 plots with 5 treatment rates of both N and K (N range: SOA from 0 to 9 kg/palm and MOP from 0 to 7 kg/palm).

Results

Yield data for 2013 and three years running average for 2011-2013 were analysed using polynomial regression function in Genstat. The model (Equation 3) for yield in 2013 was;

Yield (2013) = 11.4 + 0.77.SOA + 3.87.MOP + 0.07.SOA*SOA – 0.13.MOP*MOP - 0.33.SOA*MOP

Equation 3 Regression model used for determining yield in 2013.

The model accounted for only 18.4 % of the variance with a standard error of 4.14. The variance accounted for the model was not improved when mean yield from 2011-2013 was looked at. The mean yield fell from 31.6 t/ha in 2012 to 23.4 t/ha in 2013 and this appears to have distorted any responses to the fertilisers in 2013.

With the leaf tissue contents Equation 4 was used to determine the SOA and MOP combination that will provide the maximum rachis K content.

*Rachis K (2013) = 0.74 - 0.064.SOA + 2.91.MOP + 0.0071.SOA*SOA – 0.025.MOP*MOP - 0.0084.SOA*MOP*

Equation 4 Regression model used to determine maximum rachis K content in 2013.

The model accounted for only 17.7% of the variance with a standard error of 0.273 however was not statistically significant. The response in rachis K decreased with increasing MOP rate and appears not to be influenced by SOA (Figure 13).

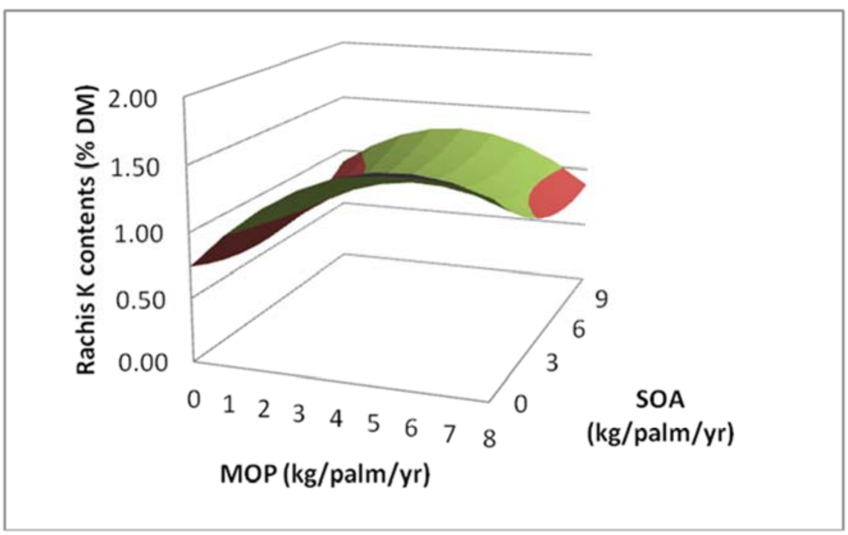

Figure 13 Trial 516 surface response curve for rachis content determined by SOA and MOP

Conclusion

The 2013 results were inconclusive because yield fell in 2013 by 26 % from 2012. The fell in yield distorted the response curve by flattening it. Therefore, it was not possible to determine the maximum yield from the SOA and MOP combinations. It was recommended the trial continued.

Trial 513: Spacing and Thinning Trial, Padipadi

(RSPO 4.2, 4.3, 8.1)

Summary

With increasing cost of production especially labour costs, use of machinery for infield crop evacuation, fertilizer application and EFB spreading is looked-for. The effect of use of machinery on the soils and eventual crop production and sustainability of the system are unknown. The trial was established to look into different planting patterns and ways to mitigate effects on the environment to sustain crop yields over time. There was no yield response in 2013, and it is recommended palms are planted at low densities even if spacing is altered to allow for mechanization and no thinning. It was recommended the trial closed.

Introduction

With the increasing costs of labour, the use of machinery will be inevitable in the future for crop evacuation, fertilizer application and spreading of EFB in the fields. Little is known about the impact that traffic has on the physical properties and long-term sustainability of the soils. 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. 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 operations with minimal effect on the sustainability of the system. Wider avenue spacing may allow more sunlight, better cover crop growth and less soil damage in the inter-rows used by vehicles. The purpose of the trial was to determine the effects of spacing configuration, thinning and density on palm yield . 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 65.

Table 65 Trial 513 back ground information

Trial number	513	Company	Milne Bay Estates
Estate	Padipadi	Block No.	1051
Planting Density	See Table 3	Soil Type	Alluvial
Pattern	Triangular	Drainage	Good
Date planted	2003	Topography	Flat
Age after planting	9	Altitude	Not known
Recording started	Apr-06	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

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 66). 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 followed normal plantation practice for an immature fertiliser program up to year 6.

Table 66 Trial 513 treatment allocations. '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) (m)
1	128	9.5	7	128	8.23
2	135	9.25	7	135	8.01
3	143	9	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.

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 3).

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 unthinned palms even at similar densities.
2012 Yield: there was significant difference between thinned and unthinned palms even at similar densities.
2013 Yield: There was no treatment effect on yield even number of bunches was affected. Yield on the whole fell in 2013.

In 2013, the number of bunches was affected by the treatments (p=0.016) but this was not translated to yields (Table 67). However for the combined 2011-2013 period, the yields in Treatments 1, 2 and 3 were significantly greater than treatments 4, 5 and 6 after thinning. This was mostly due to the significant effects on the number of bunches. On the whole, before thinning, the high density plots were yielding more than the low density treatments (1, 2 and 3) (Figure 14).

The mean yield in 2013 was 21.1 tonnes/ha, fell from 31.1 tonnes/ha in 2012.

Table 67 Trial 513 Main effects of density treatments on FFB yield (t/ha) and its components for 2013 and 2011 to 2013 (three years averaged data). P values less than 0.05 are presented in bold

Density treatment	2013			2011-2013		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
128	23.9	**1357**	18	**28.4**	**1705**	17.0
135	21.9	**1264**	17.6	**27.1**	**1641**	16.7
143	22.9	**1314**	17.8	**27.1**	**1653**	16.6
128 (192)	18.9	**1046**	18.5	**23.8**	**1375**	17.6
135 (203)	20.0	**1169**	17.4	**24.0**	**1456**	16.6
143 (215)	19.3	**1109**	17.6	**23.3**	**1403**	16.8
p values	0.142	0.016	0.663	0.002	<0.001	0.467
Grand Mean	21.1	1210	17.8	25.6	1539	16.9
SE	2.35	95.2	0.815	1.243	59.2	0.665
CV %	11.1	7.9	4.6	4.9	3.8	3.9

(..) previous density

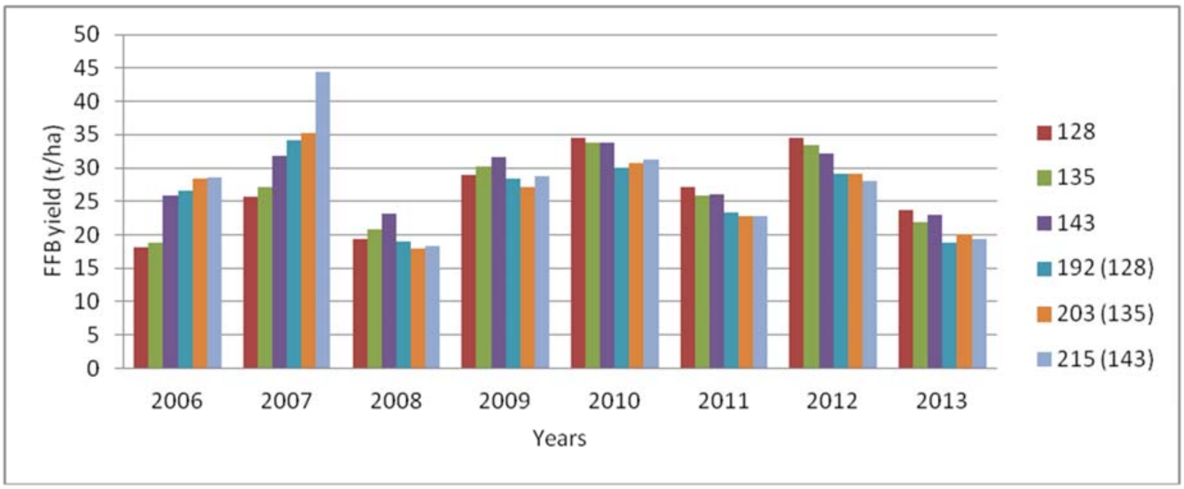

Figure 14 Trial 513: FFB yield for the pre-thinning years (2006 and 2007) and the post-thinning year (2008 - 2013)

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

In the long term it was better to plant at a lower density of 128 palms/ha and retain the density without thinning. However where machines were intended to be used, palms should be planted at altered spacing with wider avenues but at 128 palms per ha and not thinned later. It was recommended the trial closed.

SMALLHOLDER RESEARCH REPORT IN 2013, ORO OIL PALM PROJECT

Murom Banabas and Merolyn Koia

Summary

Smallholder sector comprises 30-40% of the industry however yields are only a third to half the potential of the crop that can be achieved. Various factors contribute to the low yields seen in the blocks. The smallholder studies done by agronomy section looked at leaf nutrient contents and involve with other PNGOPRA sections in field days and transfer of information to contribution to increased yields in the sector. Yields in the smallholder sector could be tripled if N and K fertilizers are managed well. It was recommended smallholder agronomy activities closed.

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 happens for 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 2013.

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 - Smallholder Leaf Sampling

(RSPO 4.2, 4.3, 8.1)

Method and materials

Leaf sampling was carried out in selected representative blocks of the five smallholder oil palm divisions; Sorovi (21 blocks), Igora (12 blocks), Saiho (12 blocks), Aeka (4 blocks) and Ilimo (8 blocks) Divisions.The blocks were selected to represent the whole project area in Northern Province. In addition to sampling the blocks for tissue analysis, vegetative measurements were also done on selected palms within the blocks. The blocks agronomic standard were also assessed and scored as per attached guide (Appendix 2).

Results

Leaf tissue nutrient concentrations

The results for each division are presented inTable 68. 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 five divisions as suggested by the low N contents in the sampled blocks. The lowest N content ranged from 1.96 % DM at Aeka to 2.21 % DM at Saiho. The K contents in the rachis were also low and ranged from 0.73% DM at Ilimo to 1.28 % DM at Sorovi. The rachis K values are very low but N status has to be improved first. The general trend in the low nutrient contents continued from 2009 to 2013 and showed no indications of any improvement with time (Table 69). 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 to provide nitrogen and potassium.

Table 68 Trial 336 mean leaf tissue nutrient contents of 57 smallholder blocks in 2013

Division	Leaflet (% DM except B in mg/kg))								Rachis (% DM)			
	Ash	N	P	K	Mg	Ca	B	Cl	Ash	N	P	K
Aeka	12.83	1.96	0.133	0.66	0.3	0.76	14	0.36	3.37	0.22	0.095	0.83
Igora	15.42	2.02	0.132	0.58	0.26	0.91	16	0.4	4.22	0.24	0.082	0.99
Ilimo	12.77	2.18	0.141	0.65	0.25	0.94	14	0.47	3.9	0.27	0.098	0.73
Saiho	13.57	2.21	0.141	0.65	0.26	0.94	16	0.42	3.98	0.28	0.074	0.77
Sorovi	13.43	2.13	0.141	0.67	0.26	0.89	16	0.44	4.53	0.25	0.138	1.28
Mean	13.75	2.12	0.139	0.65	0.26	0.9	15.71	0.43	4.18	0.26	0.104	1.00
std dev	2.148	0.196	0.01	0.148	0.051	0.124	2.414	0.088	0.701	0.04	0.054	0.41
CV %	16	9	7	23	19	14	15	21	17	15	52	41

Table 69 Trial 336 mean leaf nutrient contents (% DM and mg/kg for B) of smallholder blocks from 2009 to 2013

Year	Leaflet (% DM except B in mg/kg))								Rachis (% DM)			
	Ash	N	P	K	Mg	Ca	B	Cl	Ash	N	P	K
2009		2.17	0.139	0.67	0.25		13			0.26	0.105	0.96
2010	15.4	2.00	0.134	0.67	0.27		13		3.94	0.26	0.097	0.91
2011	14.4	2.13	0.139	0.68	0.27	0.84	12	0.23	4.14	0.25	0.104	0.98
2012	13.9	2.16	0.137	0.60	0.24	0.80		0.4	3.73	0.24	0.089	1.00
2013	13.7	2.12	0.139	0.65	0.26	0.90	16	0.43	4.18	0.26	0.104	1.00
Mean	14.3	2.12	0.137	0.66	0.26	0.85	13.4	0.35	4	0.25	0.100	0.97
Std dev	0.754	0.066	0.002	0.033	0.014	0.052	1.67	0.105	0.208	0.009	0.007	0.039
CV%	5.3	3.1	1.7	5.0	5.4	6.1	12.5	29.8	5.2	3.6	6.8	4.0
Critical value		2.45	0.145	0.65	0.2					0.32	0.08	1.3

Leaf area index and petiole cross section

Leaf area index and petiole cross section of palms ranging from 4 years to 23 years old were measured in 2013 (Table 70). Leaf area index was less than 5.00 for all the ages, which implied poor leaf area development in the smallholder oil palms. The petiole cross sections ranged from 25 to 48 cm^2 for the different palm ages. Note here this is a snap short of different age groups in 2013 and not measurements done over time. The measured values are low for the age groups again implying low management inputs especially use of inorganic fertilisers in sustaining good growth for higher yields. The poor fertiliser management has a lot of implications on low leaf nutrient contents, poor leaf area and petiole cross section development and the resultant low oil palm yields that is seen across the industry in smallholder blocks.

Table 70 Trial 336 leaf area index and petiole cross section (PCS) of fronds from smallholder block in 2013

Age	LAI	PCS (cm^2)
4	4.87	25.3
5	4.34	32.5
6	4.34	28.6
7	4.64	28.4
8	4.57	37.3
12	4.25	39.5
13	4.17	42.6
14	3.86	46.5
15	4.41	43.3
16	3.8	46.2
17	4.39	48.7
18	4.25	41.1
19	3.87	42.3
20	4.74	37.8
23	4.29	29

Smallholder Block Assessments

The summarized scoring results of block assessment in 2013 are presented in Table 71. The mean nutrient deficiency score was 2.3 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 67. General block upkeep (weeded circles (1.6) and general weeds (1.6)) were low in all the divisions. Average pruning standards were 2.7 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.

Table 71 Trial 336 smallholder block assessments scores in 2013, in brackets are the number of blocksfor each of the divisions

Criteria used for scoring block assessment	Division					Average Score
	Aeka (4)	Igora (12)	Ilimo (8)	Saiho (12)	Sorovi (21)	
Palm Nutrient Deficiency	2	2.2	2.4	2.5	2.4	2.3
Block Standard	2.6	3	2.7	3	2.9	2.9
Frond stack	3	2.8	2.9	2.8	3	2.9
Ganoderma	3	2.9	3	3	3	3
Ground cover-deficiency	3	2.9	3	3	3	3
Harvest standard	2.6	3	2.4	2.9	2.7	2.8
Harvest paths	1.4	2.1	2.1	1.9	2.1	2
Insect Damage	3	3	3	3	3	3
LPC	2.6	2.6	2.6	2.6	2.5	2.6
Pruning <7years	2	3		3	2.5	2.7
Pruning >7years	1.8	2.5	2.3	2.6	2.5	2.4
Rat Damage	3	3	3	3	3	3
Trunk weeds/ferns	2.6	2.8	2.9	2.9	2.9	2.8
Trunk weeds/woods/vines	2	2	1.7	2.1	2.1	2
Weeded circle	1.2	1.9	1.4	1.3	1.7	1.6
Weed-ground cover	1.6	1.5	1.6	1.4	1.8	1.6

Field visits

There were field visits to smallholder blocks for various activities; there were also visits for completing soil pit descriptions for the sustainability project and for agronomy leaf sampling which was done in 57 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 71). There was no major field day organised in 2013 but there were 13 small minor field days. The field days were mostly for new oil palm farmers who were involved in infield planting program.

Table 72 Trial 336 number of field days and radio broadcasts in 2013

Extension mode	Section		Total
	Agronomy and others	Agronomy alone	
Field days (Major)			
Field days (Minor)	8	5	13
Radio broadcasts			

Conclusion

The major agronomic limiting factor in smallholder blocks was lack of attention to inorganic fertilizing oil palm especially N and K fertilizers. Yields could easily triple or quadruple with proper management of fertilisers in the blocks. The management ranged from proper timing of delivery and distribution to growers, ensure all fertilisers were applied at correct rates to the growers and consistent awareness of the importance of fertilisers.

Trial 337: Smallholder oil palm/food crop intercropping demo block, Sangara and Biru

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

Summary

Food crop gardening is a very important part of lives of many oil palm growers. Crops are grown for own use, marketing to earn cash, to feed livestock and for cultural/religious activities. However land pressure on available land is a major concern in the smallholder oil palm farming system. The trial was set up with the aim to try out altered oil palm planting pattern to intercrop oil palm with food crops. A significant proportion of food crop dry matter were removed from the system along with possible significant nutrients from the system. It was recommended the demonstration trials continue.

Introduction

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. 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 LSSs 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.

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.

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. One portion 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 73 and Table 74 while the sketch maps are shown in Figure 15 and Figure 16 respectively.

Table 73 Trial 337, Block information - Sangara

Trial number	337	Soil Type	Volcanic ash plain
Block owner	Mr. R. Safitoa	Drainage	Good
Block No.	50136	Topography	Flat
Location	Sangara	Altitude	m asl
Division	Sorovi	Previous Land-use	Oil Palm
Planting Density	128		
	128	Supervisor in charge	Meroly Koia
Pattern	Triangular		
Date planted	2008		
	2010		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2010 (Food crops)		

Table 74 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	Meroly Koia
Pattern	Triangular		
Date planted	2012		
	2012		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2012 (Food crops)		

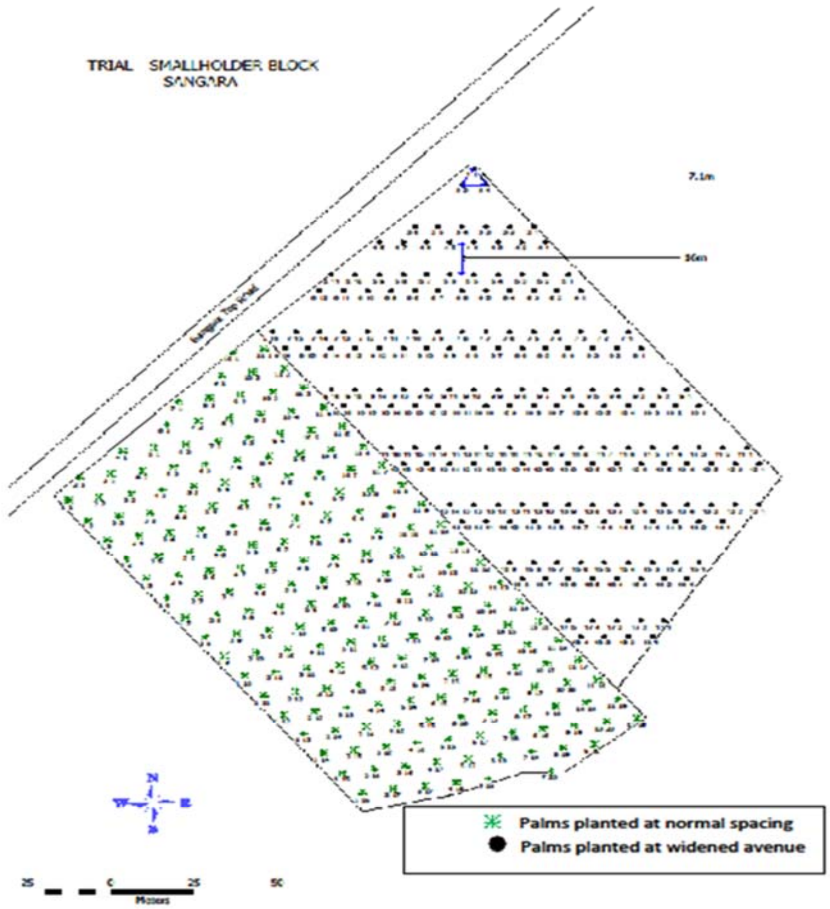

Figure 15 Trial 337 map outline of food security block at Sangara in Popondetta

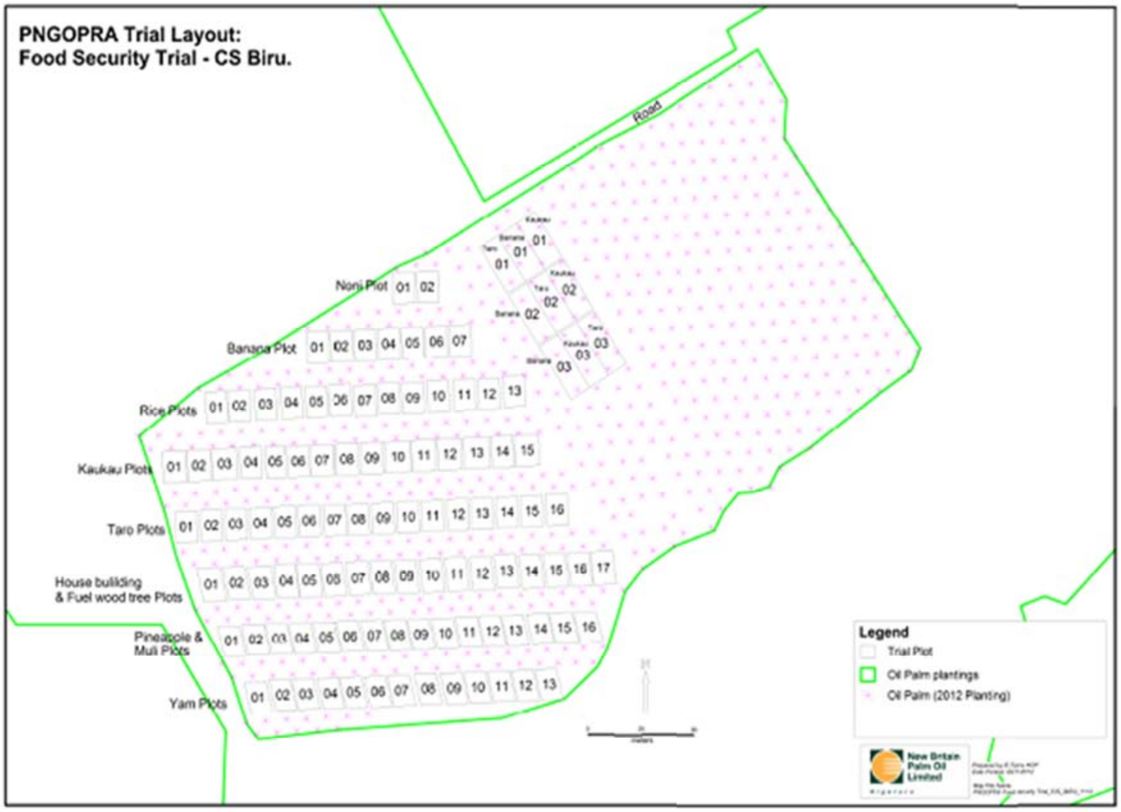

Figure 16 Trial 337 map outline of food security block at Biru in Popondetta

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 in Table 75and Table 76. Other crops not included are mandarin, noni, fuel wood, wood for house roof, pineapples, bananas and cassava. Data collection from Sangara Block 050136 was incomplete because of the lack of cooperation from the farmer. The duration of cropping is 4-6 months for the major crops.

Table 75 Trial 337 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 spoilt			3	10m x 10m

Table 76 Trial 337 major food crops and date of planting in Block 88888 at Biru– CIS

Crop	Total plots	Rounds	Date planted	Date Harvested	Months	Planted plots	Plot size (m)
Normal oil palm spacing							
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	6-Mar-13	Sep-13	6	3	10 x 24.5
	3	4	Sep-13	Mar-14	6	3	10 x 24.5
	3	5	Mar-14			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	13-Jul-13	7	3	10 x24.5
		3	1-Aug-13	7-Nov-13	4	3	10 x 24.5
		4	8-Nov-13			3	10 x 24.5
Banana	3	1	22-May-12	6-Mar-13		3	10 x 24.5
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	21-Sep-13	5	4	10 x 14
	15	4	1-Oct-13		5	4	10 x 14
Taro	16	1	8-Nov-12			3	10 x 14
Rice	13	1	5-Jun-12	2-Oct-12	4	4	10 x 14
	13	2	2-Jan-13	9-May-13	4	4	10 x 14
			21-May-13	11-Sep-13	4	4	10 x 14
Yam	13	1	9-14 Nov-13	26-Mar-13	4	4	10 x 14
		2	9-Apr-13	29-Jul-13	4	4	10 x 14
		3	10-Apr-13	29-Aug-13			10 x 14
			11-Apr-13	29-Sep-13			10 x 14
			11-Apr-13	26-Sep-13			10 x 14
			12-Apr-13	26-Sep-13			10 x 14

Results and discussion

Data from only Biru block is discussed because there were irregularities in cropping and data collection from Sangara Block due to the farmer not cooperating with harvesting and oil palm block upkeep. The palms were still young (1 year old) and therefore yield data was not collected however results of vegetative measurements are presented inTable 77. There has been fire in the widened avenue side of the block and this has affected petiole cross section being lower than in normal spaced palms. LAI is higher in the normal spaced palms because of higher density (128 palms/ha) than in widened avenue palms (89 palms/ha). The LAI will be monitored over time with reduction in food cropped area and yields.

Table 77 Trial 337 LAI and petiole cross section of oil palm at Biru food security demonstration block

Month	LAI		Petiole cross section (cm^2)	
	Normal spacing	Widened avenue	Normal spacing	Widened avenue
Oct-12		1.63		8.6
Jan-13	2.91	1.49	12.4	10.2
Aug-13	3.56	1.89	13.4	11.3

The dry matter produced in the food crop plots are presented in Table 78. For kaukau crop, 40-60% of the dry matter was in the tubers, for yam, 33% of dry matter was in the tubers while for rice, 11-22 % of the total dry matter was good grain. A significant proportion of the crops were removed from the system with nutrients.

Table 78 Trial 337 dry matter production for kaukau, yam and rice in widened avenue cropping in 2013

Crop	Crop part	Dry matter (kg/ha/crop)		Proportion of total DM (%)	
		1st Crop	2nd crop	1st Crop	2nd crop
Kaukau	Vines and leaves	14030	7456	48	35
	Tubers	12426	13180	43	59
	Roots	2431	1030	9	5
	Mean	9629	7222		
	Std dev	6427	6386		
	CV %	67	88		
Yam	Vines and leaves	7211		50	
	Tubers	4898		33	
	Roots	2593		16	
	Mean	5122			
	Std dev	11861			
	CV %	232			
Rice	Good rice grains	1543	263	21	11
	Bad rice grains	618	339		
	Rice stalk	5031	2449		
	Mean	2397229	1194070		
	Std dev	2088265	1211016		
	CV %	87	101		

Conclusion

Oil palm leaf area index increase with time but is different due to different densities. A large proportion of total dry matter (40-60%) from kaukau is removed from the farming system compared to 33 % for yams and 11-21% with rice grains and possibly with significant crop nutrient elements. The major staple crops can be produced twice a year. It was recommended the trials continue.

TRIAL 256 NEW IRELAND SMALLHOLDER FERTILISER/BMP DEMONSTRATION BLOCKS

(RSPO 4.2, 4.3, 4.5, 4.6, 4.8, 8.1)

Murom Banabas, Paul Simin, Erwin Kea and Akia Aira

Summary

Oil palm yields in smallholder blocks in New Ireland are very low and less than 15 t/ha/year. The palms are grown on thin soil soils and require good agronomic practices to get high yields. Two fertilizer demonstration block were established in 2008 to demonstrate best management practices the farmers. Addition of 2-3 kg AC (or equivalent N fertilisers) and 2 kg MOP is required to produce yields greater than 20 t/ha/year. It was recommended the demonstration blocks continue.

Introduction

Smallholders make up 27% of the oil palm planted area in New Ireland but produce only 15 % of the annual crop. The yields in the smallholder blocks are generally very low, less than 15 t/ha/year. The soils in New Ireland are thin (20-60 cm depth) with outcrops limestone common across the project site. The soils are marginal and require good agronomic practices to get high yields. The smallholder blocks demonstrations were established to demonstrate best management practices to farmers in New Ireland province.

Methods

Trial setup

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. The demonstration blocks information ispresented in Table 79. Each of the 2 blocks had a different number of palms with nil fertilised and fertilised plots. At Lakurumau, Block 2655 had 40 palms not receiving any fertilisers while the rest of the block received fertilisers. Yield recording was done on the 40 nil fertilised palms and from 80 of the fertilised palms. The fertilised palms in both blocks received 6 kg SOA and 2 kg MOP per palm per year in 2008 but SOA was reduced to 3 kg and while MOP remained at 2 kg/palm/year in 2009 and thereafter. Another block (Block 1618) was established in 2010 to replace the previous block at Kafkaf because the grower at Kafkaf was having problems in harvesting.

Table 79 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	Mar-08		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2010 (Food crops)		

Fresh fruit bunch yield data was collected on a fortnightly basis from the nil fertilised and selected fertilised palms while petiole cross section was measured, initially twice a year and later once per year. Leaf tissues were collected once a year for nutrient analysis.

Results and discussion

Oil palm yields and petiole cross section measurements

Yield data and petiole cross section data are presented in Table 80andTable 81. Data collection started in June 2009. The fertilised palms yielded more bunches and had higher single bunch weights than from the nil fertilised palms. This resulted in higher FFB yields from the fertilised palms than from the nil fertilised palms. However in 2013, yield fell by 8 tonnes in Block 2655 (Table 80) and about a tonne in Block 1618 (Table 81), both from the fertilised plots. Yield response to fertilisers was immediate after a year (Figure 17). The increase in yield in nil fertilised plots was probably due to the palms accessing fertilisers from neighbouring fertilised palms.

Petiole cross section and frond length in fertilised plots were greater than in nil fertilised plots in the two blocks (Table 80andTable 81). There was continued increase in petiole cross section both with time and fertiliser treatments and were independent from changes in yield.

Table 80 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	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	37.1	
2011	- Fert	17.4	1059	16.4	23.5		497.6
	+ Fert	25.1	1256	20	32.7		523.5
2012	- Fert	17.5	1024	17.1	24.5		497.5
	+ Fert	27.1	1235	22	34.7		559.3
2013	- Fert	16.3	874	18.7	25.4		484.3
	+ Fert	19	853	22.3	35.9		543.4

PCS = petiole cross section (cm2) measured in April (PCS-1) and October (PCS-2) in 2009
FL = frond length (cm)

Table 81 Trial 256, Yield and yield components in 2011-2013 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	598.8
	+ Fert	19.5	1486	13.1	25.3	559.5
2013	- Fert	13.5	1043	12.9	25.4	554
	+ Fert	17	995	17	28.4	599

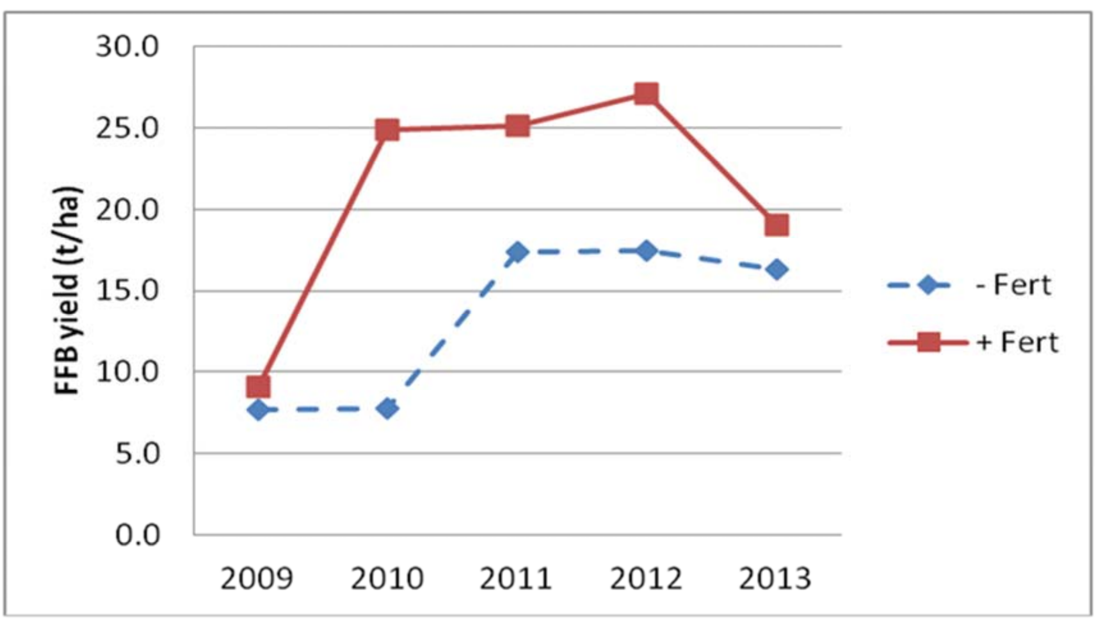

Figure 17 Trial 256 Fresh fruit bunch yield from Block 2655 in fertilised and nil fertilised plots from 2009 to 2013

Leaf and rachis tissue samples results

Analysed leaf tissue results are presented in Table 82and Table 83for the two demonstration blocks. Leaf tissue contents for Block 2655 for 2013 are not presented however 2012 data is presented. 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. While the increase in rachis K content from 0.28% to 0.75 % in 2013 in Block 1618 corresponded with a 4T increase in FFB yield. The increased rachis K contents in 2012 in Block 2655 and in Block 1618 were still lower than the critical levels of 1.35% DM.

Table 82 Trial 256, Leaf tissue nutrient contents (% DM except B in mg/kg) 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	2.1	0.15	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		3.6	0.29	0.145	0.3
2010	- Fert	6.68	2.33	0.152	0.42	0.36	1.38		17	0.18	3.45	0.27	0.114	0.2
	+ Fert	6.11	2.59	0.157	0.61	0.27	1.17		12.3	0.2	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	0.2
	+ 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 83 Trial 256, Leaf tissue nutrient contents (% DM except B mg/kg) in 2011 and 2013 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	0.2
	+ 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	2.8	0.171	0.58	0.44	1.3	0.67	16.1	0.22	3.46	0.43	0.102	0.54
2013	- Fert	7.73	2.37	0.143	0.42	0.49	1.29	0.71	16.5	0.2	3.3	0.31	0.075	0.28
	+ Fert	7.04	2.66	0.147	0.63	0.37	1.11	0.75	14.1	0.22	3.4	0.28	0.066	0.75

Conclusion

Nitrogen and potassium fertilizers are very important for oil palm production in New Ireland Province. It is important that 2-3 kg AC and 2 kg MOP is added to palms in smallholder blocks in these New Ireland marginal soils. It was recommended the demonstration blocks continued however with whole block receiving fertilizers.

APPENDIX

Appendix 1. Field trials operations

Fresh fruit bunch yield recording

Fresh fruit bunch is determined from counting and weighing every single harvested bunch from the experimental palms in the plots. Loose fruits are also collected and weighed. The recording is done every 10-14 days. The sum of the weights for each of the plots in a year is transformed to a hectare basis and this gives the production for that particular plot in a year. The data is then statistically analysed depending on the trial design.

Leaf tissue sampling for nutrient analysis

Leaf sampling from frond 17 is done annually for nutrient analysis. Leaflets and rachis samples are collected from around 0.6 of the frond length for analysis. The samples are collected from each individual palm in a plot and then combined. Standard leaf processing procedures are followed to process, oven dry (70-80 C) and then grounded before being sent away for analysis. Depending on the aims of the trial, the leaflets are analysed for Ash, N, P, K, Mg, Ca, Cl, B and S while the rachis samples are analysed for Ash, N, P and K.

Vegetative measurements

While taking leaf tissue samples for tissue analysis, leaflet samples are also collected for measurements to determine the leaf area and annual dry matter production. For leaf area determination, six leaflets are collected from 0.6 of the frond length and lengths and widths are measured. In addition to leaflet measurements, number of leaflets, frond length and total number of fronds on the palm are also measured. For dry matter production, petiole cross section and biannual frond production rates are measured. Height measurements are measured annually to determine total biomass and nutrient use efficiency where required is selected trials. The data is entered into the data base system and summarised for each plot which is then analysed.

Trial maintenance and upkeep

The trial blocks are maintained regularly by respective estates and include weed control (either herbicide spraying or slashing), wheelbarrow path clearance, pruning, cover crop maintenance and pests and diseases monitoring and control. In the fertiliser trials, all fertiliser treatments are carried out by PNGOPRA Agronomy Section to ensure that correct fertiliser type and rates are applied. In large systematic trials, the basal applications are done by the estates but supervised by PNGOPRA. In the large non fertiliser trials such as the spacing and thinning trials, the estates do the fertiliser application.

Data Quality

A number of measures are in place for ensuring quality data is collected from experiments. The measures include;

a) The trial yield recording checks are done once a month by randomly reweighing four to five bunches or even more after the recorders had weighed to ensure that the weights recorded already by a recorder are actually correct and scale is not defective or misread.

b) Trial inspection and standard checks are done once a month on harvest path clearance, frond stacking, ground cover, visibility of ripe bunches, weighing of loose fruits, pruning and pests and diseases. This information is passed on to the plantation management with quarterly reports to assist in improving the block management standards.

c) The accuracy check for marking frond one (1) and cutting frond seventeen (17) is done during tissue sampling, vegetative measurements and frond position count to be sure the activity is not based on any other fronds.

d) Scales are checked against a known weight once a week.
e) Other tools are inspected to ensure there are no defects before using them.
f) Field data is checked by supervisors and agronomists before passing them to data entry clerks for data entry. Data base entry checks are done prior to commencement of data analysis and report writing for each year to ensure that no wrong entries of dates, unusual figures, and all data are captured in the system.
g) All samples sent for analysis have standard samples sent along with to ensure data results are within the accepted range.

Appendix 2. Smallholder block assessment guides.

The attached guides are used for assessing field standards for smallholder blocks. The first table provides the procedure used for assessing the blocks while the second table provides the scoring guide. The scores are used during leaf sampling of smallholder blocks and each block is scored. An average of a division is provided annually and this gives a documented report of status of agronomic standards of blocks sampled.

a) Procedure for assessing smallholder block standards.

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

b)

Scoring guide for smallholder block assessment

Small holder block – hygiene and block management assessment

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

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

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	

Appendix 3. Papers published from sustainability project.

a) Nelson, P. N., Gabriel, J., Filer, C., Banabas, M., Sayer, J. A., Curry, G. N., Koczberski, G. and Venter, O. (2013), Oil palm and deforestation in Papua New Guinea. Conservation Letters. doi: 10.1111/conl.12058

b) Soil carbon balance following conversion of grassland to oil palm. Goodrick, I., Nelson, P. N., Banabas, M., Wurster, C. M. and Bird, M. I. (2014), GCB Bioenergy. doi: 10.1111/gcbb.12138

c) Methods to account for tree-scale variability in soil and plant-related parameters in oil palm plantations, P. N. Nelson & M. J. Webb & M. Banabas & S. Nake & I. Goodrick & J. Gordon & D. O'Grady & B. Dubos (2014), Plant Soil 374:459–471

2. ENTOMOLOGY SECTION

HEAD OF SECTION II: DR MARK ERO

Solomon Sar, Brian Kiely, Tabitha Manjobie, Richard Dikrey, Simon Makai, Seno Nyaure, Barnabas Sapau, Akia Aira

OVERVIEW OF THE SECTION AND ACTIVITIES

The Entomology Section undertakes applied research on oil palm pests and provides technical advice on best management practices to the oil palm industry in PNG to help mitigate damage caused by pest infestations. Apart from the research and advisory activities, the section also conducts pest infestation surveys in member company plantations and smallholder blocks upon requests from Plantation Managers and OPIC Divisional Managers, and issues treatment recommendations where treatment intervention is required.

Most of the research activities of the section were conducted at its head office in Dami, West New Britain Province (WNBP) in 2013 but with a few spread across PNGOPRA Sub-Centers located at Bialla (Hargy Oil Palms Ltd-HOPL), Higaturu (NBPOL) and Poliamba (NBPOL). The alternative insecticide evaluation, pollinating weevil monitoring, and *Segestidea defoliaria defoliaria* biology studies were conducted in WNBP with all activities coordinated from Dami. The sampling of aquatic invertebrates for the SADP water quality monitoring study was done both in Northern and WNB Provinces. The main activity at Higaturu was the survey of bagworm infestation at Ambogo Estate, whilst at Poliamba it was the monitoring and investigation into the management options for *Oryctes rhinoceros* beetles. Apart from the collection of male inflorescences for weevil monitoring at Barema, very few research activities were conducted at Bialla because the staff currently based there was transferred from Higaturu half way through the year (July 2013).

This report covers all operational and research activities conducted by the section in 2013. The report for each research activity presents mainly the results and key recommendations. Whilst most of the research activities are ongoing and will continue into 2014, a few were concluded during the year (2013).

Apart from the operational work and research activity reports, additional activity reports such as publications, trainings and field days, conferences attended, pest and disease meetings, and visitors to entomology section during the year are also presented.

ROUTINE PEST REPORTS AND MANAGEMENTS

Oil Palm Pest Reports- (RSPO 4.5, 4.6, 8.1)

The frequency of pest occurrences reported for different taxa increased in 2013 from those reported in 2012. Most of the pest reports in PNG were from WNBP for both smallholders (OPIC) and the plantations (HOPL and NBPOL) (Figure 18, Figure 19 and Figure 20). No major pests were reported from the Solomon Islands (GPPOL). The species with high proportion of reports were *Segestes decoratus* (Tettigoniidae), *Segestidea defoliaria defoliaria* (Tettigoniidae), *Segestidea defoliaria gracilis* (Tettigoniidae) and *Eurycantha calcarata* (Phasmatidae). Both Tettigonnidae and Phasmatidae belong to the order Orthoptera. Apart from these regularly reported species, *Oryctes rhinoceros* (Scarabaeidae: Coleoptera) was frequently encountered in replants at New Ireland (NI), and required management intervention. Proportionately similar numbers of major pests were reported from the smallholders (OPIC) and Plantations. A few other minor insect species (e.g. mole cricket- *Gryllotalpa* spp.) and rodents (e.g. *Rattus* spp.) were also reported occasionally but did not require any treatment intervention. There are sporadic pest species known to cause damage occasionally to oil palm but none were reported during the year. The insect species include *Segestidea novaeguineae* (Tettigoniidae), *Eurycantha horida* (Phasmatidae), *Eurycantha insularis* (Phasmatidae), *Acria emarginella* (Oecophoridae), *Eumeta variegatta* (Psychidae), *Mahasena corbetti* (Psychidae), *Manatha conglacia* (Psychidae), *Dermolepida* sp. (Scarabaeidae), *Lepidiota* sp. (Scarabaeidae), *Rhinocophorus billineatus* (Curculionidae), *Sparganobasis subcruciata* (Curculionidae), *Rhabdoscelus obscurus* (Curculionidae), *Oryctes centaurus* (Scaraebaeidae), *Scapanes australis* (Scarabaeidae) and *Papuana* spp. (Scaraebaeidae). No pests were reported from the Solomon Islands.

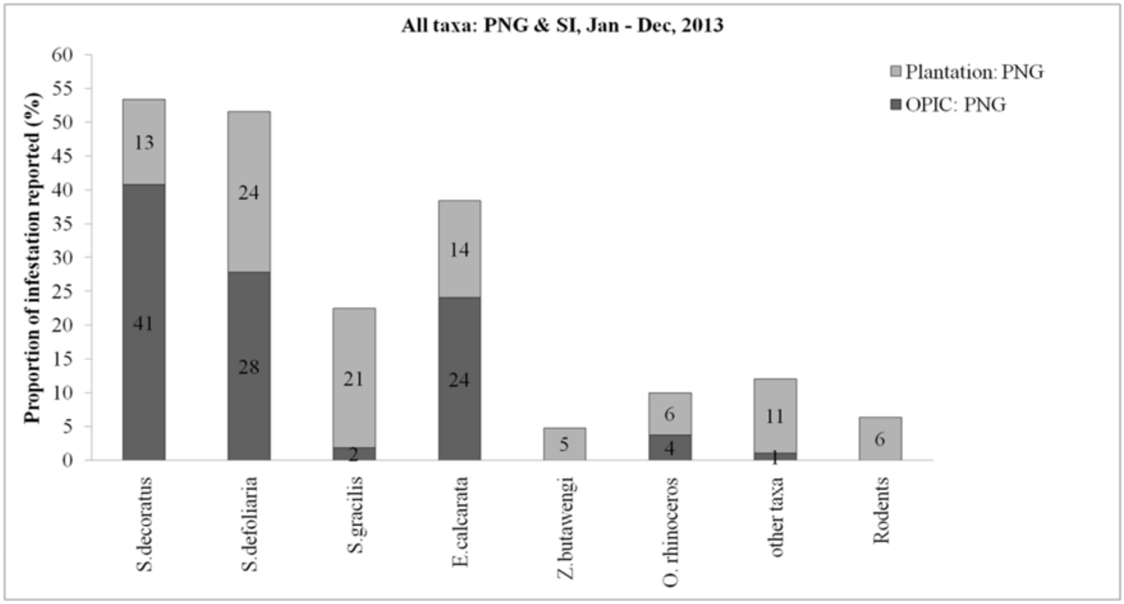

Figure 18 The proportion (%) of major pests reported in 2013 from PNG by plantations and smallholders

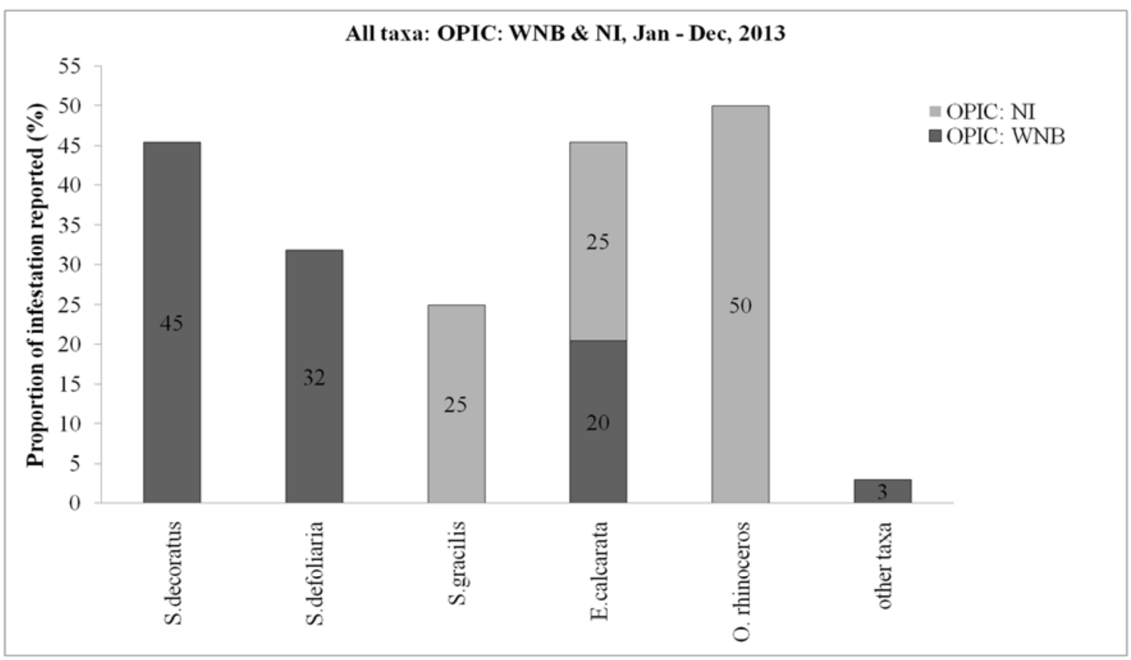

Figure 19 The proportion (%) of major pests reported by smallholders from NI and WNB in 2013

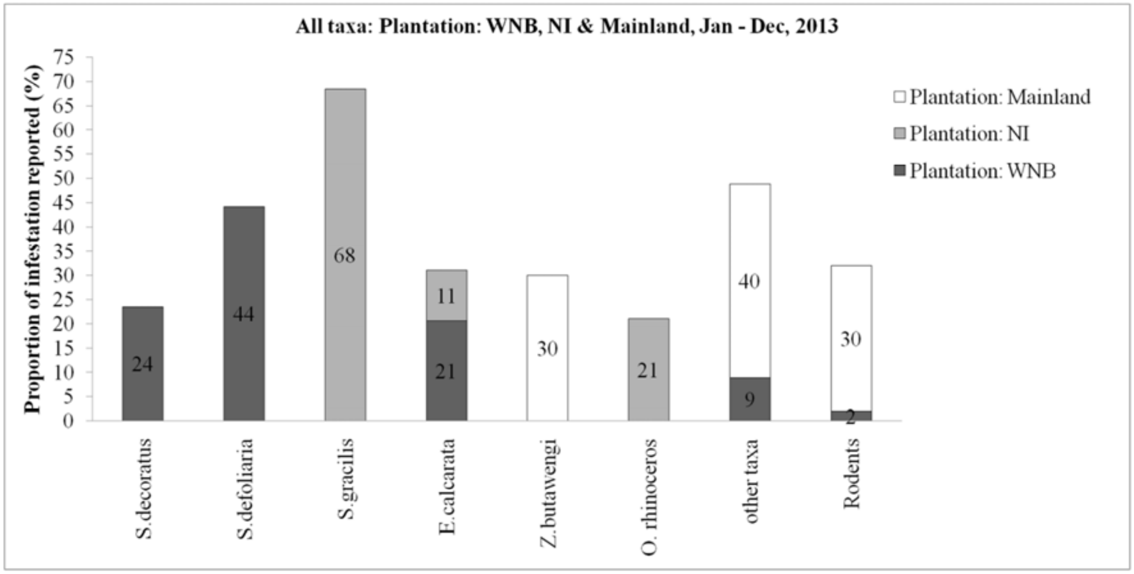

Figure 20 The proportion (%) of major pests reported by the plantations from the Mainland, WNB and NI in 2013

Monthly Pest Infestation Reports in 2013 (RSPO 4.5, 8.1)

A total of 105 (44 from plantation and 61 from smallholders) infestation reports were received in 2013 from PNG (Figure 21). This was an increase of 51% from the reports received in 2012. For both sectors, the highest numbers of reports were received during the months of October and November. Most of these reports were from WNB and NI (Figure 22 and Figure 23). Only 4 reports were received from the Mainland (Figure 24).

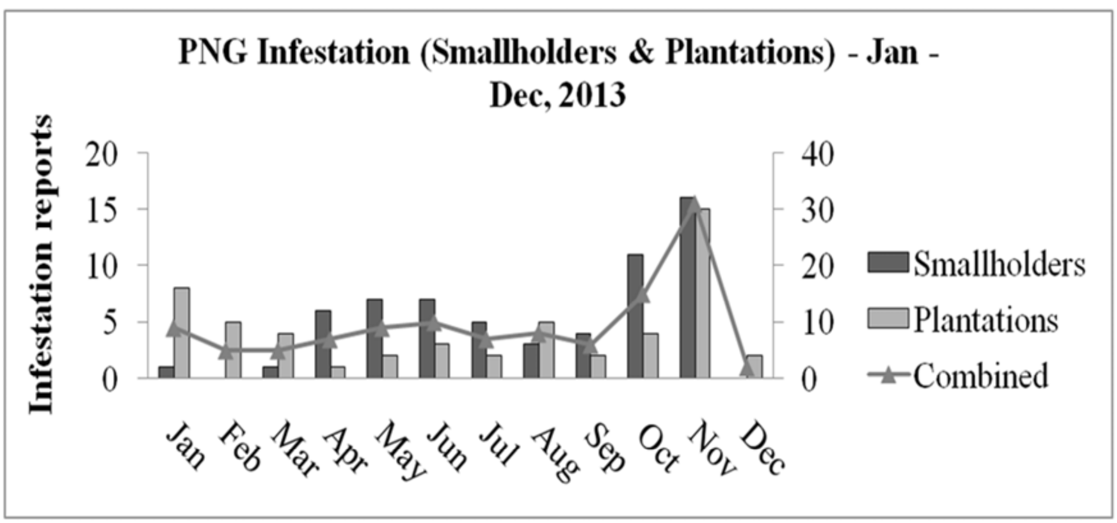

Figure 21 Pest infestation reports received from smallholders and plantations in 2013

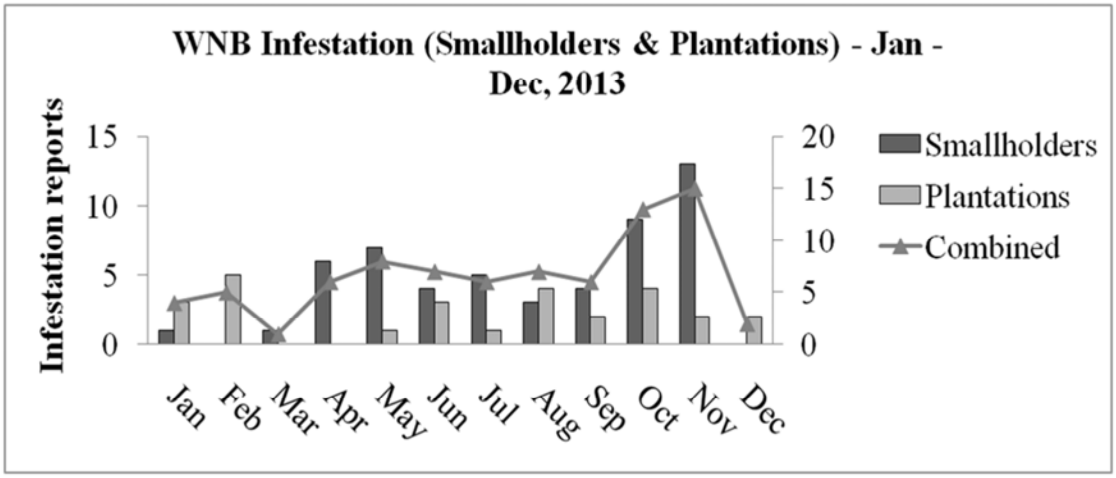

Figure 22 Pest infestation reports received from smallholders and plantations for WNB in 2013

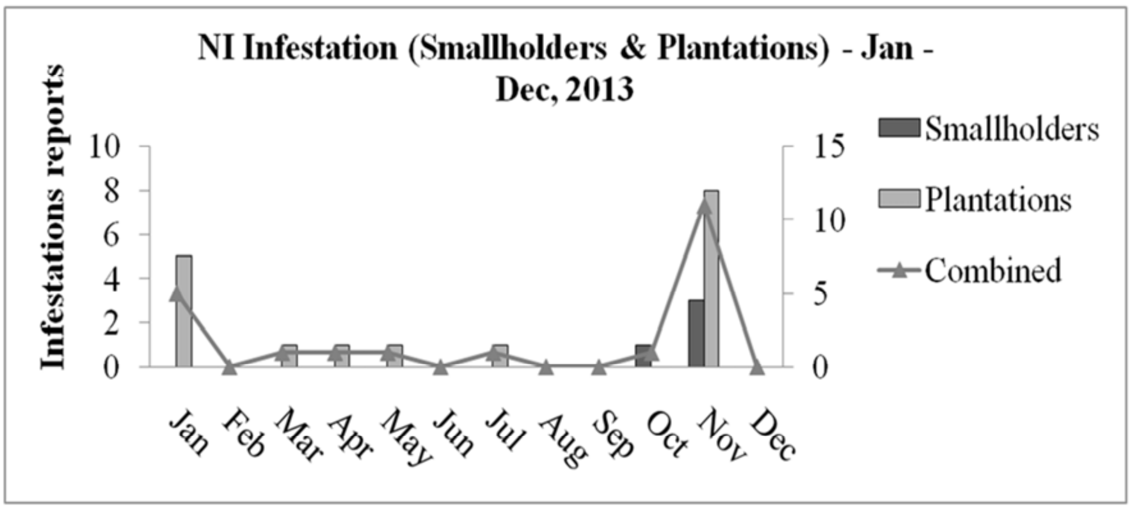

Figure 23 Pest infestation reports received from smallholders and plantations for NI in 2013

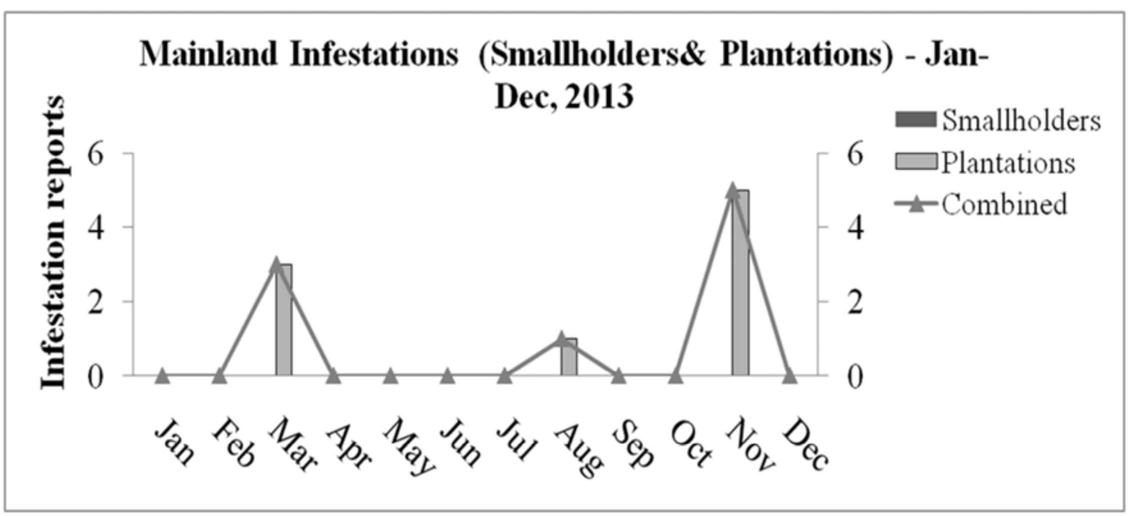

Figure 24 Pest infestation reports received from smallholders and plantations for the mainland in 2013

The 4 reports from the mainland included 3 from Milne Bay Province (Milne Bay Estate) and 1 from Northern Province (Mamba Estate- HOP).

The first report from Milne Bay Estate was of a leaf miner (*Agonoxena* sp.) colloquially known as Milne Bay Leaf Miner (MBLM) causing damage to oil palm foliage at Hagita Estate (Kwea, Waigani and Naura Divisions) (Plate 1). The pest was first reported in November 2011 and continued to spread in 2012 and 2013 particularly on younger palms. The older palms have grown out of the susceptible stage and no fresh damage was noticed. A recommendation was made to consider spraying palms using DiPel® after testing its effectiveness against the pest on a smaller severely infested block, as the insecticide has never been used against this pest. DiPel® is a biological insecticide made of the naturally occurring bacterium called *Bacillus thuringiensis* (Bt). The bacterium contains proteins and spores that become active inside the insect's gut when ingested. Once ingested the BT toxins bind to the mid-gut cells thereby causing the insect to stop feeding within several minutes from ingestion. The implementation of this recommendation was awaiting arrival of DiPel® from Higaturu Oil Palms (HOP) in Popondetta. It will be implemented in 2014 as the recommendation was made during the last quarter of the year.

Plate 1 Photograph of Mine Bay Leaf Miner (MBLM) (*Agonoxena* sp.), adult moth to the left and type of damage the caterpillar causes to oil palm leaflets to the right (Photograph by Charles Dewhurts)

The second report was for *Zophiuma butawengi* (causing Finschafen Disorder) at Mariawattee and Padipadi Estates (Plate 2). A recommendation was made to consider Targeted Trunk Injection (TTI) using Monitor® (methamidophos) after having it tested on a smaller block to see if the situation would improve as there were also frond collapse problems in the plantations from unknown causes. This recommendation will be implemented once the procurement of Monitor® and Personal Protective Equipment (PPE), as well as the training of staff is done. It will also be implemented in 2014 because the recommendation was made at the same time as for MBLM.

Plate 2 Photograph of *Zophiuma butawengi* showing the distinctive black and white spots on the tip of the forewings (Photograph by Charles Dewhurst)

The final report was of mole crickets (*Gryllotalpa* sp.) attacking seedlings at Hagita Nursery (Plate 3). The problem resulted due to excess water on the seed beds. It was recommended for elevation of the seedlings, and hand killing by flashing them out using water mixed with detergent. The recommendation has been implemented and the crickets were controlled.

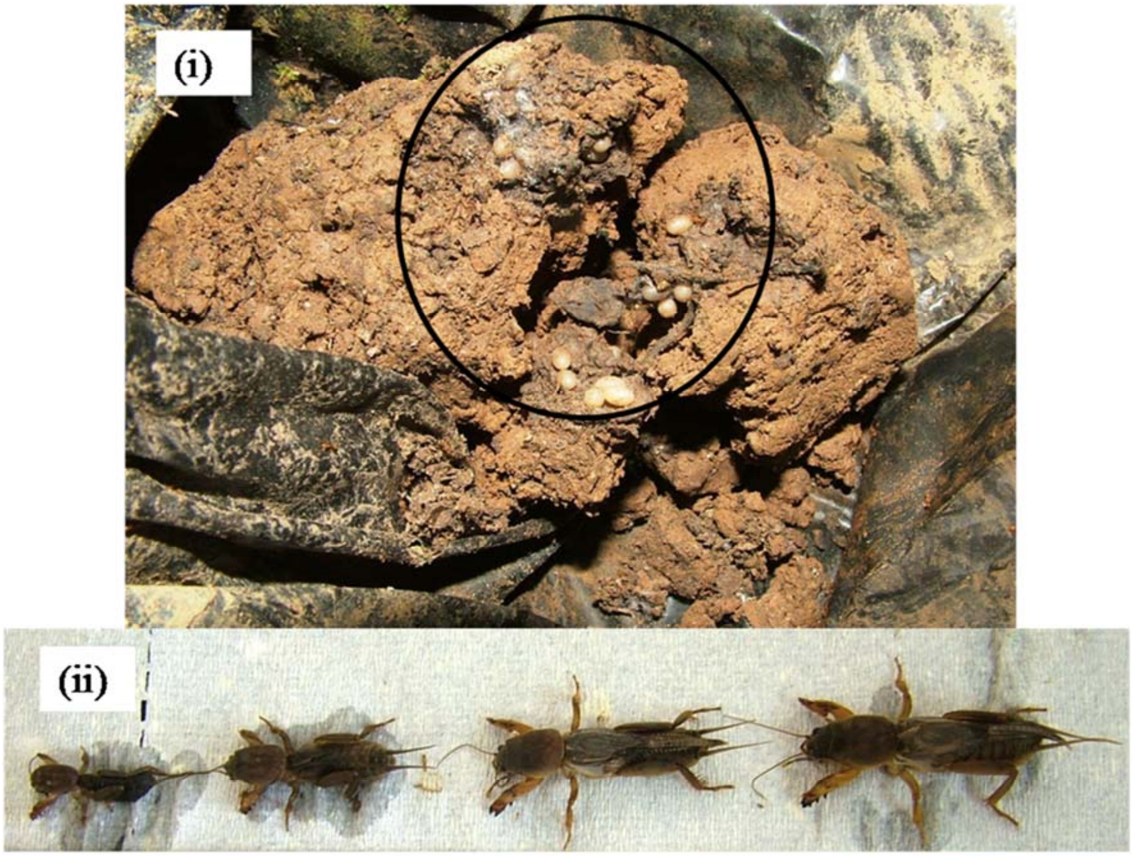

Plate 3 Photographs of eggs (i) and the nymphal stages (ii) of the mole cricket (*Gryllotalpa* sp.) from Hagita Nursery, MBE (Photograph by Carmel Pilotti)

The report from Mamba Estate was of rats (*Rattus* spp.) damaging young palms (Plate 4). Application of rat bait poisons (wax blocks of either Waffrin® or Bromadiolone®) was recommended for their control as an immediate measure. Over time, the palms will grow out of the damage, only young palms are susceptible to such damage. No feedback was received from the Estate as to whether the recommendation was implemented or not.

Plate 4 Photograph of a young palm destroyed by rat (*Rattus* sp.) at Mamba Estate, HOP

Apart from this, no other pest infestation reports were received from the Oro Province during the year. The monthly monitoring survey for bagworm infestation for Ice Cream Cone Bagworm (*Manatha conglacia*) (Plate 5) at Ambogo Estate continued throughout the year, but was terminated in December as the number of bagworms sampled dropped off noticeably in 2013 (Figure 25 and Figure 26). No ice cream cone bagworms were sampled in February and June (Figure 25).

Plate 5 Photographs of Ice Cream Cone Bagworm (*Manatha conglacia*) from Ambogo Estate, HOP; (i) larva in the cone (bag) feeding on oil palm foliage, and (ii) dissected cone showing a female pupa with head facing upwards (male pupa has head facing down)

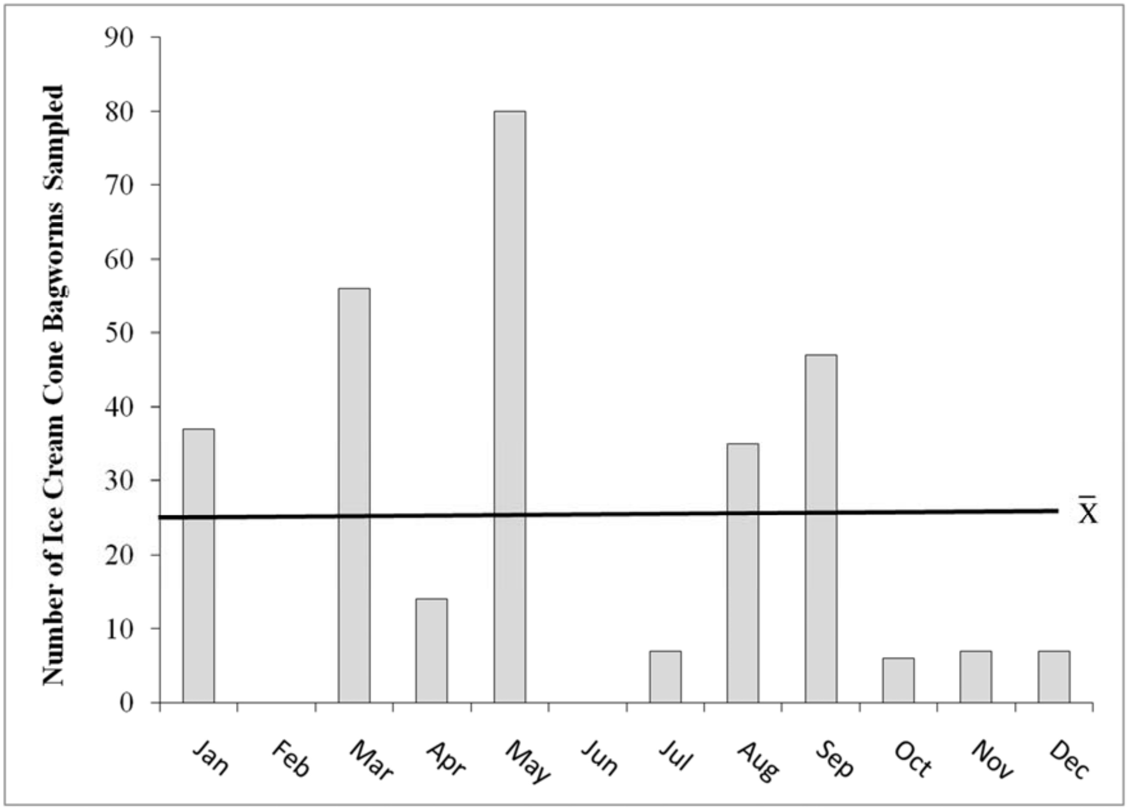

Figure 25 Number of Ice Cream Cone bagworms sampled per month in 2013 from Ambogo Estate, Higaturu Oil Palms

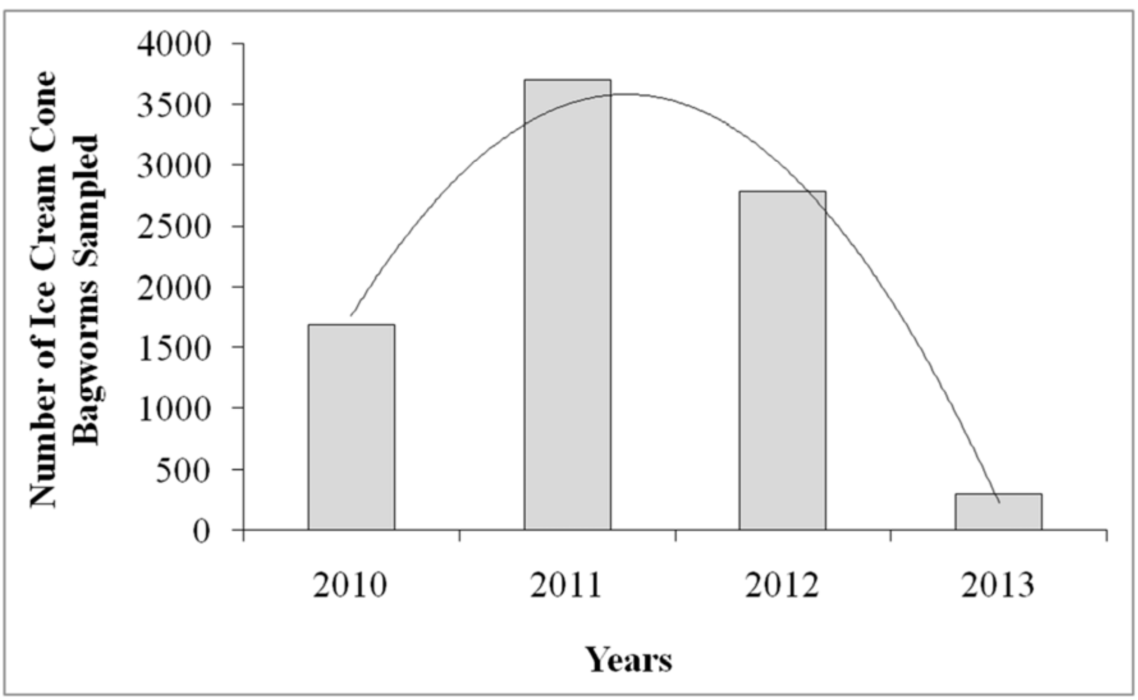

Figure 26 Number of Ice Cream Cone bagworms sampled from Ambogo Estate, Higaturu Oil Palms from 2010 to 2013.

Pest Damage Levels, Management Recommendations and Targeted Trunk Injection (TTI) in 2013- (RSPO 4.5, 4.6, 8.1)

The most common pest species on which chemical treatment is normally applied are *S.decoratus*, *S.defoliaria defoliaria*, *S.defoliaria gracilis* and *E.calcarata*. Treatment is only done in areas with moderate to severe infestation. Areas with light infestation are normally recommended for monitoring. The only insecticide used presently in PNG is Monitor® (methamidophos).The application is done through Targeted Trunk Injection (TTI) where 10ml of the insecticide is injected (using a 10ml calibrated drench gun) into a 15cm hole drilled at 45° angle. The hole is drilled at about breast height of the palm using a motorized STIHL drill. PNGOPRA is obliged to monitor the amount of Monitor® applied. Hence, monitoring of the insecticide use is done through the completed Targeted Trunk Injection Daily Report (TTIDR) Forms it receives from treatment team supervisors during treatment.

Insecticide application through TTI was only done in WNB and NI. Figure 27 presents the amount of methamidophos used in 2013.The figures provided are only for those treatment programmes where the TTIDR reports were received. This feedback was from 64 (WNB= 53, NI= 11) treatment recommendations that were sent out during the year. A total of 10,273L of Monitor® was applied through TTI in 2013 for whole of PNG. More than 90% of the insecticide (9,367L) was applied in WNB. Of this, smallholders (Hoskins and Bialla Projects combined) applied 2,754L and the plantations (NBPOL and HOPL combined) applied 6,613L. A total of 906L was applied on both the smallholder blocks and plantations in NI. Three key pest species (*S.defoliaria defoliaria, S.decoratus, E.calcarata*) for which TTI is applied are well established in WNB than NI; hence the difference in the volume of Monitor® applied reflected this situation. Treatment in NI is done mainly for *S.defoliaria gracilis* and *E. calcarata*.

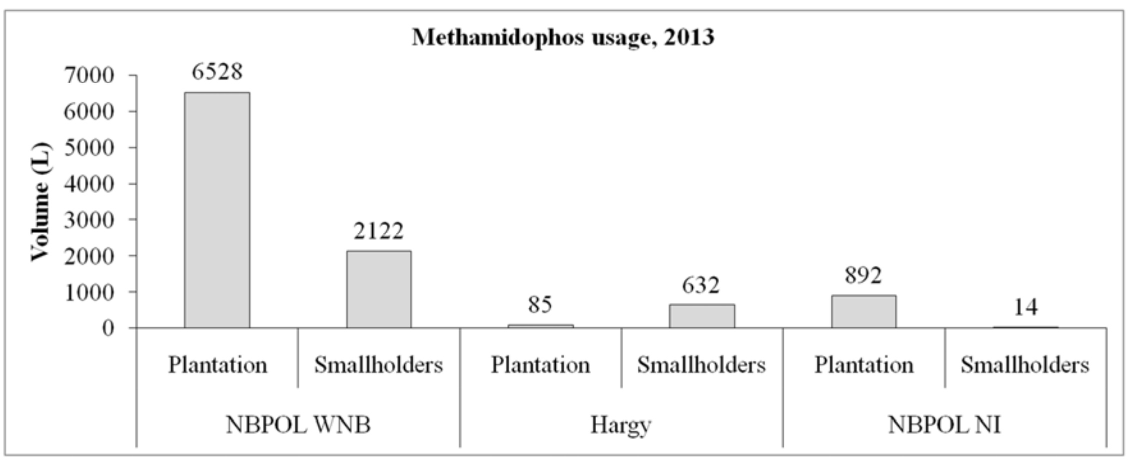

Figure 27 Volume (L) of Monitor® (methamidophos) applied in Smallholder blocks and Plantations in 2013[1]

Biological Control Agent Releases

The number of biological control agents released in 2013 increased noticeably from those released in 2012 for all agents (Figure 28, Figure 29, Figure 30 and Figure 31**)**. There were four (4) biological

[1]The figures are only for those treatments updated to PNGOPRA, Entomology through the completion of and submission of TTIDR forms.

control agents (*Stichotrema dallatorreanum* for *S.defoliaria defoliaria, Anastatus eurycanthae* for all stick insects, *Doirania leefmansi* and *Leefmansia bicolor* for all Sexavae) that were reared in the laboratory and released in the field. Large cultures of all four agents were reared in the laboratory and maintained throughout the year (2013) for field releases. Field releases of biological control agents reared in the laboratory are necessary to augment the field natural enemy populations.

Field collection of eggs from 3 different locations (two smallholder blocks [Buvusi, Siki] (Figure 32Figure 32 and Figure 33) and one in Navarai Plantation) (Figure 34) were done throughout the year and dissected to monitor the level of field parasitism. The results showed that there were high levels of parasitism in all of the sites. This level of parasitism is highly likely the result of continual mass release of biological control agents by PNGOPRA and the establishment of wild populations of beneficial plants that support the biological control agent populations.

Whilst the parasitoid release programmes and the establishment of beneficial plants in oil palm systems still need to be further investigated and refined, PNGOPRA has refined its techniques of rearing the biological control agents (*S.dallatorreanum*, *A.eurycanthae,* and *L.bicolor* and *D.leefmansi*) over the years, and is successfully rearing the agents and releasing them in the fields where infestation is encountered at *ad hoc* basis. The entomology section is confident in its rearing techniques as it has managed to consistently increase the production of the parasitoids since 2011 and is releasing them in high numbers as illustrated in Figure 28, Figure 29 and Figure 30.

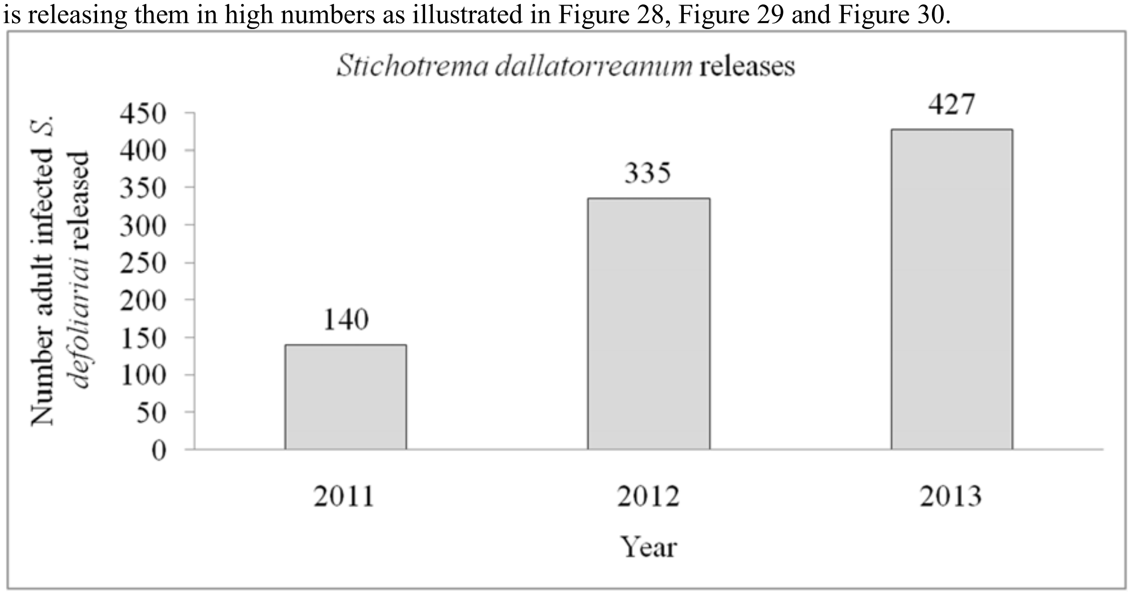

Figure 28 Number of laboratory cultured *Stichotrema dallatoreanum* infected adult males of *S.defoliaria defoliaria* released in 2011, 2012 and 2013 for the control of *S.defoliaria defoliaria*[2]

[2]Males *S.defoliaria defoliaria* infected with *S.dallatorreanum* do not mate.

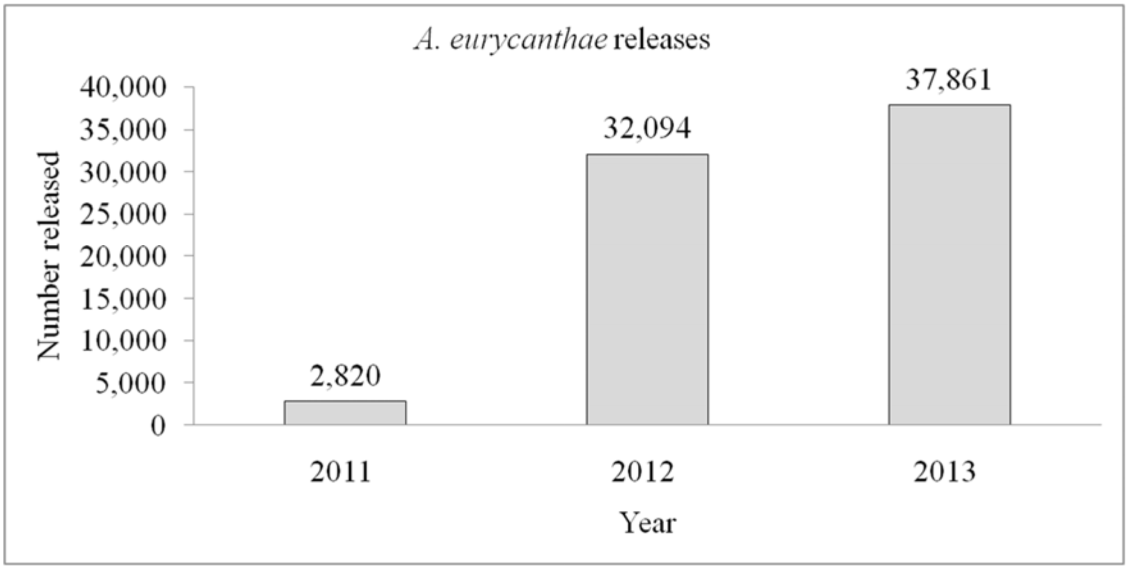

Figure 29 Number of *Anastatus eurycanthae* laboratory reared and field released in 2011, 2012 and 2013 for the control of stick insect pests

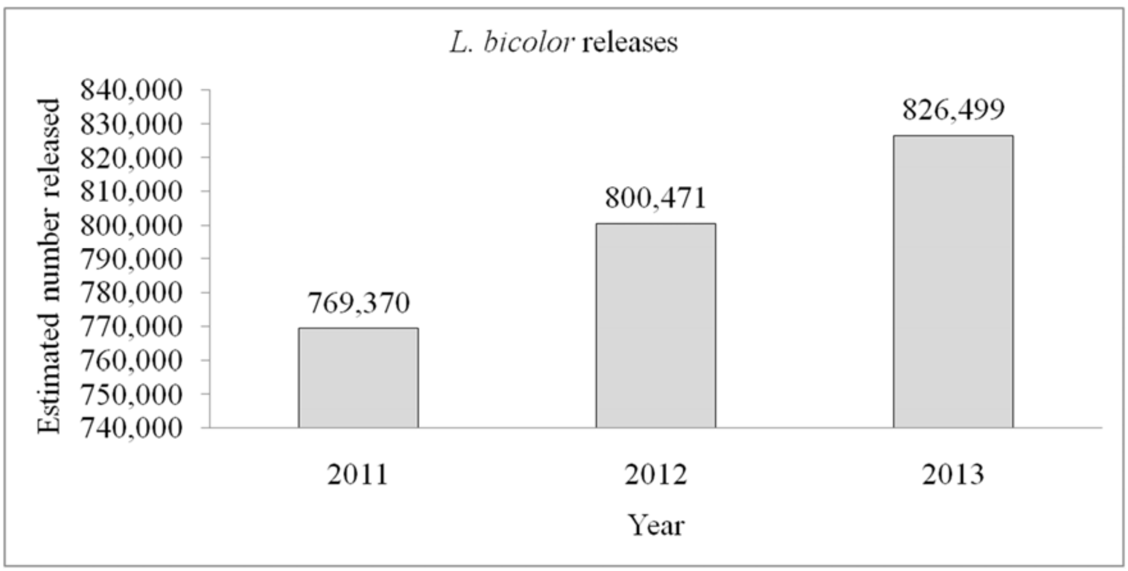

Figure 30 Estimated number of *Leefmansia bicolor* laboratory reared and field released in 2011, 2012 and 2013 for the control of Sexavae pests

As for *D.leefmansi* rearing capacity the entomology section has experienced some ups and downs in last few years and further research is still needed before routine work can be carried out. However the good performance in 2013 indicates very good progresses as demonstrated in Figure 31.

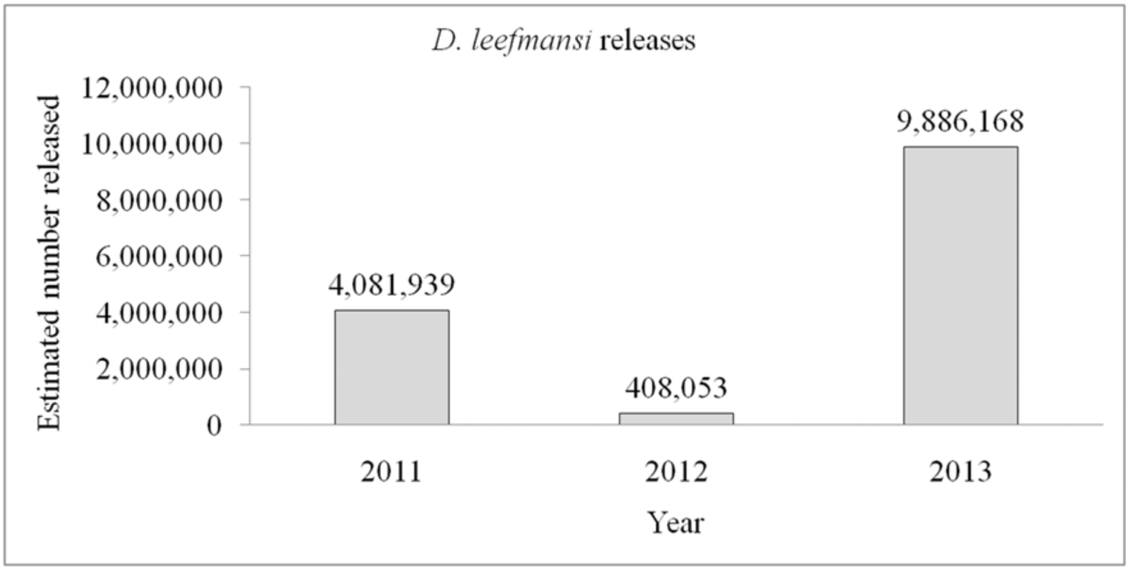

Figure 31 Estimated number of *Doirania leefmansi* laboratory reared and field released in 2011, 2012 and 2013 for the control of Sexavae pests[3]

The field sampled (Buvussi, Siki and Navarai) Sexavae eggs are showing that high percentages of eggs are being parasitised, apart from those that are hatching as shown in Figure 32, Figure 33 and Figure 34. The results are indicating that the parasitoids are helping to keep the pests under check, thereby preventing them from reaching high infestation levels. The high levels of parasitism are attributed to the mass releases of biological agents carried out by PNGOPRA. The mass rearing and *ad hoc* release programmes will continue whilst attempts will be made to develop a systematic biological agent release programme and improve the guidelines for the establishment of beneficial weeds in the oil palm systems.

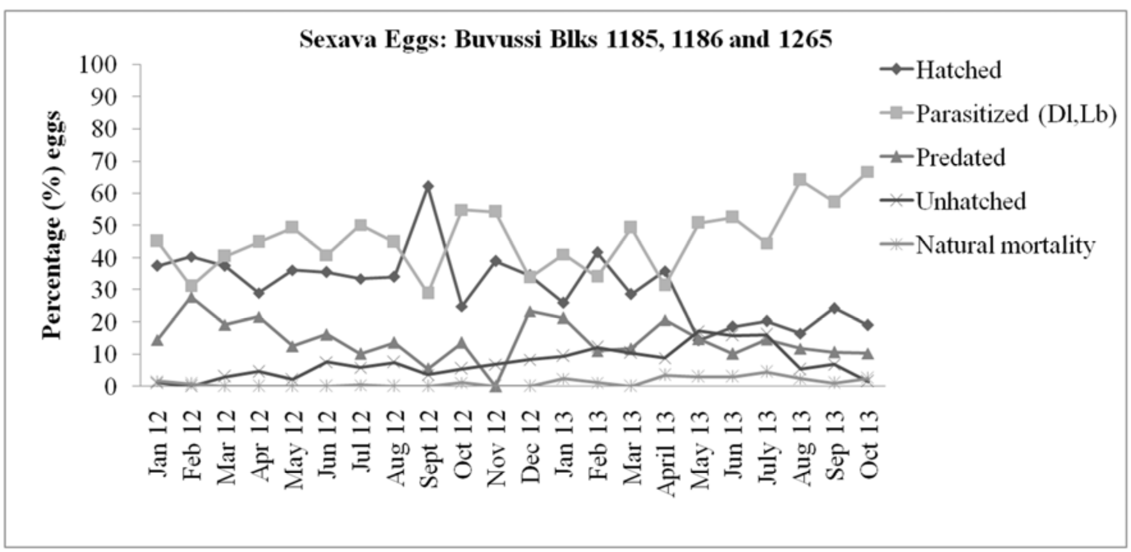

Figure 32 Percentage (%) of various states of eggs collected from smallholder blocks at Buvusi in 2013: hatched, parasitized, predated, unhatched and natural mortality

[3] The number was estimated because they are too small to be counted. Actual size is less than 2mm.

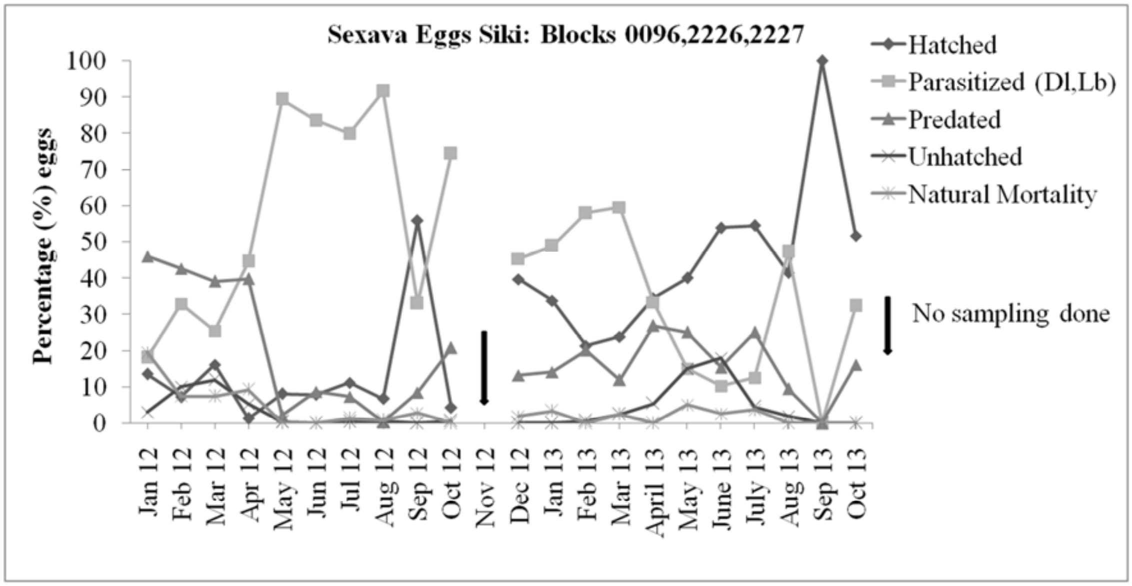

Figure 33 Percentages (%) of various states of eggs collected from smallholder blocks at Siki 2013: hatched, parasitized, predated, unhatched and natural mortality

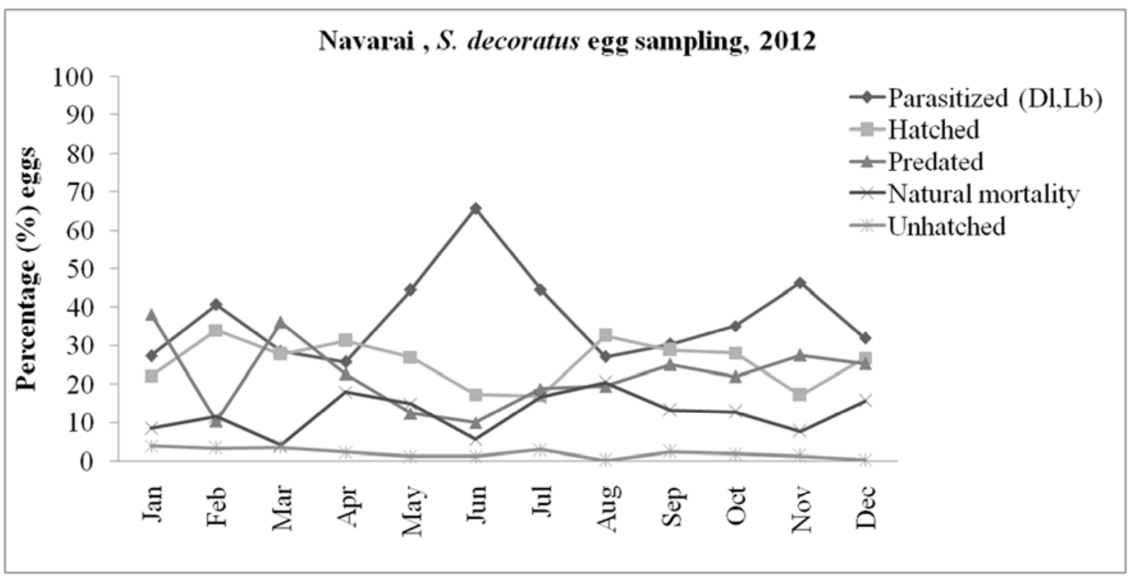

Figure 34 Percentage (%) of various states of eggs collected from Navarai Plantation in 2013: hatched, parasitized, predated, unhatched and natural mortality

Weed Management

As part of the Entomology Section's ongoing sustainable management efforts for pests and weeds, the section also monitors the distribution of the biological control agents of weeds throughout Oil Palm growing areas on *ad hoc* basis. The target weeds are *Chromolaena odorata* (Siam weed), *Sida rhombifolia* (Arrow leaf sida), *Mikania micrantha* (Mile-a-minute), *Eichornia crassipes* (Water hyacinth), *Pistia stratiotes* (Water cabbage), and *Mimosa invisa* (Giant Sensitive Weed). Some of the biological control agents are maintained at the Dami, Entomology Laboratory and released where required.

Table 84 presents the list of weeds and their respective biological control agents.

Table 84 List of the key weeds and the biological control agents which have been released and monitored.

Weeds	Biological Control Agents
Pistia stratiotes (Water Cabbage)	*Neohydronomus affinis* (Water cabbage leaf weevil)
Eichornia crassipes (Water Hyacinth)	*Neochetina eichhorniae* (Water hyacinth weevil)
Mimosa invisa (Giant Sensitive plant)	*Heteropsylla spinulosa* (Psyllid bugs)
Chromolaena odorata (Siam Weed)	*Cecidochares connexa* (Gall fly)
Sida rhombifolia (Arrow leaf Sida)	*Calligrapha pantherina* (Sida leaf beetle)
Mikania micrantha(Mile-a-minute)	*Puccinia spegazzinii* (Rust)

APPLIED RESEARCH REPORTS

Evaluation of Dimehypo® as an alternative insecticide to Monitor® (methamidophos) for the management of pests of oil palm- (RSPO 4.5, 4.6, 8.1)

Introduction

Monitor® (methamidophos) is currently used for the control of oil palm pests in PNG through Targeted Trunk Injection (TTI). However, the insecticide is an organophosphate, and is highly toxic (WHO Class 1B). Its use in the country (PNG) is restricted to the oil palm industry, and is only applied with authorisation from the Entomology Section of PNGOPRA. In many parts of the world, its use is either restricted or banned. Because of these restrictions, there is likelihood of a complete worldwide ban on its use in near future. Hence, there is an urgent need to evaluate alternative insecticides to recommend to the oil palm industry for use in PNG in the event that it is phased out.

In 2013, the study on evaluation of alternative insecticides concentrated on Dimehypo®. Dimehypo® is a systemic broad spectrum insecticide with thiosultap disodium as the active ingredient. It kills insects by affecting the digestive system. Because of its broad spectrum mode of action, Dimehypo® is used against insect pests from many different insect orders. In China and other Asian countries, it is mainly used against foliage eating insect pests of rice and maize (IRRI, 1980). There are no published records of the use of the insecticide against oil palm pests elsewhere. The insecticide comes in both liquid and solid formulations. The formulation used in the current trials is 18% Soluble Liquid (18% SL).

In comparison to Monitor®, Dimehypo® is moderately hazardous (WHO Class II) and the price is almost half that of Monitor®. The current whole sale price for 18% SL Dimehypo® is K10.00 per litre, whilst it is K19.25 per litre for Monitor®. With lower toxicity and price than Monitor®, Dimehypo® stands as a suitable candidate for recommendation to the industry if found effective.

Materials and Methods

Trial Site and Palm Age

Two separate trials were conducted on different age palms in two different fields at Bebere Plantation (NBPOL), WNBP. Trial 1 was conducted on 9 year old palms in Avenue 1 (18.3) whilst Trial 2 was conducted on 8 year old palms in Avenue 5 (8.3). Bioassay feeding was done in the Entomology Laboratory at Dami.

Study insects

Adults of *S.decoratus* were collected from the field and used in the trials. Only females were used as this species is parthenogenetic[4]. The insects used in Trial 1fledged two weeks prior to the trial, whilst those used in Trial 2, fledged 2 days before the trial.

Targeted Trunk Injection (TTI) Procedure

The standard TTI procedure was followed for the treatment (Dewhurst, 2006). A motorised STIHL drill with 25cm long drill bit was used to drill the holes. The holes were drilled at waist height (about 1m high), 45° angle pointing downwards and 15cm deep into the palm trunk (Figure 35). The diameter of the hole was 2.5cm. The expected volume of the drill hole was of a minimum of 17cm^3.The respective volumes of the insecticides were injected into the holes immediately after drilling using calibrated (10ml, 15ml, 20ml[5]) drench guns. Separate drench guns were used for each insecticide (Monitor® and Dimehypo®). The holes were plugged off using cooked oil palm seed kernels obtained from the Seed Production Unit (SPU) of NBPOL at Dami.

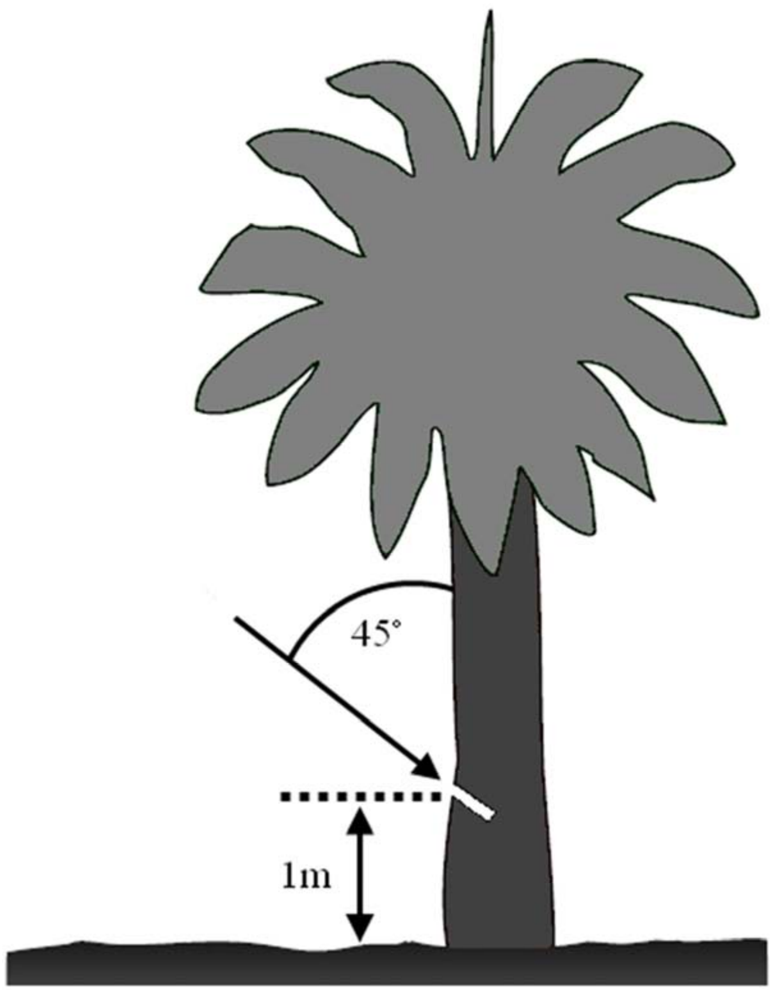

Figure 35 Schematic diagram illustrating the TTI protocol on the palm

[4]*Segestidea defoliaria defoliaria*, the other pest species which is not parthenogenetic could not be used because field collected nymphs and adults were often infected by *S.dallatoreanum* (an endoparasite). Feeding is reduced in *S.dallatorreanum* infected *S.defoliaria defoliaria*, and the adults do not reproduce once infected.

[5]20mls was still able to fit into the 17cm^3 hole. The actual size would be slightly bigger because of the widening of the hole by the vibratory movement of the drill bit and the liquid is rapidly absorbed by trunk fibres.

Trial 1. Evaluation of two (2) different volumes of Dimehypo® (10ml, 20ml) against 10ml of Monitor®

Eighteen (18) palms were selected in three rows (6 palms per row). An inner frond base located at waist height from each palm was cleaned and painted with white paint (Figure 36). After the paint had dried, the palms were labelled according to treatment and replicate. The "**pick without replacement system**" was used to randomise the treatments and replicates. This process was continued until the last label was used for the last marked palm. There were four treatments and were assigned the following: T1= Dimehypo® (20ml), T2= Dimehypo® (10ml), T3 = Monitor®(10ml) and T4 = Control. Each treatment was replicated 6 times.

After marking, the palms were drilled following the standard drilling procedure. Three different injectors injected the insecticides according to the different volume and insecticide [i.e. one injector for 20ml (3.6g a.i) Dimehypo®, one injector for 10ml (1.8g a.i) Dimehypo®, one injector for 10ml Monitor® (6g a.i)]. The holes were pluggeda fter chemical injection using cooked oil palm seed kernels obtained from the seed production unit (SPU) at Dami.

Bioassay feeding started on the first day after trunk injection. Four (4) leaflets each were collected from each palm for feeding. Two leaflets were collected from lower fronds (1 each from opposite compass directions) and two leaflets from upper fronds (1 each from opposite compass direction, but not in the same directions as those collected from lower fronds). The positions were alternated during each collection. The individual leaflets were cut down using a sharp sickle mounted onto a harvesting pole. The order of collection of leaflets for the treatments was Control®, 10ml Dimehypo®, 20ml Dimehypo® and 10ml Monitor®. Soon after all four leaflets were cut down from each palm; a different person cut the basal ends of the leaflets with a sharp pair of scissors and wrapped all 4 leaflets in paper towel splashed with water. Each treatment was labelled (according to treatment and replicate) using paper label and wrapped around the base over the tissue paper. The leaflets were immediately placed into clean 1 litre plastic coke containers cut around the base and filled half way with tap water. The tops were sealed with leads. One container (labelled according to treatment) each was used for each treatment.

Once at the laboratory, the leaflets together with the paper towel were transferred immediately into individual styrofoam cups filled one third with tap water. Each cup containing the leaflets was placed into their respective feeding cages labelled according to treatment and replicate. One empty ice cream container was filled with river sand and placed inside each cage for egg deposition. Each cage contained 10 *S.decoratus* each put in the morning to allow them to become accustomed to the cages. At approximately 1500hrs of every second day, fresh leaflets were collected from the trial palms and fed to the insects. Each afternoon at approximately 1600hrs, the leaflets in the cages were checked and any dead insects were recorded. For the days where leaflets were replaced, the checking of dead insects was done during the time of leaflet replacement. The dead insects and eggs laid were counted. These were recorded according to treatment and replicate into the data sheet. These processes were continued until 30 days at which time they were terminated.

Trial 2. Evaluation of three (3) different volumes of Dimehypo® (10ml, 15ml, 20ml)

The same protocols used in Trial 1 were followed for treatment (TTI), leaflet collection and bioassay feeding. Two exceptions were that adults that fledged a day before the trial were used and only 3 different volumes of Dimehypo® were tested. The treatments were labelled as T1= 20ml Dimehypo®, T2 = 15ml Dimehypo®, T3 = 10ml Dimehpo® and T4= Control. The protocol for data collection was the same as in Trial 1.

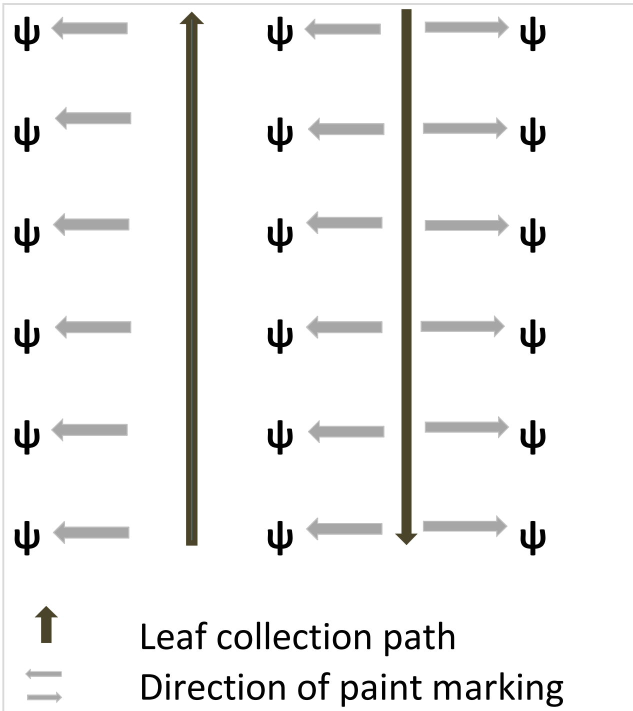

Figure 36 Schematic set up of paint marking and leaf collection path

Natural mortality was corrected using Abbot's Correction Factor (Formula below)

$$\text{Corrected \%} = 1 - \frac{\text{n in T after treatment}}{\text{n in C after treatment}} \times 100$$

Where n = insect population (number of insects)
T = treatment
C = control

Evaluation of impact on pollinating weevils

Anthesing male inflorescences from the trial palms were cut down using a sharp sickle (attached to harvesting pole) and the number of spikelets counted. After counting, 10 spikelets representative of the different positions on the inflorescences were cut out using a sharp kitchen knife. The spikelets were bundled using rubber bands, and labelled according to treatment and replicate. These were taken back to the Entomology Laboratory at Dami and set up in separate Bug Dom® insect rearing cages, to allow the weevils to emerge. After all the weevils had emerged and died, they were counted and recorded according to treatment and replicate. The spikelets were split up to check for any larvae or pupae. The total numbers of pollinating weevils per male inflorescence were projected according to the total number of spikelets.

Results

Percentage sexavae mortality

In Trial 1 insects fed on palm leaflets treated with Monitor® died more quickly (50% mortality by the 4th day and 100% mortality by the 13th day) than the insects fed on palm leaflets treated with both volumes (10ml and 20ml) of Dimehypo® and the untreated control (Figure 37 and Figure 38).
Between the two Dimehypo® volumes, the insects fed on palm leaflets treated with 20ml died more quickly (50% mortality by the 8th day and 100% mortality by the 22nd day) than the insects that were fed on palm leaflets treated with 10ml(50% mortality by the 12th day but no total mortality during the 30 days of feeding). Mortality of insects fed with leaflets from untreated control palms remained below 50% throughout the bioassay feeding period (30 days) (Figure 37).

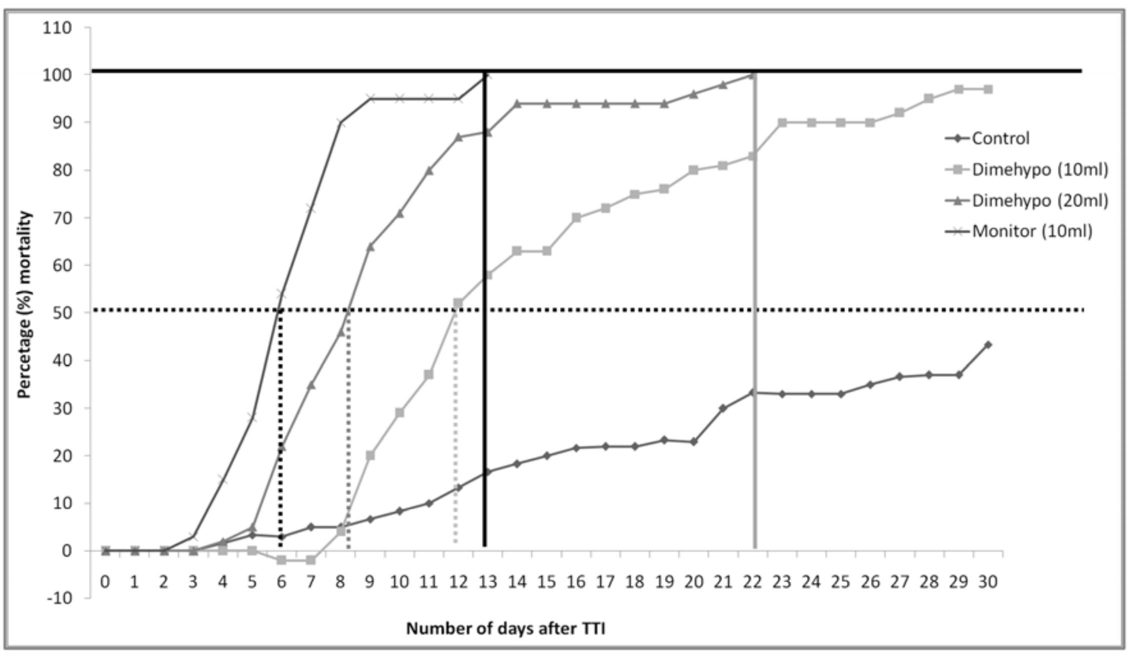

Figure 37 *Segestes decoratus* mortality from the different treatments (10ml Monitor®, 10ml Dimehypo®, 20ml Dimehypo® and Untreated Control) in Trial 1

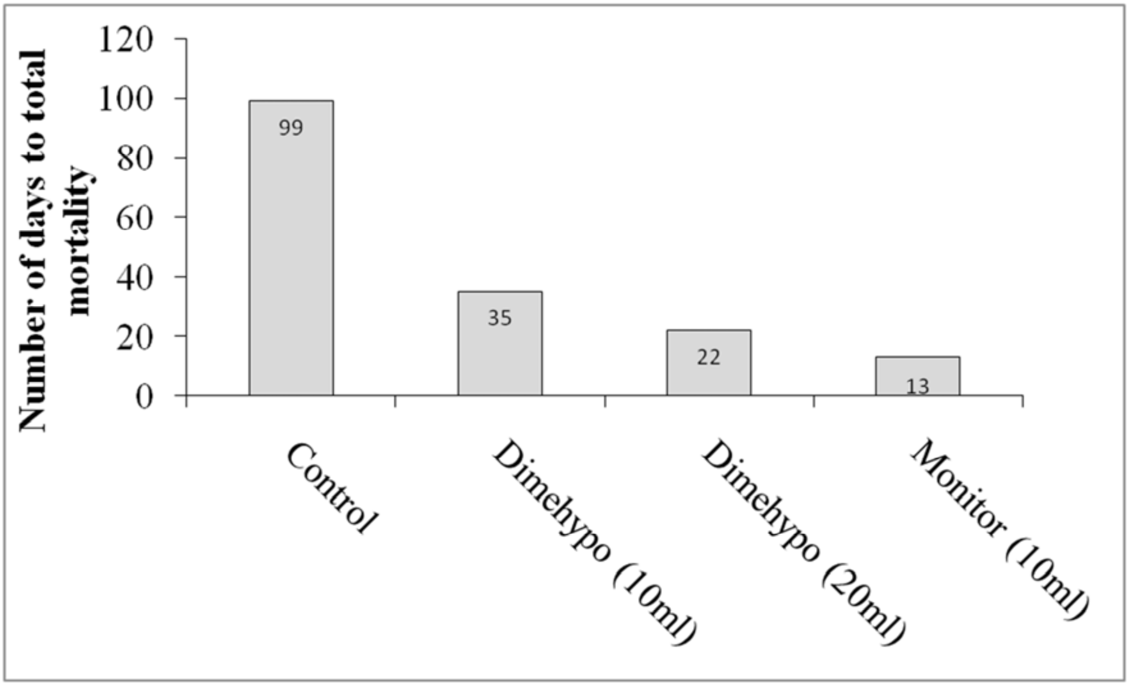

Figure 38 Number of days to total mortality by *S.decoratus* across the different treatments (10ml Monitor®, 10ml Dimehypo®, 20ml Dimehypo® and Untreated Control)in Trial 1

When comparing the three volumes of Dimehypo®, the insects that were fed on palm leaflets treated with 20mls died more quickly than those insects fed on palm leaflets treated with 10ml and 15ml (Figure 39). Fifty percent (50%) of the insects fed on palm leaflets treated with 20ml died by the 3rd day of feeding whilst those fed on palm leaflets treated with 10ml and 15ml Dimehypo® had 50% mortality on the 9th and 8th day respectively. One hundred percent (100%) of the insects fed on palm leaflets treated with 20ml Dimehypo® died by the 15th day whilst there was no total mortality for insects fed on leaflets from palms treated with 10ml and 15ml within the 30 days of feeding. The percentage mortality of insects fed with leaflets from the untreated control palms remained consistently low (below 10%) throughout the bioassay feeding period (30 days).

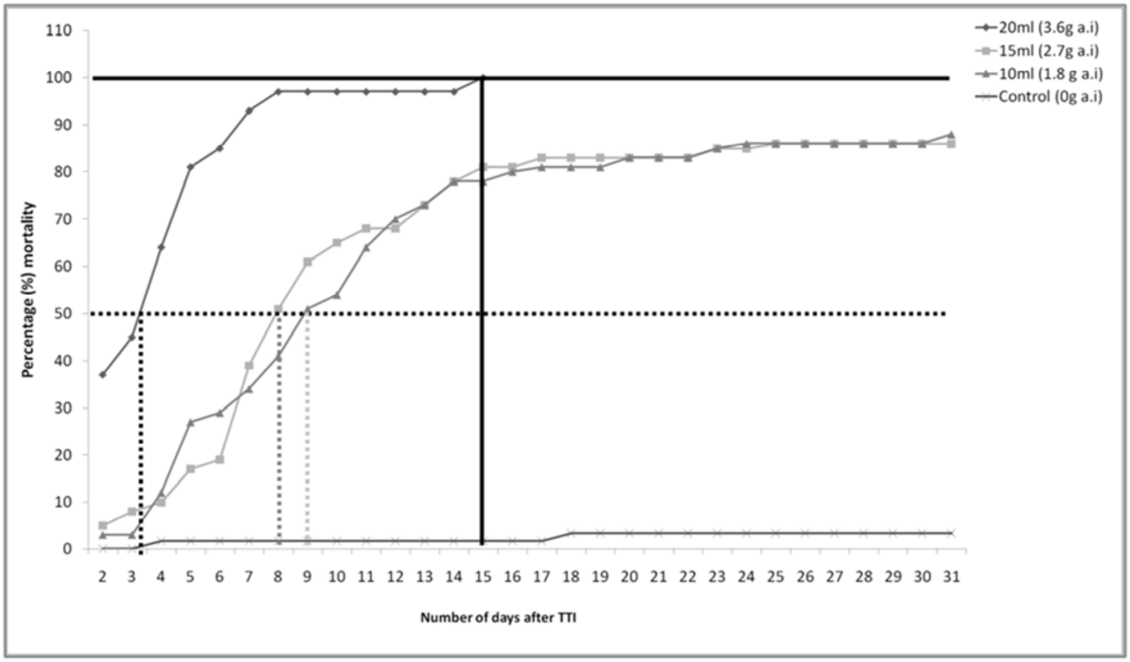

Figure 39 *Segestes decoratus* mortality from three different volumes of Dimehypo® (10ml [1.8g a.i], 15ml [2.7g a.i] and 20ml [3.6g a.i] and the Control in Trial 2

Number of eggs laid

From both trials, more eggs were laid by *S.decoratus* fed with leaflets from untreated palms (Control) (688) than those fed with leaflets from palms treated with insecticide whether Dimehypo® or Monitor® (Figure 40 & Figure 41).

In Trial 1, the total number of eggs laid by *S.decoratus* fed with leaflets from untreated control palms was 688 (Figure 40). The number of eggs laid by *S.decoratus* fed with leaflets from palms treated with 10ml and 20ml Dimehypo® had 97.7% (16 eggs) and 100% (no eggs) reduction respectively whilst those fed on leaflets from palms treated with 10ml Monitor® had a 75.9% (166 eggs) reduction relative to the control. The percentage reduction of eggs from insects fed on 10ml Monitor® treated palm leaflets was approximately 21.8% less than those fed on the palm leaflets treated with 10ml Dimehypo® and 24.1% less than those insects fed on the palm leaflets treated with 20ml Dimehypo®.

In Trial 2, the total number of eggs laid by *S.decoratus* fed with leaflets from untreated control palms was 2,237 (Figure 41).There was a 99.8 % reduction in the number of eggs laid by the insects fed with leaflets from palms treated with 20ml Dimehypo® (5 eggs), whilst those treated with 10ml Dimehypo® (36 eggs) and 15ml Dimehypo® (37 eggs) both had a 98.4% reduction in the number of eggs laid compared to the control (Figure 41).

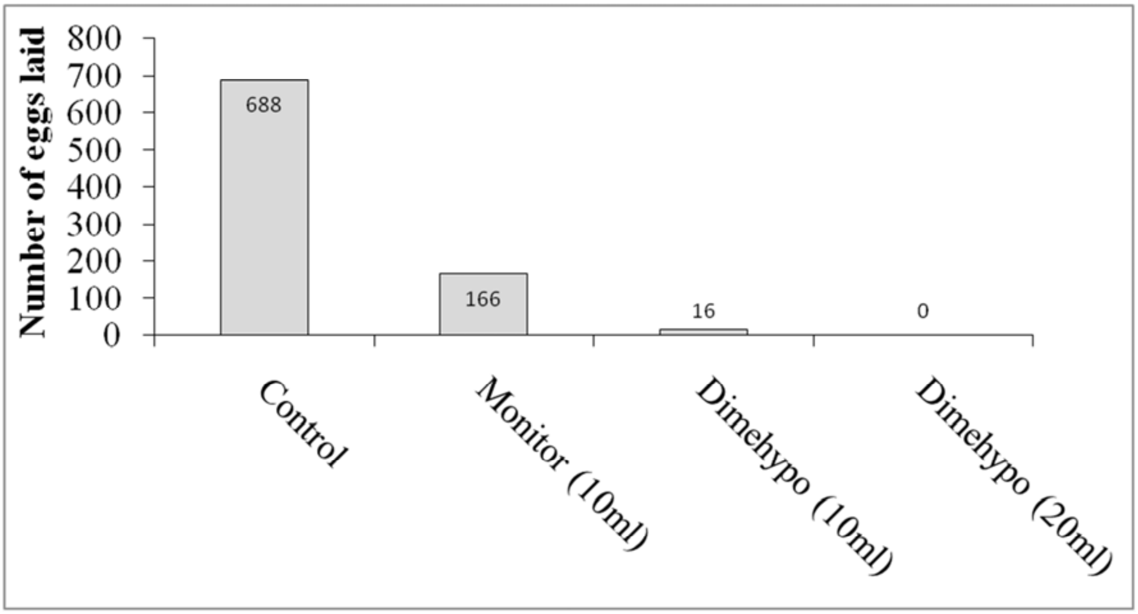

Figure 40 Number of eggs laid by *S.decoratus* from each treatment (10ml Monitor®, 10ml Dimehypo®, 20ml Dimehypo® and Untreated Control) over the 30 day bioassay feeding period in Trial 1

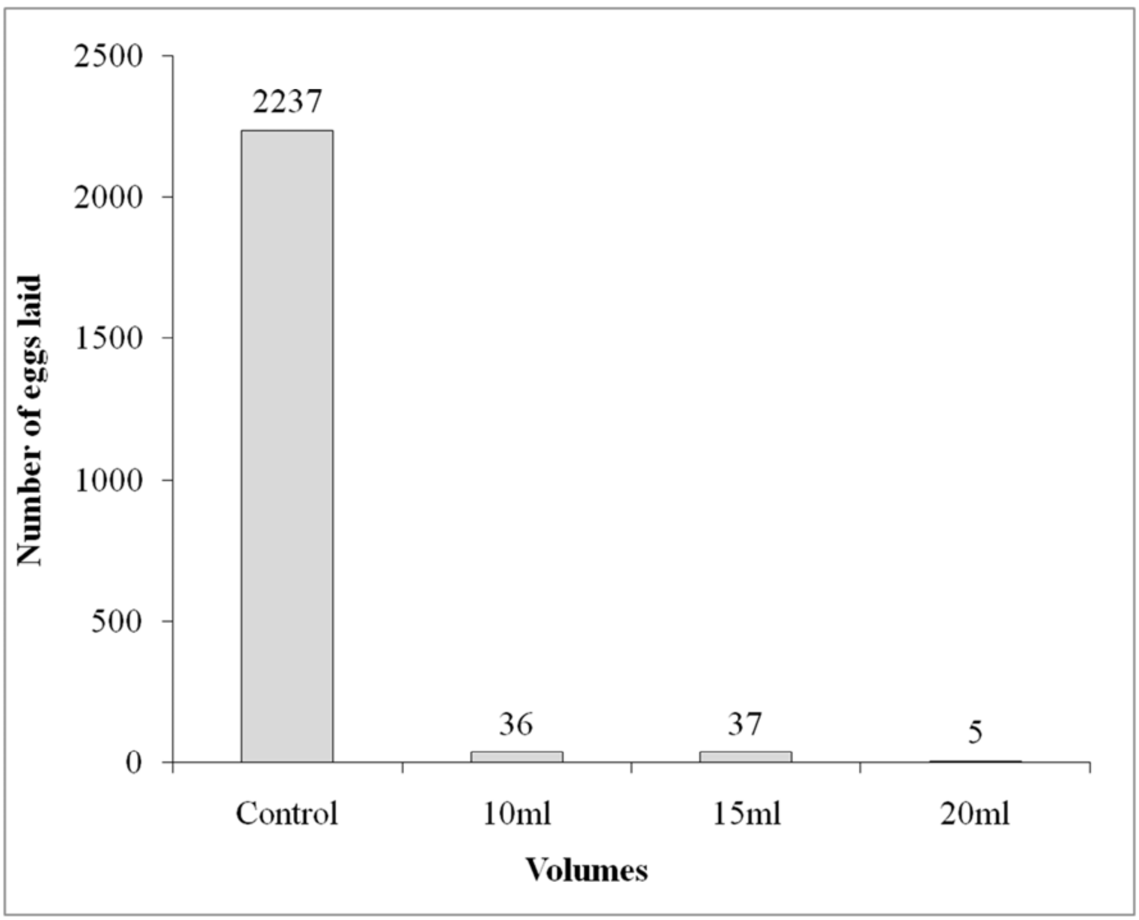

Figure 41 Number of eggs laid by *S.decoratus* from each treatment (10ml [1.8g a.i], 15ml [2.7g a.i], 20ml [3.6g a.i] and the Control) over the 30 day feeding period in Trial 2

Impact on pollinating weevils

The number of weevils emerging per male inflorescence from all treatments including those palms treated with the two different volumes of Dimehypo® (10ml and 20ml) and Monitor® (10ml) during the 30 day feeding period was high (above 5,000 weevils). The number of pollinating weevils emerging from the untreated control male inflorescences was 6,373; from palms treated with 10ml Monitor® was 7,926; from palms treated with 10ml Dimehypo® was 11,875 and from palms treated with 20ml Dimehypo® was 9,772 (Figure 42).

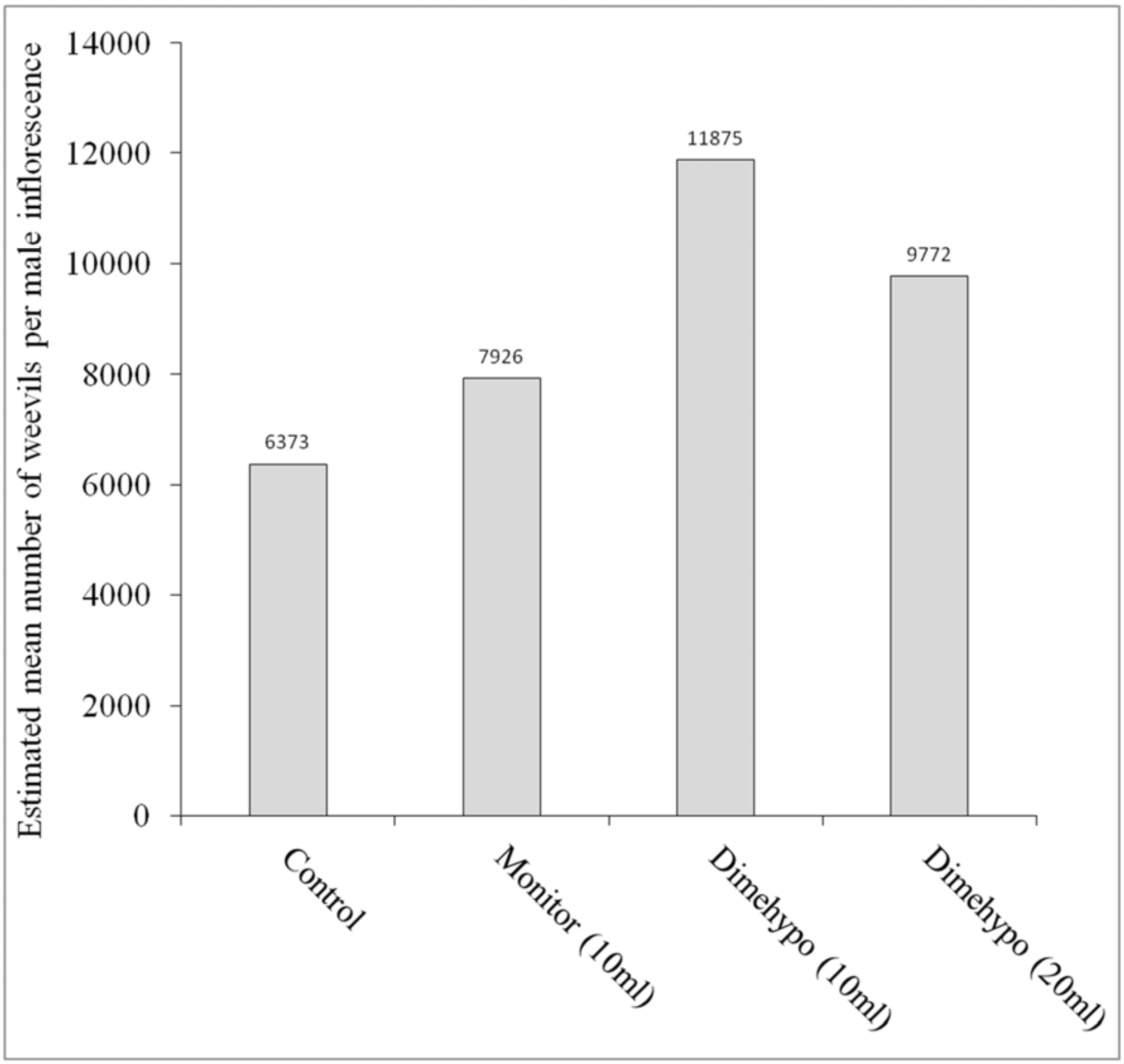

Figure 42 Estimated number of pollinating weevils emerging per male inflorescence from each treatment during the 30 day feeding period

Discussions and Conclusions

Although it took twice the number of days (22 days) to get 100% mortality in 20ml Dimehypo® versus 10ml Monitor® (14 days) (Figure 37), the percentage of eggs laid by *S.decoratus* fed with leaflets from palms treated with 20ml Dimehypo® was reduced by 100% (Figure 40). We hypothesise that the slow rate of mortality by insects fed on leaflets from palms treated with Dimehypo® was due to reduced feeding resulting from disruptions to the digestive system by the chemical. The reduced feeding caused the insects to ingest small amounts of chemical at a time thus prolonging its effect. Un-quantified observations during the trials showed that the feeding was reduced dramatically over time for insects fed with leaflets from palms treated with Dimehypo®, whilst those fed with leaflets from palms treated with 10ml Monitor® continued to feed aggressively even after ingesting the chemical.

For the three (3) volumes (10ml, 15ml, 20ml) of Dimehypo® evaluated, 20ml gave a more effective kill than the two lower volumes (10ml and 15ml) (Figure 39). Although, this volume (20ml) is greater than the volume of Monitor® (10ml) currently used, the active ingredient concentration is almost half (3.6g a.i) that of 10ml Monitor (6g a.i). Whilst, the higher volume may mean greater cost, this can be offset by the price difference, as Dimehypo® is almost half (K10.00 per litre) the price of Monitor® (K19.25 per litre).

The results from the evaluation of impact of the insecticides to the pollinating weevils showed that both Dimehypo® and Monitor® did not have any effect on the pollinating weevils. High numbers of pollinating weevils were retained from palms treated with both Dimehypo® and Monitor® (Figure 42).

Because of the lower price of Dimehypo® (compared to Monitor®), effective kill, reduction in feeding and egg deposition, and lack of impact on pollinating weevils, it is recommended that use of 20ml Dimehypo® be considered as an alternative option to 10ml Monitor® for the control of oil palm foliage pests in PNG through targeted trunk injection (TTI).

Chemical residue analysis and field testing will continue in 2014 for possible registration as an alternative to Monitor® during the year.

Pollinating Weevil Monitoring in Relation to Poor Fruit Set Problem- (RSPO 8.1)

Introduction

Naturally fresh fruit bunch production in oil palm is expected to fluctuate annually. Such fluctuations are normally seasonal and occur in response to changes in climatic factors (Corley & Tinker, 2003). Fluctuations in revenue as a result of such changes are expected and normally captured into annual crop projection calendars accordingly to cater for any drop in production. However, there are some extreme cases where fruit set is poor and yield (fruit bunch weight) significantly low compared to normal seasonal yield fluctuations. Under such situations fertilization fails, fruits are aborted and sometimes entire fruit bunches fail to develop (Bonneau L. , 2012), thereby significantly reducing revenue.

Between 2012 and 2013, the problem of poor fruit set was experienced in fields at Lolokoru Plantation (NBPOL) and Barema Plantation (Hargy Oil Palms Ltd). The problem was so severe that fruit bunches were discarded, and as a consequence, the Average Bunch Weight (ABW) declined dramatically. In Lolokoru, the problem was so severe that in August 2012, approximately 200tonnes of FFB were harvested from the affected fields compared to the weight in February of the same year of more than 3,000 tones, and the percentage of discarded bunches rose to around 90% of the harvest weight (Bonneau L. , 2012).

Since the problem was more severe than would have been expected as a result of normal seasonal fluctuations induced by changes in climatic factors, it was necessary that all possible factors influencing the situation were investigated to determine the cause. According to Corley & Tinker, 2003, bunch weight can be depressed by high planting density, severe pruning, soil fertility problem and pollination inefficiency. It was therefore necessary that pollinating weevil (*E.kamerunicus*) population was monitored to assess the possible impact of pollination inefficiency on the cause of the problem. Hence, this study was instigated to investigate the activities of pollinating weevil populations in the fields experiencing the problem. In Lolokoru similar problems were encountered in 2010 and a collection was done, but the results from this initial study were questionable as the data collection was inconsistent and some key information was missing. Hence, the data were discarded.

A more structured data collection programme for Lolokoru and Dami (comparison site without problem) was started in November 2012, and for Barema it was started in February 2012. Sampling at both plantations continued through to December 2013 where the fruit production started picking up again. The results for these studies are presented here.

Study Procedure

Six (6) sites within the problem fields were selected from Barema and Lokoloru. Two sites each were from severe poor fruit set areas, and the other 3 sites were from either low or moderate poor fruit set problem sites. Samples from a site at Dami (non-problem site) were also collected for comparison of results.

An anthesing male inflorescence from each site was collected by the plantations (for Barema and Lolokoru) during the first week of each month, put into open wooden boxes with six compartments (Plate 6), and dropped off at Dami. Census of unopen, anthesing, post-anthesing and old male inflorescences were also done by the plantations and the data provided to the Entomology Section. Both the census and the sampling for the Dami site were done by the Entomology team during the first week of each month.

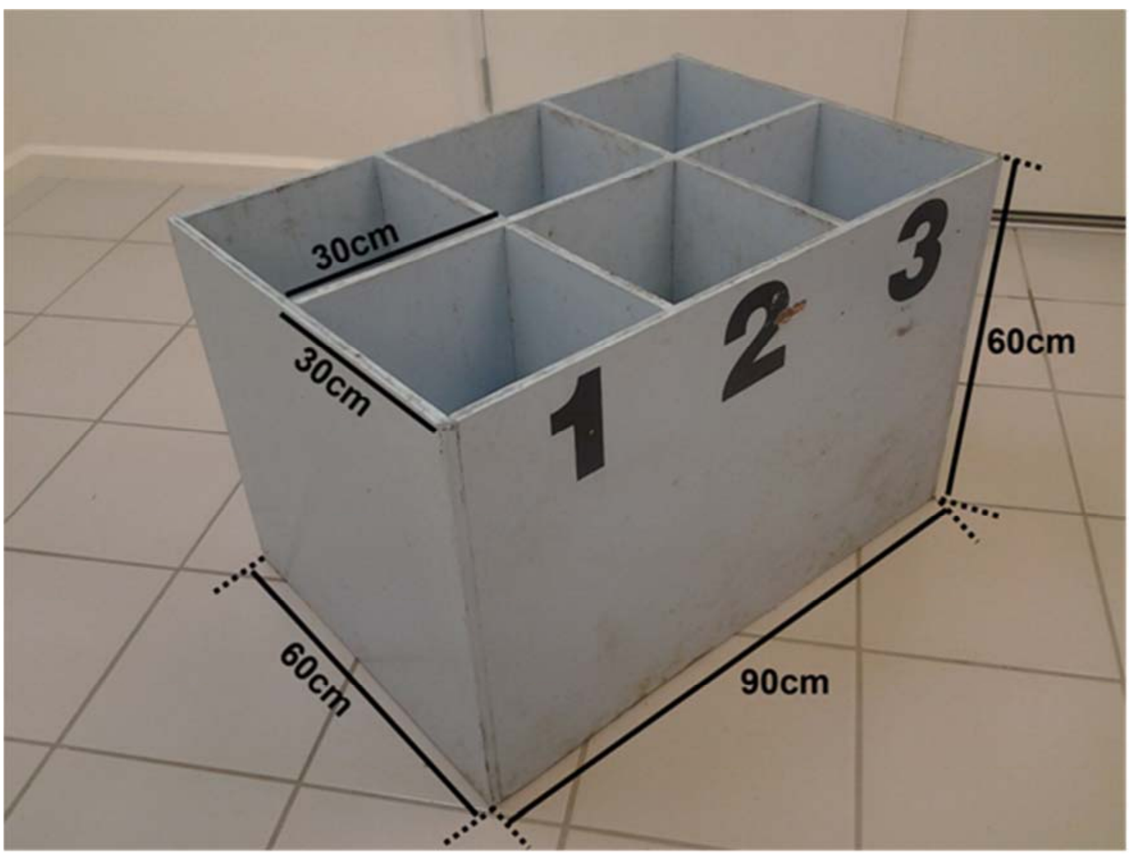

Plate 6 Photograph of boxes used for transporting anthesing male inflorescences to PNGOPRA, Entomology, Dami

In the lab, 20 spikelets each from different positions on the male inflorescences were removed for each site (including Dami) and set up in individual rearing cages (per site) and kept in the quarantine room. The total number of spikelets on each male inflorescence was counted after which they were disposed of into the field (to allow for weevils to emerge). The set ups were checked over time. Once all the weevils had emerged and died in the cages, they were removed and the dead weevils counted. The numbers of weevils emerging from the 20 spikelets were used to project the total number of pollinating weevils per male inflorescence according to the total of male inflorescences.

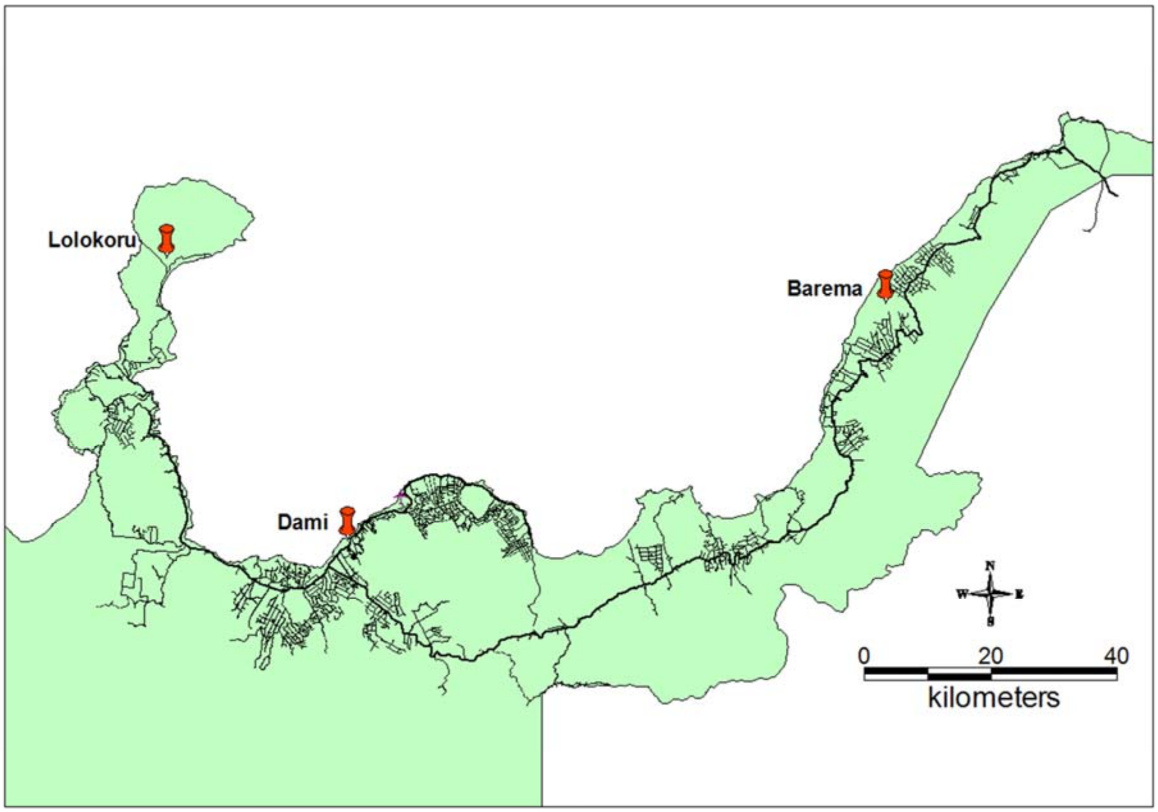

Figure 43 Partial map of WNBP showing the study locations (Barema, Dami, Lolokoru)

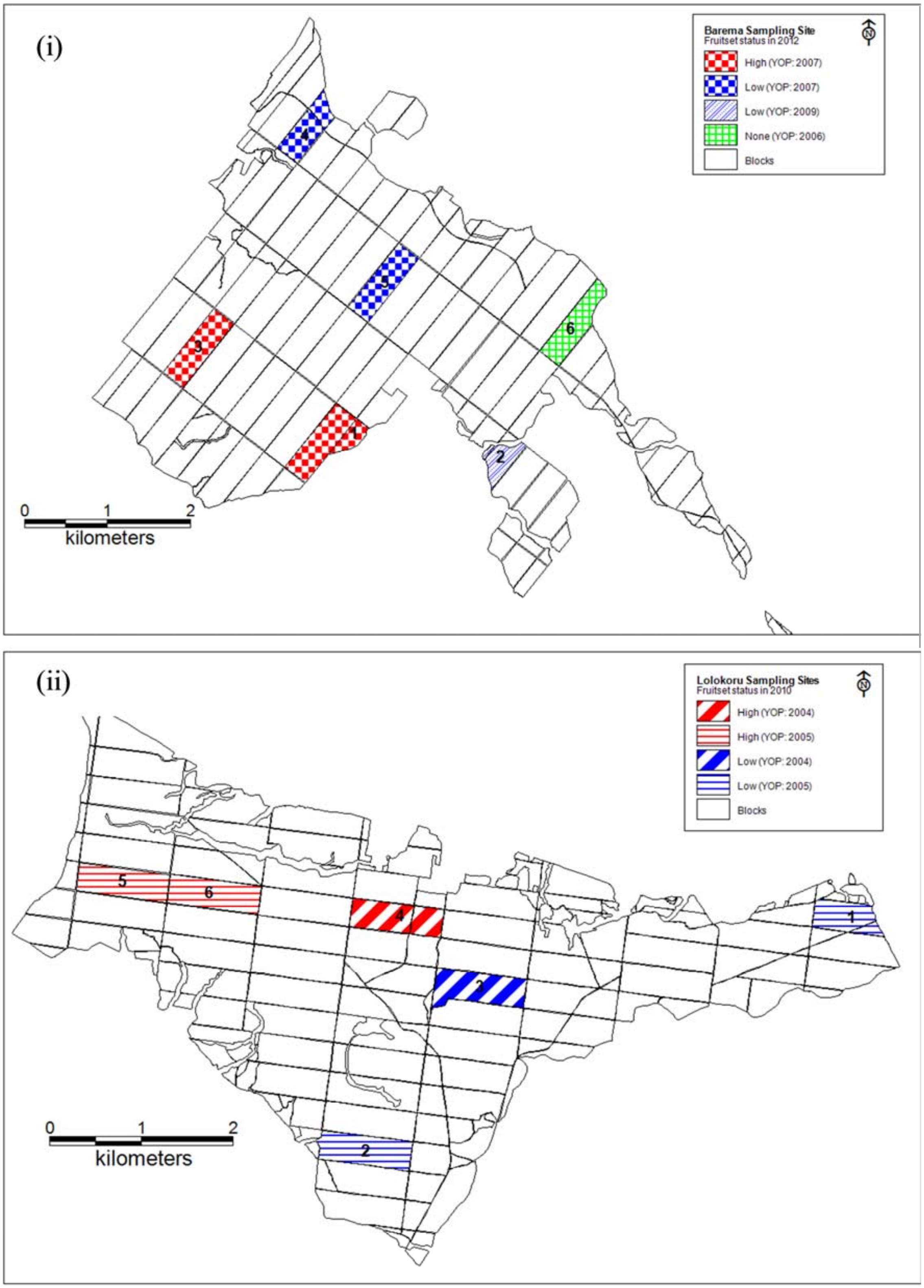

Figure 44 Maps of Barema (i) and Lolokoru (ii) Plantations showing the poor fruit set sites used for pollinating weevil monitoring

Results

When combined for all sites, the number of pollinating weevils sampled in 2013 at Barema remained at or above the critical threshold of 100,000 weevils per hectare[6] required for successful pollination throughout most of the months except for July and December, which were slightly below (Figure 45). Barema Plantation did not sample in March and April, so no male inflorescences and data were sent to PNGOPRA, Entomology.

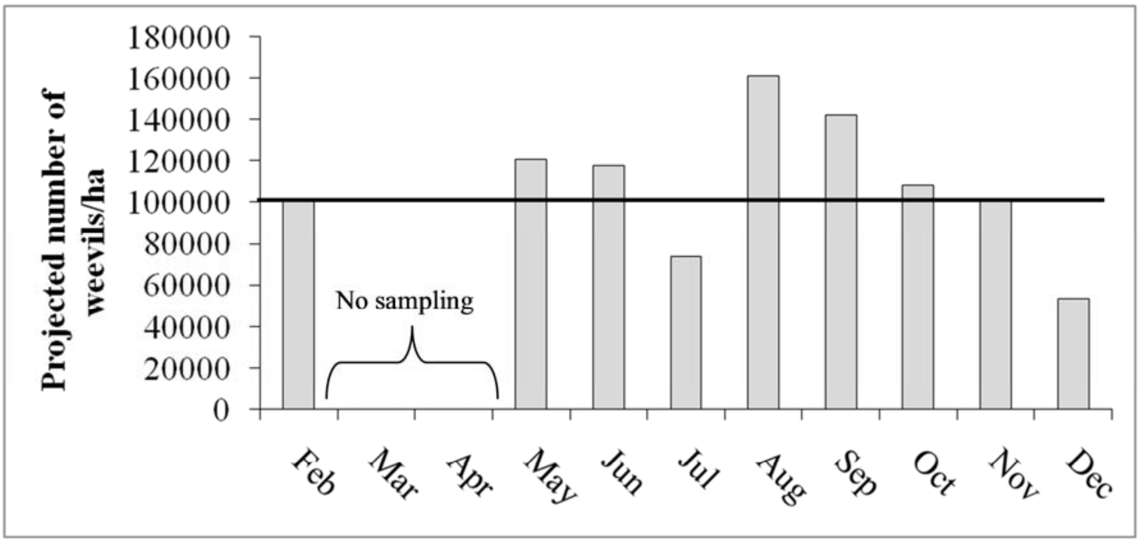

Figure 45 Monthly projected number of pollinating weevils per hectare at Barema in 2013

When combined across all the months for each site at Barema, the projected numbers of pollinating weevils per hectare were well above the critical threshold of 100,000 weevils per site required for successful pollination, although there were marked differences among some of the sites. Sites 1, 2 and 3, which were the sites with severe to moderate poor fruit set problems, had almost half the number of weevils found in sites 4, 5 and 6 which were sites with low to nil poor fruit set problems (Figure 46).

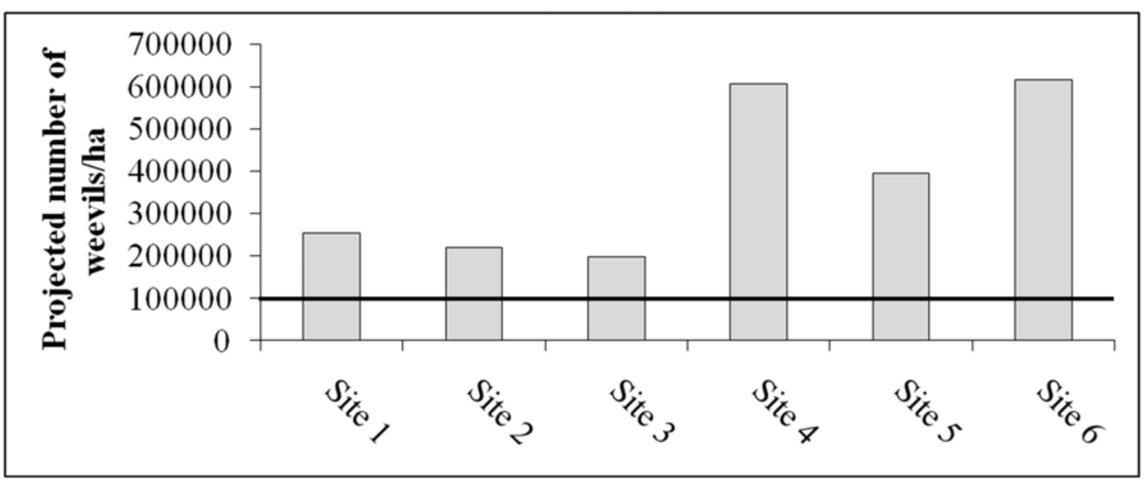

Figure 46 Projected number of pollinating weevils per hectare for each site at Barema in 2013 combined across all sampling months (excluding March and April)

[6]As a rule of thumb, weevil population greater than100, 000 are sufficient for successful pollination of oil palm.

There was a noticeable difference in the mean number of post anthesing male inflorescences (PAMI) per hectare for each site at Barema. Less post anthesing male inflorescences were sampled from the three (3) problem sites (sites 1, 2 and 3) with an average of 4 PAMI per month per site resulting in more severe fruit set problem than the other three (3) sites. Site 6 which had no poor fruit set problem had the highest number of post anthesing male inflorescences per hectare and averaged 15 PAMI (Table 85).

Table 85 Number of post anthesing male inflorescence counted per month for each site at Barema

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Feb 13	***5***	***6***	***2***	4	9	12
May 13	***3***	***3***	***6***	26	10	15
Jun 13	***5***	***9***	***4***	7	4	20
Jul 13	***5***	***5***	***4***	4	5	8
Aug 13	***6***	***8***	***3***	8	10	2
Sep 13	***4***	***1***	***7***	8	6	50
Oct 13	***6***	***3***	***1***	8	5	9
Nov 13	***2***	***3***	***6***	6	11	15
Dec 13	***3***	***2***	***2***	7	6	8
Average	**4**	**4**	**4**	**9**	**7**	**15**

When combined across all sites, the number of pollinating weevils sampled per month at Lolokoru remained at or above the critical threshold of 100,000 weevils per hectare required for successful pollination throughout most of the months except for August, which was slightly below (Figure 47).

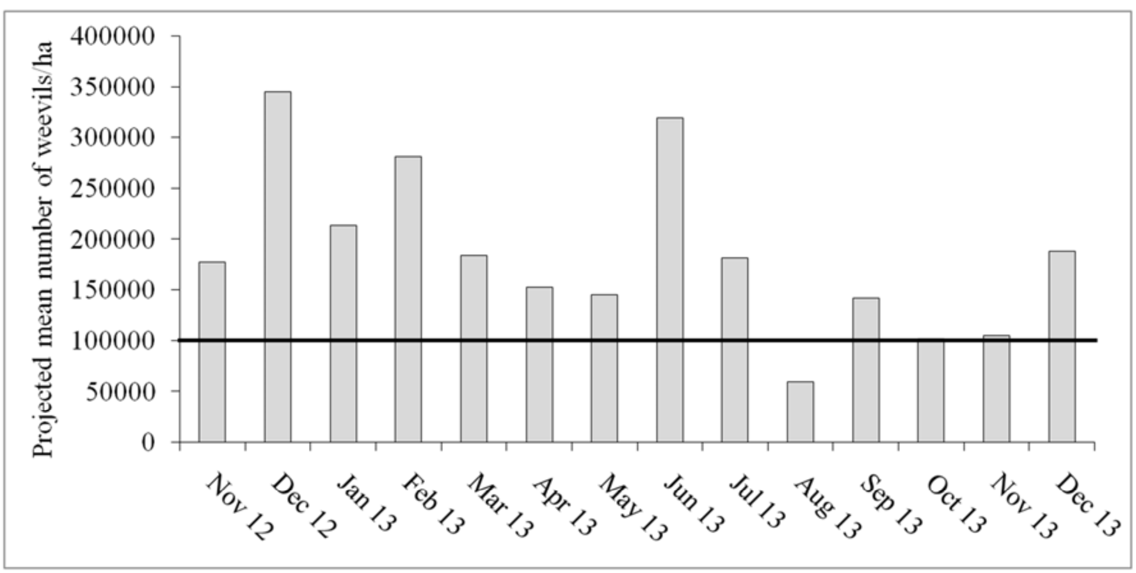

Figure 47 Monthly projected number of pollinating weevils per hectare at Lolokoru

When combined across the months for each site, the projected numbers of pollinating weevils per hectare were above the critical threshold of 100,000 weevils per site required for successful pollination. Site 5, which was the most affected site, had slightly less weevils than the rest of the sites (Figure 48).

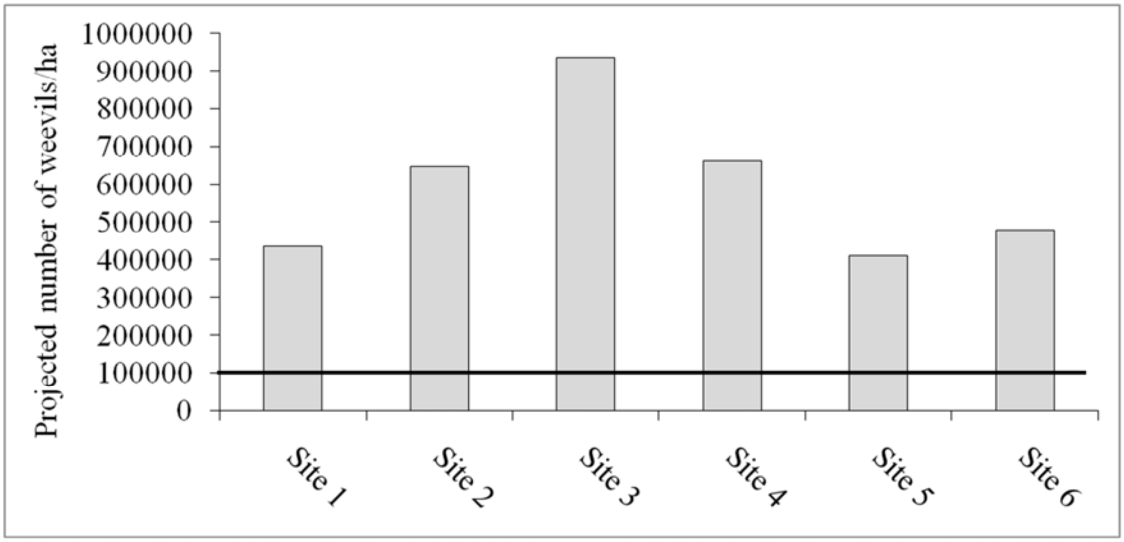

Figure 48 Projected number of pollinating weevils per hectare for each site at Lolokoru combined across all sampling months

As was the case for Barema, there was a noticeable difference in the mean number of post anthesing male inflorescences counted per hectare for each site at Lolokoru. Site 5, which was the most affected site, had almost half the number of post anthesing male inflorescences than the rest of the sites (Table 86).

Table 86 Number of post anthesing male inflorescence per month for each site at Lolokoru

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Nov 12	***22***	***28***	***14***	23	10	23
Dec 12	***19***	***13***	***19***	27	9	13
Jan 13	***14***	***14***	***14***	10	5	17
Feb 13	***21***	***28***	***21***	13	6	7
Mar 13	***8***	***22***	***14***	5	6	12
Apr 13	***16***	***17***	***25***	16	3	8
May 13	***14***	***9***	***5***	21	3	12
Jun 13	***19***	***14***	***20***	31	16	37
Jul 13	***22***	***11***	***11***	9	7	4
Aug 13	***2***	***4***	***3***	9	1	1
Sep 13	***5***	***16***	***20***	12	2	11
Oct 13	***8***	***7***	***7***	7	1	7
Nov 13	***10***	***9***	***8***	5	9	11
Dec 13	***7***	***11***	***15***	13	15	13
Average	**13**	**15**	**14**	**14**	**7**	**13**

When combined across all sites, the number of pollinating weevils sampled at Dami remained above the critical threshold of 100,000 weevils per hectare required for successful pollination throughout most of the months except for March and December, which were slightly below. August, September and October had considerably higher numbers of weevils (Figure 49).

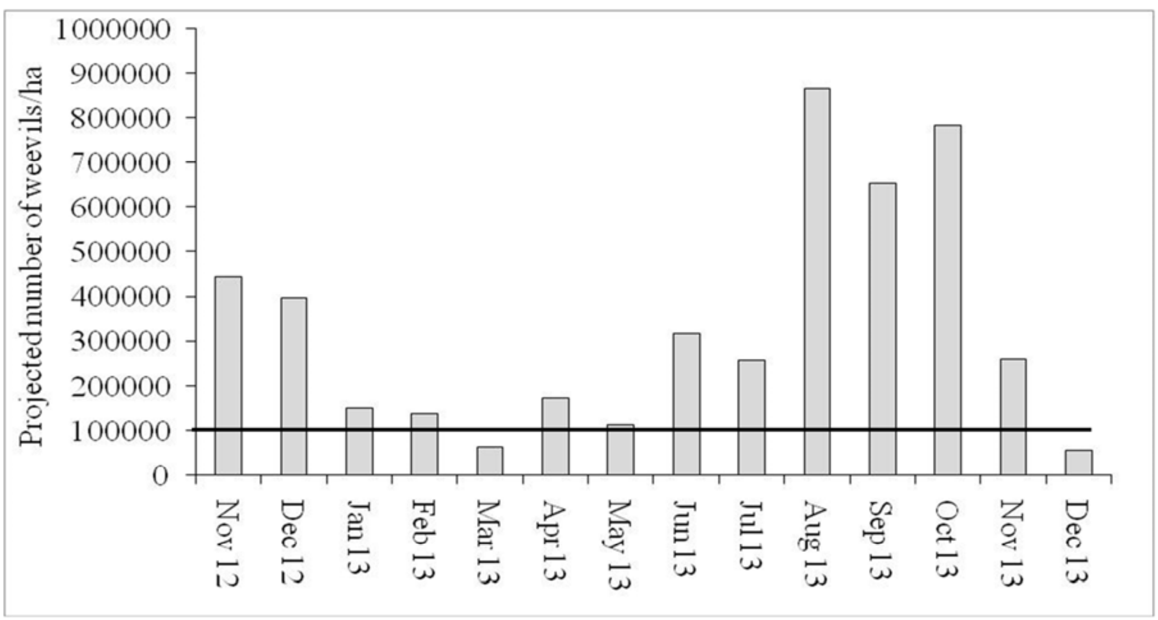

Figure 49 Monthly projected number of pollinating weevils per hectare at Dami

The monthly post anthesing male inflorescence numbers at Dami remained consistent above the critical number (5 post anthesing male inflorescence per hectare/month) required to support the number of pollinating weevils (more than 100,000) that is required to successfully carry out pollination (Figure 50).

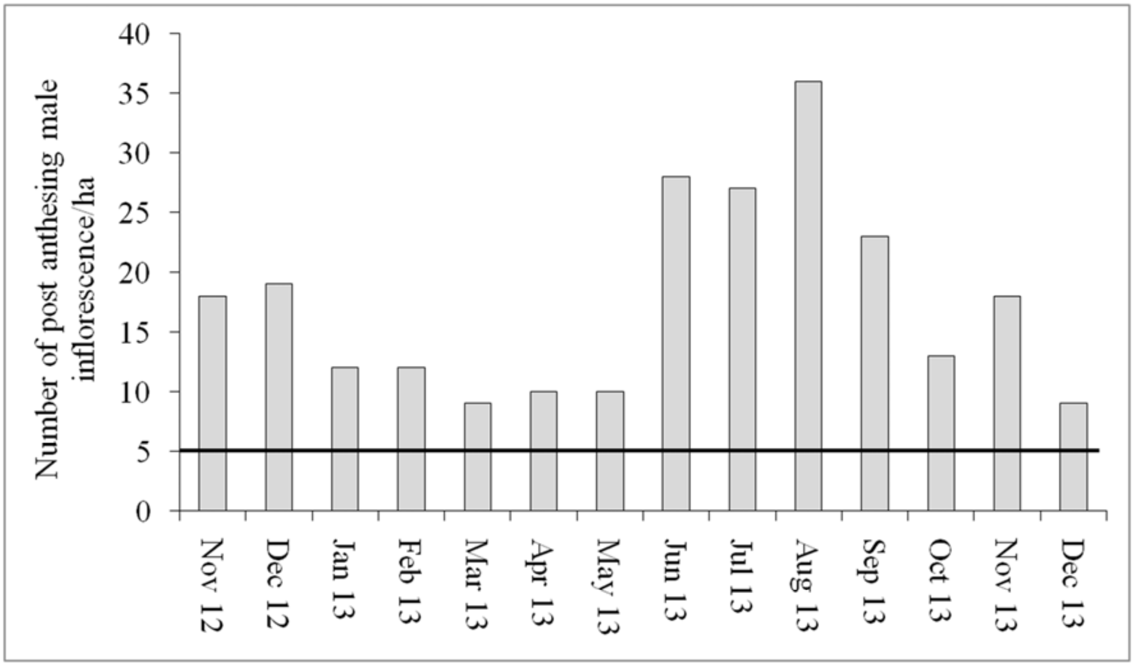

Figure 50 Number of post anthesing male inflorescence sampled per month from Dami.

When Lolokoru data was used to compare the relationship between the number of weevils and the post-anthesing male inflorescences, there was a strong positive correlation between them (data log transformed for analysis). About 75% of the number of pollinating weevils in the field was influenced by the number of post-anthesing male inflorescences (Figure 51).

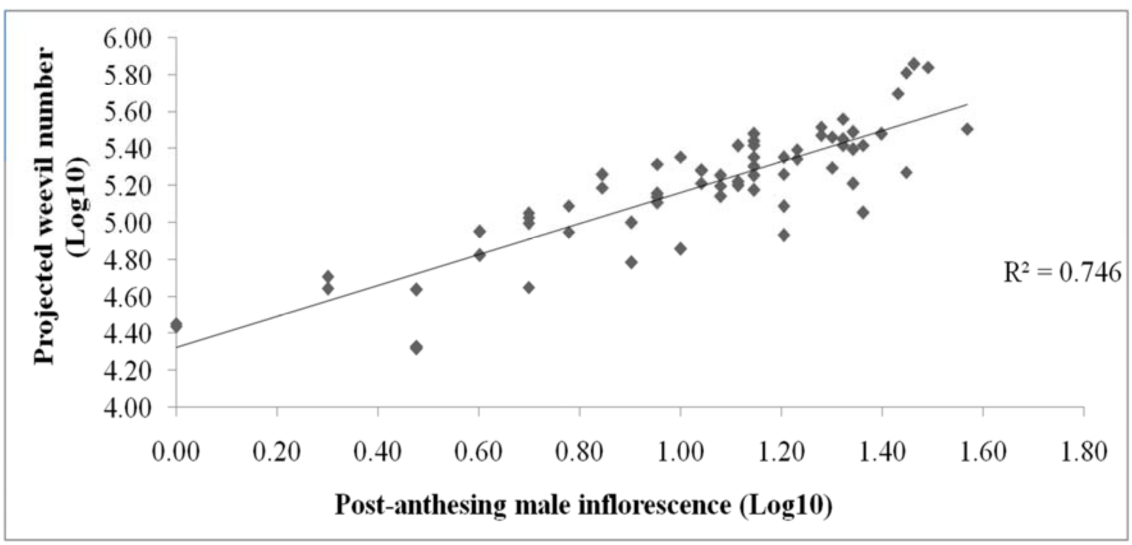

Figure 51 Correlation between the number of weevils and the number of post anthesing male inflorescences using the Lolokoru data

Discussion and Conclusion

The numbers of pollinating weevils were consistently high across all sites (Figure 46 and Figure 48) and over time (Figure 45, Figure 47 and Figure 49) in all 3 study locations sufficient enough for successful pollination, although the numbers in sites with severe fruit set problem (Sites 1 & 3 for Barema and Sites 4, 5 & 6 for Lolokoru) were low.

The number of weevils correlated positively with the number of post anthesing male inflorescences (Figure 51) indicating that the drop in weevil population in problem sites was directly influenced by the low number of male inflorescences. The pollinating weevil numbers in those sites were low because there was a limitation to breeding habitats (low number of male inflorescences) influenced by high female sex ratio. It was not a result of general decline in weevil population within the plantations. *Elaedobius kamerunicus* strictly feeds and breeds within male inflorescences, and only moves in search of breeding and feeding sites (male inflorescences). It does not move to search for female inflorescences to pollinate. Pollination is only a chance event that happens because of the attraction of the weevils during movement by the strong aniseed smell that the estragole of the female inflorescences produce. In most instances movement is restricted because oil palm is monoecious and both male and female flowers are produced on the same palm (Henderson, 1986). The pollen source needs to be within close proximity of the female inflorescences for adequate pollination.

The results from this study therefore indicate that the poor fruit set problems at Barema and Lolokoru were not influenced by low pollinating weevil population. The problem is most likely physiological, associated with breeding line selection whereby breeding of high oil yielding progenies caused the increase in female sex ratio resulting in low number of male inflorescences. The drop in the number of male inflorescences subsequently limited the breeding sites of the weevils, thereby reducing the weevil numbers in the problem sites. The problem subsided once the palms grew out of the high female sex ratio, and the number of male inflorescences (breeding sites) picked up. If the problem is encountered in future, close attention should be given to breeding lines/progenies planted in the area.

Investigation into the biology of *Segestidea defoliaria defoliaria* and its egg parasitoid *Doirania leefmansi*- (RSPO 4.5, 8.1)

Introduction

Understanding the biology of pests is important for making informed management decisions. Without such knowledge, incorrect decisions can be made, which subsequently can lead to management failures resulting in fund and time wastages.

Key pests for oil palm in PNG include Sexavae (*Segestes decoratus*, *Segestidea novaeguineae, Segestidea defoliaria defoliaria*, *Segestidea defoliaria gracilis*) and stick insects of the genus *Eurycantha* (*E.calcarata, E.insularis*). These pests require routine monitoring and management by the oil palm industry to prevent any major outbreaks. The industry in PNG has chosen to develop and implement Integrated Pest Management (IPM) for their control. The application of an integrated management approach involves the understanding of the biology of individual pest species as well as their biological control agents. Whilst efforts have been made to understand the basic biology of the pest species, much still remains to be investigated for some of the pests and their biological control agents.

Segestidea defoliaria defoliaria is one of the common sexavae pests in WNB. The other species is *S.decoratus*. Whilst *S.decoratus* is parthenogenetic, *S.defoliaria defoliaria* goes through the normal male-female mating cycle for reproduction. The information on the life cycle, the number of eggs the females lay, the embryonic developmental stages and the rate of egg parasitism by the egg parasitoids of *S.defoliaria defoliaria* are not yet fully understand. This information is important for developing management programmes.

Doirania leefmansi is an egg parasitoid of all Sexavae pest species. The parasitoid is native to PNG, having been first described from New Hanover (Froggatt, 1937). It has, over the years, been mass reared and field released as part of the Sexavae pest IPM programmes in oil palm cropping systems, but its basic biology and ecology, as well as the role of beneficial plants in supporting the adult parasitoid population is not yet being fully understood.

In 2013, studies on the biology of Sexavae till continued but concentrated on *S.defoliaria defoliaria* and one of its egg parasitoids (*D.leefmansi*). The study formed part of Tabitha Manjobie's MPhil studies at the PNG University of Technology, Unitech, Lae.

Study procedure

Initial stock of both males and females (adults and nymphs) of *S.defoliaria defoliaria* were collected from Malalimi Plantation, NBPOL (Longitude 150 ◦ 25' 42.672"Latitude -5◦37'48.9"). Newly fledged adults free of *Stichotrema dallatoreanum* infection from the collection were used for the trials.

Doirania leefmansi were obtained from laboratory maintained cultures. The laboratory stock was reared from parasitized Sexavae eggs collected from Lolokoru Plantation. The parasitoids to be used in the trials were kept separately from the main stock. The parasitoid is parthenogenetic and the females were used for the trials a day after emergence, as they normally start laying eggs within 24 hours from emergence.

To determine the reproductive potential and the embryonic development stages of *S.defoliaria defoliaria*, unmated 2 day old male-female pairs were removed from the main stock cages and set up in insect rearing Bug Dorm™ cages (BD42260F) and kept in the quarantine room for mating and egg laying. Each cage was labeled according to the replicate number. A small round clear plastic pot (11cm in diameter and 8.2cm tall) was filled up to the top with sterilized moist river sand and placed inside the cage for oviposition. A small plastic tube (50ml) filled with water (without lid) was pushed into the sand (base-wise) in the pot. The tube held 2 fresh leaflets which were changed at 2 day intervals. The leaflets served as the food source for the insect pair. The room temperature was set at 26-27°C with photoperiod of 12h:12h (light to dark) and Relative Humidity (RH) at 78-90%. Mating was checked each morning and the number of eggs laid counted. Mating was confirmed by the presence of spermatophore (white gelatinous substance) on the female genitalia.

From the batch of eggs laid in the same day, 10 eggs were drawn and placed in clear plastic pots with sterilized sand. The eggs were covered 2cm below the sand, and the top of the pots covered with mesh cloth fastened with rubber band. These were maintained in a bigger outdoor Sexavae breeding cage under ambient environmental conditions. The pots were watered whenever the soil moisture level dropped and the eggs monitored for nymph emergence until 150 days. Eggs that did not hatch after this period were dissected to see if they were viable or not. For the eggs that hatched, the dates of nymph emergence and sexes were recorded. The nymphs were fed with fresh clean young palm leaflets (washed with distilled water) in the Bug Dorm™ 42222cages. The cages were held in a second room with air condition set at a constant temperature (26^0C) and monitored. For those that died, the date of death and the sex was recorded. For those nymphs that fledged to adult, the number of molts and the date of fledging were recorded, and transferred to bigger feeding cages and fed with mature palm leaflets until they died and the date of death was recorded.
The parameters for which the data were collected included:
ISSP = Immature Stage Survival Period (period from nymph emergence to fledging)
POP = Pre Oviposition Period (period from fledging to start of egg laying)
ELP = Egg Laying Period (period from first egg deposition to last egg deposition)

PELP = Post Egg Laying Period (period from last egg lay to death)

For embryonic development assessment, the same protocol as above was followed for mating and egg laying. Five (5) female and 2 male adults each of *S.defoliaria defoliaria* were set up in small separate Bug Dorm™ 42222 Insect Cages. Once the females started laying eggs after mating, 50 eggs (n = 500) each from the same cohort (all laid during the same day) were removed from each cage and set up in separate holding pots containing moistened sterilized sand. One egg each from each pot (replicated) was removed at 7, 14, 21, 28, 42, 56, 70, 84, 98, 112, 126 day intervals, weighed and dissected and the embryonic stage of the eggs determined. The remaining eggs were allowed to hatch.

Before the dissection of eggs, a Stereo Microscope (Leica MZ75) was set up using the technique described by (Sumner & Summer, 1969). Once this was done, a watch glass or petri dish filled half way with clean tap water was placed at the center stage of the microscope. The water in the petri dish was to keep the specimen moist for easy observation throughout the duration of the dissection. The egg was held lightly (frontal view) with a fine pair of metal forceps and dissected using an eye scalpel blade. This was done by running the blade very lightly along the length of the egg ensuring not to cut too deep as this can destroy the embryo. If distorted, the distinguishing characters of the different stages will be difficult to observe. Where a visible embryo was present, observation and recording of the embryonic stage was done with reference to Ingrish's Tettigoniidae embryonic development diagram (Ingrisch, 1984). The different stages were recorded accordingly.

An egg parasitism study was also conducted in the quarantine room under the same conditions as those for the Sexavae biology study. The study was conducted in a High Quarantine air conditioned room in the Entomology Laboratory, at a constant temperature of 26^0C and 12hr:12hr(dark to light) photoperiod.

Fifteen (15) each of five day (stage 0) old, 15 days old (Stage 18 - 20) and 28 days old (Stage 21 - 25) *S.defoliaria defoliaria* eggs were exposed to 5 sexually mature females of *D.leefmansi* (one day old as they normally start ovipositing within 48 hours of emergence) for 48 hours. After 48 hours, the parasitoids were removed and the eggs were monitored for parasitoid emergence. Honey (as food source for adults) and water were provided to the parasitoids. The parasitoids that emerged were counted and the dates recorded. This process continued until they stopped emerging. Un-hatched eggs were dissected to see if the embryos were still developing.

The results presented here will be progressive as some components of the study will continue in 2014.

Results

Since the focus of the study was to investigate fecundity rates, only the survival periods of females were determined. A total of 6 nymphal instars were noted for this species (*S.defoliaria defoliaria*). The different instars were differentiated by the molting process (shedding off of the skin from one stage to another). According to One-Way ANOVA test, there was no significant difference ($P = 0.92$) in the female survival period (number of days) among the different nymphal instars (Table 87). The combined mean survival period of the female immature stages was around 118.74 days (sum of the mean survival period of each instar). When the mean survival periods of each instar were pooled (118.74 days) and analysed against POP (10.9 days), ELP(66.30 days) and PELP (17.50 days), the Immature Stages Survival Period (ISSP) was significantly greater ($P < 0.001$) than the other stages (Figure 52). The Egg Laying Period (ELP) took the second highest number of days (66.30 days), whilst the Pre-Oviposition Period (POP) took the least number of days (10.90). In Figure 52, the columns with different letters above the error bars indicate that they were significantly different whilst those columns with the same letter indicate that they were not significantly different. The donut diagram in Figure 53 summarises the survival period (life span) at each stage by the female.

Table 87 Number of days (mean ± SE) taken by each female instar

Nymphal instar	Number of days (mean ± SE)
First	21.83 ± 2.07
Second	19.08 ± 1.57
Third	20.75 ± 3.40
Fourth	19.58 ± 2.07
Fifth	19.00 ± 1.94
Sixth	18.50 ± 2.54

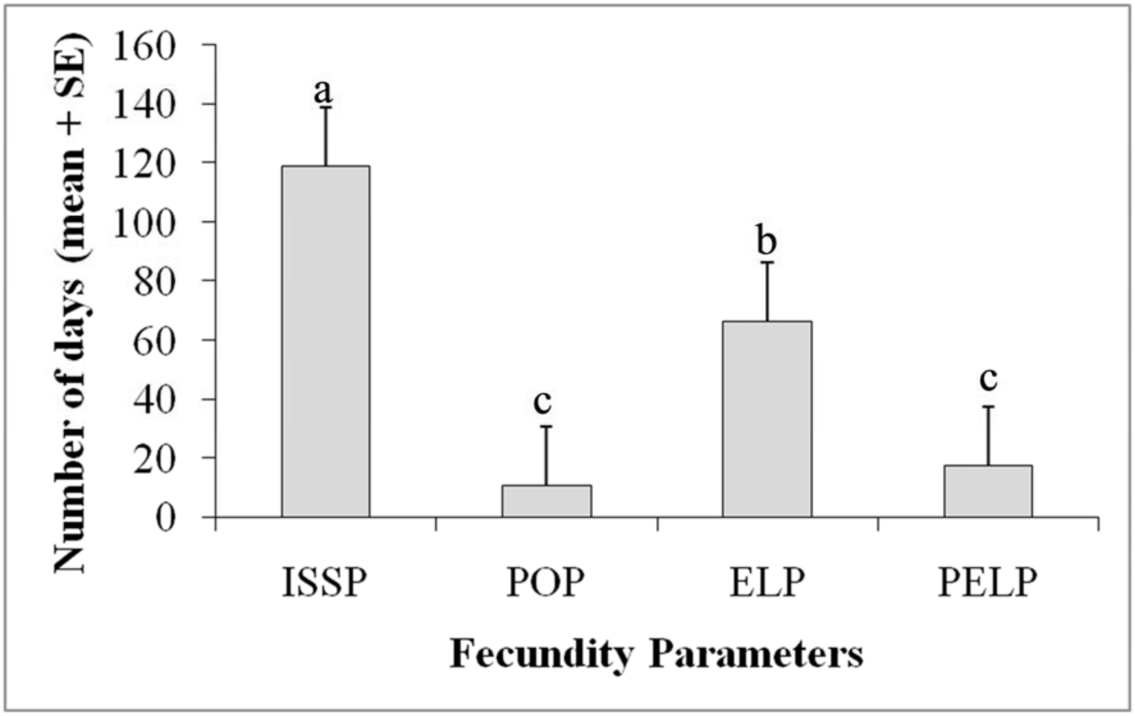

Figure 52 Mean number of days (+SE) for the various life stages of the female (ISSP, POP, ELP, PELP)

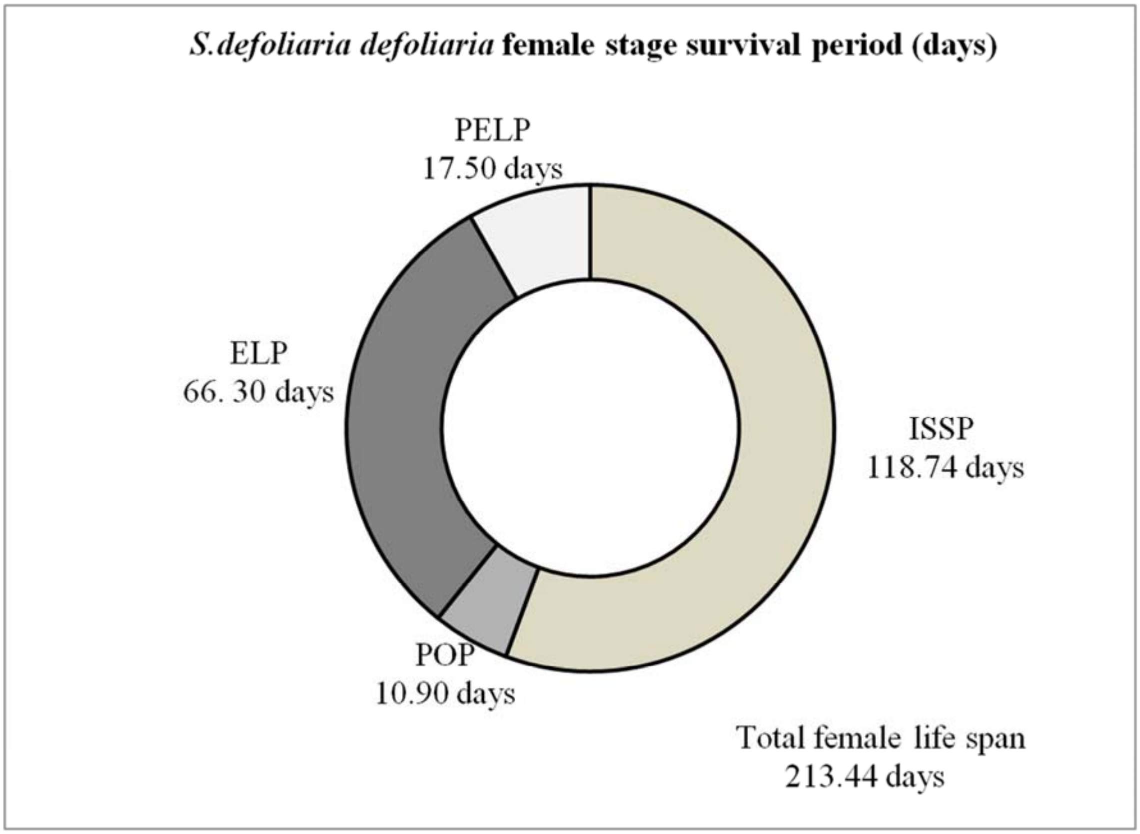

Figure 53 Mean duration (days) of the various life stages (ISSP, POP, ELP, PELP) of *S.defoliaria defoliaria* females

The egg laying period was spread across 15 weeks (Figure 54). The highest percentages of eggs were laid during the 5th week of the egg laying period. It increased from the 1st week to the 9th week and dropped off noticeably thereafter. The lowest percentages of eggs were laid between the 13th and the 16th week (Figure 54).

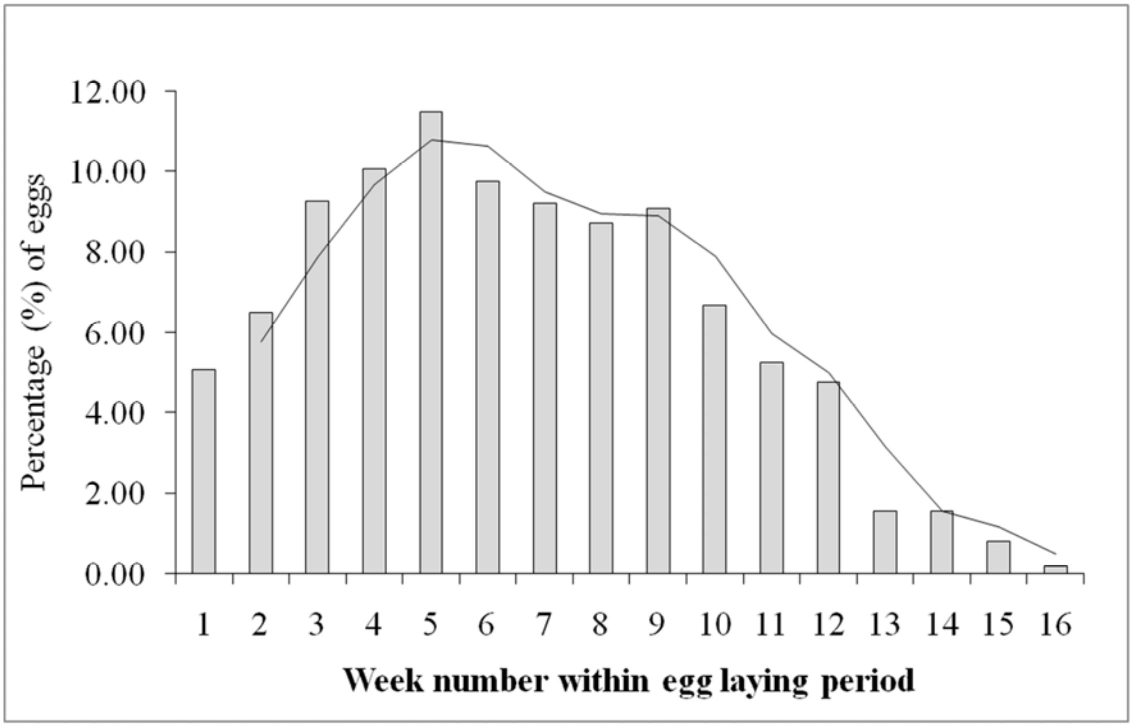

Figure 54 Mean number of eggs laid by an individual female per week during the egg laying period (ELP). [ELP spread across 15 weeks with a mean of 66 days]

There was a strong correlation between the egg mean weight and the embryonic stages with 60% (R^2 = 0.60) of the egg weight influenced by the embryonic stages (Figure 56). The embryonic weight (g) increased noticeably from one stage to another, particularly at the later stages. The egg weights (g) fluctuated at some stages and these inconsistencies have been attributed to reduced water uptake and egg diapauses (Hodek, 2003; Young, 1990).

Ingrisch, 1984 described 25 embryonic stages. However, in the current study developing embryos became visible under the stereo microscope used only from stage 9 onwards (stages 9-25). Stages 1 to 8 were not clearly visible, as the microscope used for viewing and the camera (Dino Digital Camera) used for photographing the images were not powerful enough to capture the finer details of the earlier stages. Only 4 stages (stages 14, 20, 24 & 25) where the distinguishing characters were clearly visible are presented in Figure 55. The key distinguishing characters of each of these stages include:

Stages 14 (I): The embryo was found almost at the end of the egg. Its eye pigment becomes reddish, and the antennae reach pedes I (first pair of embryonic feet).

Stage 20 (ii): Yolk is visible and protruding behind the caput (pronotal region) but not pronounced as in stages 21 and 22. Embryo is white and translucent.

Stage 24 (iii): Pigmentation of the embryo is completed and is nearly dark green in color, appendages reach the last (4^{th}) abdominal segment.

Stage 25 (iv): Embryo is fully developed; eye pigment is darkened, whole embryo becomes dark green in color, the spines darken and skin on the neck is heavily swollen, appendages reach full length of the body.

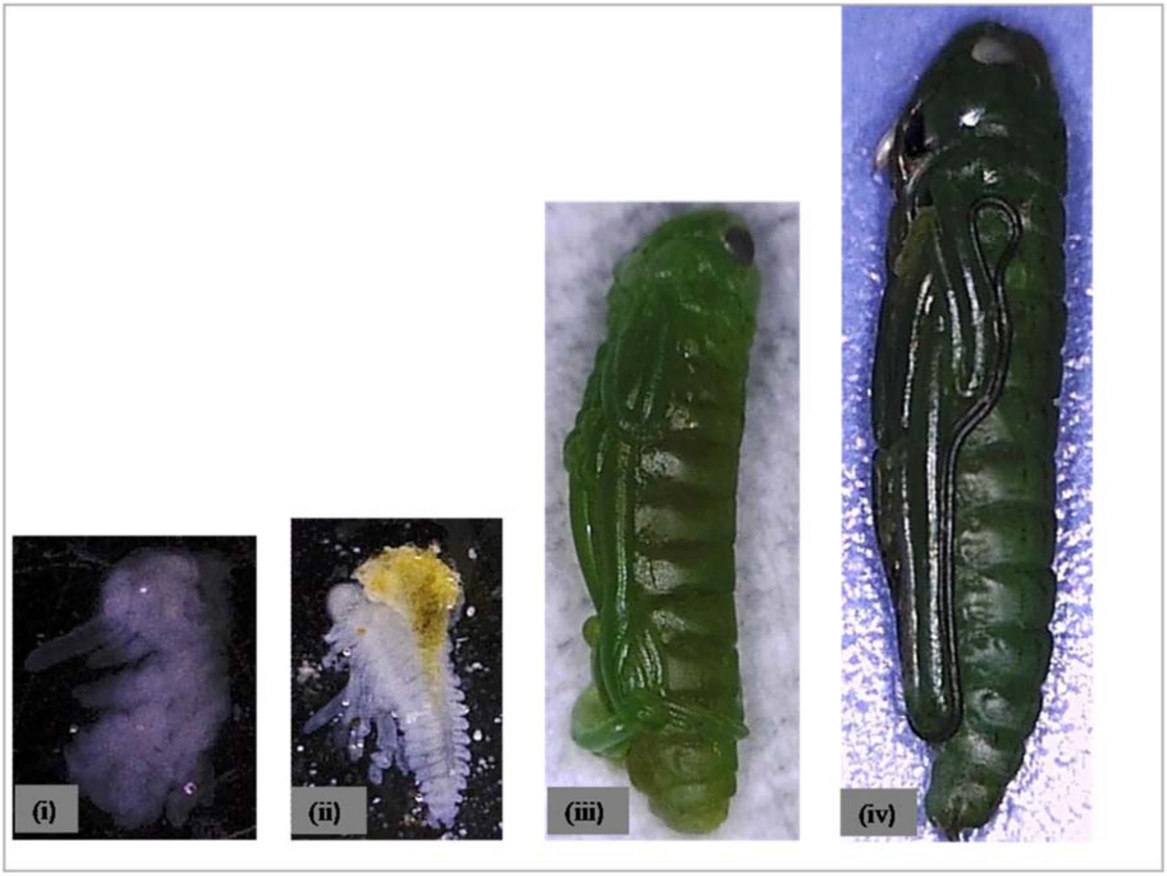

Figure 55 Four clearly distinguishable embryonic stages (I= Stage 4, II= Stage 20, III= Stage 24, IV= Stage 25) of *S.defoliaria defoliaria* under the stereomicroscope used

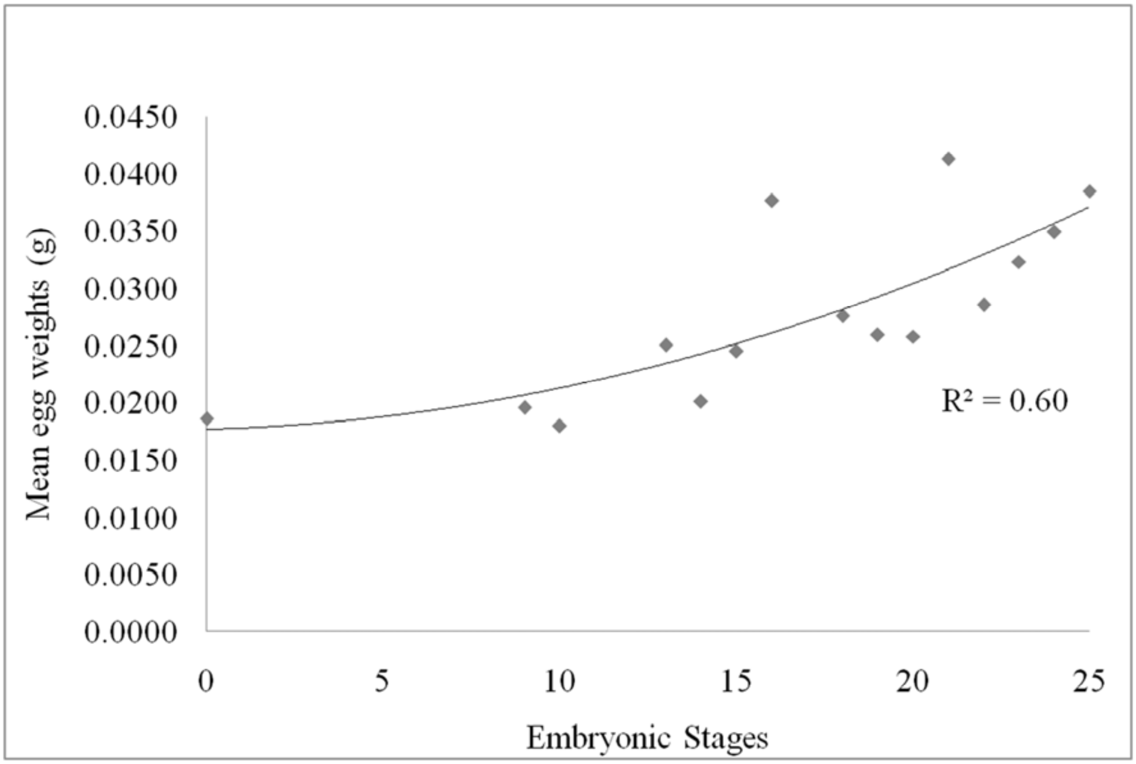

Figure 56 Mean weights (g) of *S.defoliaria defoliaria* eggs across the different embryonic developmental stages

Doirania leefmansi significantly preferred younger eggs (5 days old) than the older eggs (15 days and 28 days) for parasitism (Figure 57) when different aged *S.defoliaria defoliaria* eggs were exposed to the mature females (a parthenogenetic species). The preference for young host eggs could be influenced by the softness of the egg shell for oviposition as the parasitoids are very tiny (ca 2mm) and soft. The different letters above the error bars indicate that the number of parasitoids emerging from the different age group eggs were significantly different (P = 0.01).

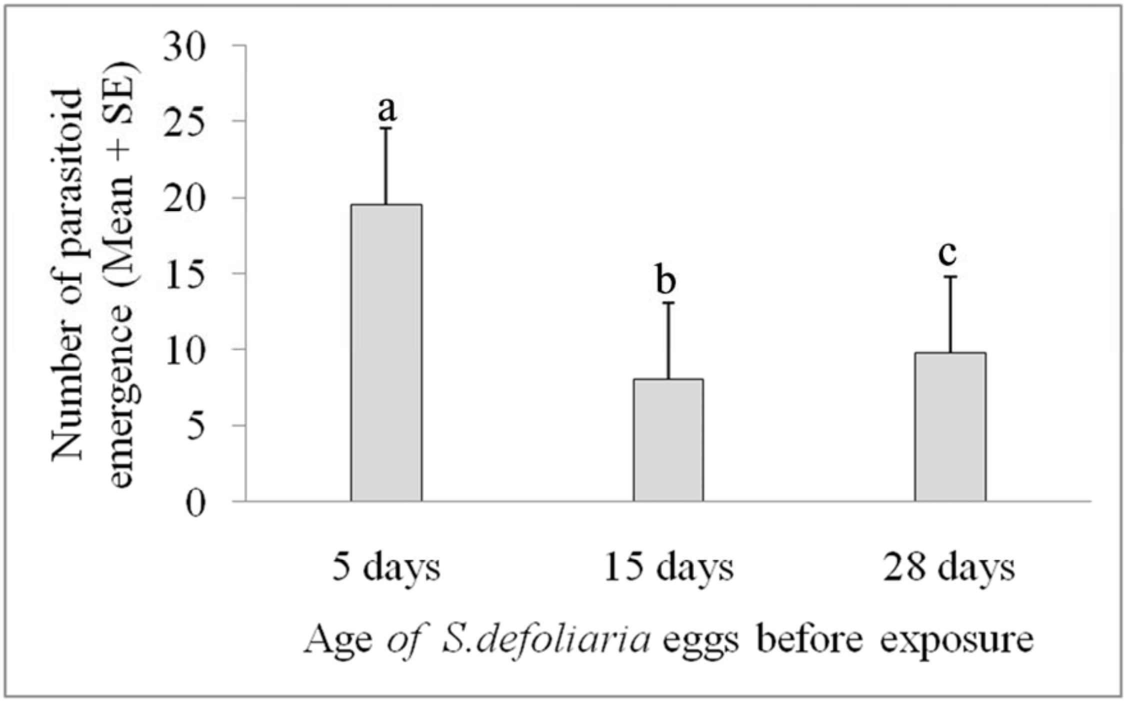

Figure 57 Parasitism of different age eggs of *S.defoliaria defoliaria* by *D.leefmansi*

Discussion and Conclusion

Information derived from this study is important for management decisions, particularly for the timing of insecticide application (Targeted Trunk Injection) and release of biological control agents.

If the level of infestation warrants insecticide treatment, it needs to be applied when the insects are at late nymphal stages or during the pre-oviposition period (POP), which is within 10 days following fledging. Precise timing of treatment will ensure the insects are killed before the laying of eggs. For fields with overlapping generations and large proportion of diapausing eggs, routine monitoring is necessary to detect and control all emerging insects.

Distinct embryonic development stages (with distinct weight differences) and the preference among the stages for parasitism by the egg parasitoids is important to identify the developmental stages of eggs in the field and to plan the timing for expected chemical treatment and release of biological control agents. Release of the egg parasitoids should be done when Sexavae eggs are at the early stages of development for maximum parasitism. Planting of beneficial plants is necessary to support the adult populations of biological control agents as adults need to feed on honey and nectar to survey. Laboratory cultures are normally fed with processed honey purchased from supermarkets. Hence, prior to release of the biological control agents in the field, it should be ensured that there are sufficient numbers of beneficial plants within the field to support the biological control agents. Precise timing of insecticide application and the release of egg parasitoids will ensure effective control of the pest.

Observation of life cycle and the field egg parasitism studies will continue in 2014, with the possibility of having the management programme developed at the end of the year (2014).

Study into the Biology and Management of *Oryctes rhinoceros* beetles- (RSPO 4.5, 8.1)

Introduction

Oryctes rhinoceros is a key pest of coconut in many parts of the world, particularly in the Pacific islands. Coconut provides a major food source for the larvae as well as the adults (Bedford, 1976). In PNG, because of the declining copra price of the once thriving coconut industry, many large plantations have been abandoned (Allen, Bourke, & McGRegor, 2009). These abandoned plantations are now thought to be acting as breeding reserves for the beetle. For any oil palm developments that are done adjacent to old coconut plantations, it is most likely that the palms will experience some level of damage by the beetle. This has possibly been the case for New Ireland where much of the province is dominated by abandoned coconut plantations, and oil palm is being grown adjacent to them. Indeed, infestation on coconuts by the beetle in the province has been recorded as early as 1953 (Bedford, 1976), and the damage from the beetle is obvious when driving along the Buliminsky Highway.

Oryctes rhinoceros breed on dead standing or fallen stumps of coconuts and oil palm, as well as in other moist organic matter (e.g. rotting cocoa pods). Females burrow and lay their eggs (mean of 49-50 eggs per female during her life time) in the breeding sites. The eggs take 8-12 days before hatching. Larvae feed and survive on dead organic matter for 82-207 days, with additional 8-13 days as pre-pupal stage. The pupal stage takes 17-18 days, and the adults live for 4-9 months (Plantwise, 2012).

It is the adults that cause the damage to the palms. The damage is normally around the base on young palms and on petiole bases in older palms cutting through central unopened leaves. Such damage normally produces wedge shaped gaps or characteristic serrated cut (Wood, The effect of ground vegetation on infestations of Oryctes rhinoceros (L.) (Coleoptera: Dynastinae) in young palm replantings in Malaysia., 1969). Because of the nature in which they cause the damage, their management through chemical application can be tricky. Application of systemic insecticides through leaf axils can effectively kill the pest, but the insects will need to burrow through the tissue to pick up the chemical before they are killed. Hence, the insects will still cause some damage to the palm before they are killed.

In 2013, *O.rhinoceros* continued to attack young replant oil palms in New Ireland (NI), particularly at Luburua and Lakurumau Plantations. The damage was mainly on young 1-2 year old palms by the adult beetles. Development and implementation of an effective management option is necessary. Pheromone trapping (purposely for monitoring) continued whilst possible biological control options were investigated. As part of this drive, *Metarhizium anisoplae* (an entomopathogenic fungus) was introduced and a further collaborative research project was developed between PNGOPRA and AgResearch NZ to map out spatial-temporal infestation levels and identify any potential virus strains (Bacculo virus) for the control of the beetle.

Study Procedure

Pheromone trapping continued in 2013 at Luburua and Lakurumau Plantations in NI both for monitoring and extraction of gut contents for virus infection confirmation and strain identification. Gut contents are normally used for analysis because once the virus enters the insect via contaminated food, it reaches the nuclei of the midgut epithelial cells and replicates before spreading to other tissues (Payne, Compson, & DeLooze, 1977). Infected guts are also easier to visually distinguish because of the colour differences between the infected and uninfected guts (Plate 9). The infected tissues in other parts of the body do not show such obvious differences.

Three (3) traps were set up in WNB (Banaule, Sarakolok, Numondo) starting in September mainly for extraction of guts for virus infection confirmation and strain identification. The traps used were the

PVC pipe pole as this type of trap was found to be more effective than the bucket traps. Plate 7 shows the photograph of the PVC pipe pheromone trap used to catch rhino beetles.

Sub-samples of female beetles collected from NI were dissected to count the number of mature and immature eggs. The difference between the mature and immature eggs was noted by the difference in the colouring and softness or hardness of the eggs. Mature eggs were darker and harder, whilst immature eggs were translucent and softer.

Plate 7 Photograph showing *O.rhinoceros* management project team members checking a PVC pipe pheromone trap set up in the middle of young replant palms at Luburua Plantation, NI

Some samples of beetles collected from the pheromone traps were dissected and gut contents checked for viral infection following the operational protocols provided by AgResearch, NZ (Jackson, 2010). Plate 8 shows PNGOPRA staff doing the gut dissection following the protocol provided by AgResearch. Guts without infection were milky, swollen and full of organic matter, whilst infected guts were dark, thin and empty of organic matter (Plate 9). Any infected gut samples extracted were sent to AgResearch in Lincoln, New Zealand to run PCRs for virus strain identification. Plate 9 provides an example of the obvious differences between infected and un-infected guts. Preliminary PCR results of the earlier collections are presented here (Table 88).

Plate 8 PNGOPRA Entomology staff doing the gut dissection to collect virus infected samples (i) cut opening of the abdomen with a pair of scissors, (ii) stretching of the gut to check for gut content and (iii) cross checking of the gut colour

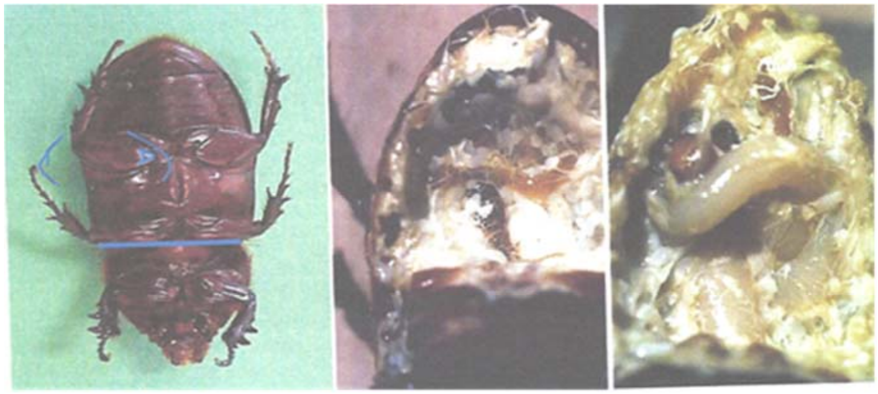

Plate 9 *Oryctes rhinoceros* showing points to cut (left), healthy gut (middle) and empty infected gut (right)

Whilst awaiting the identification and collection of the virulent strain of bacculo virus for release into New Ireland, male beetles were infected with *Metarhizium anisopliae* (entomopathogenic fungus) and released into the infested fields for field re-infection of adults and larvae that the infected males come in contact with.

Results

Oryctes rhinoceros pheromone trapping at Luburua and Lakurumau replants continued throughout 2013. For Luburua, the number of beetles trapped continued to decline since May with the lowest number caught in December (Figure 58). For Lakurumau, the number of beetles caught per trap remained consistently high throughout the year (Figure 59). The 2012 trapping data for Luburua is presented to show the overall declining trend in the number of beetles caught (Figure 58).

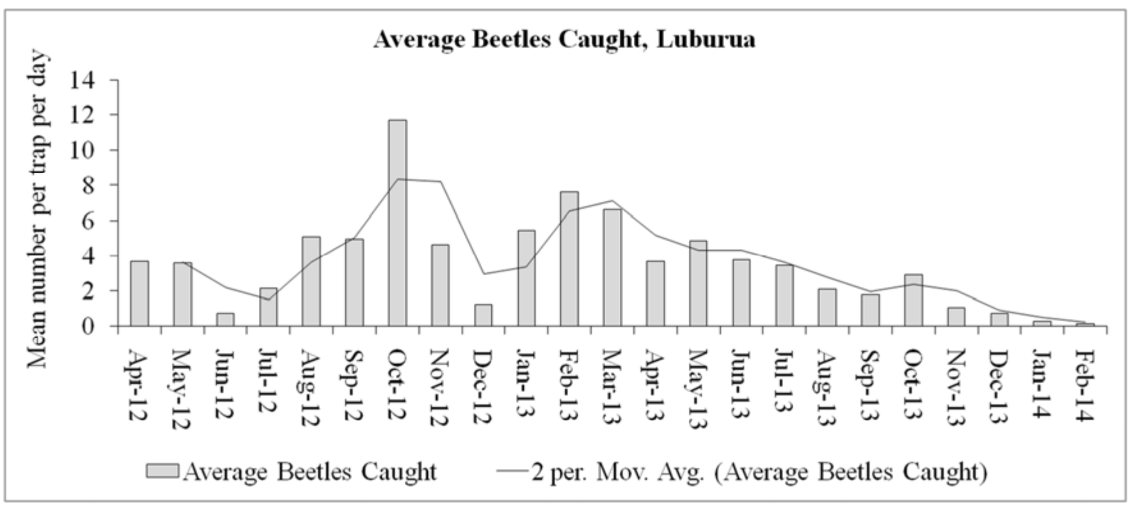

Figure 58 Number of *O.rhinoceros* beetles caught per trap per day from Luburua Plantation between April 2012 and December 2013

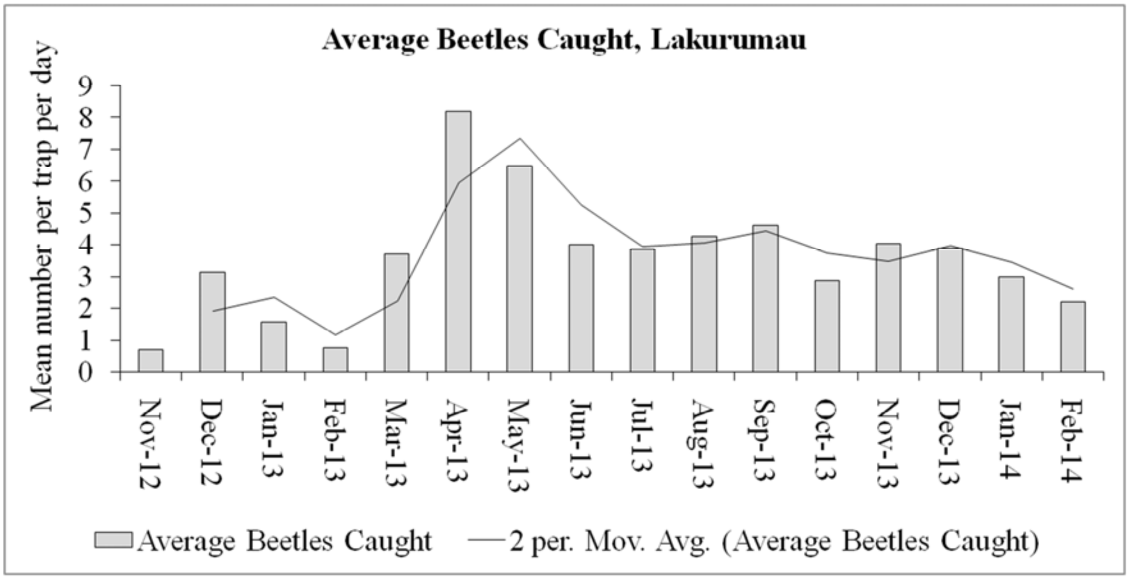

Figure 59 Number of *O.rhinoceros* beetles caught per trap per day from Lakurumau Plantation in November 2012 and February 2014

The egg loads in female beetles were consistently high throughout the year implying that they were actively breeding. Although still high, there was a marked drop in the number of eggs after the first and the second months of sampling. There was also a switch in the proportion of mature and immature eggs recorded. From January to May the number of mature eggs was greater than the number of immature eggs, but from June to September the number of immature eggs was greater than the number of mature eggs (Figure 60).

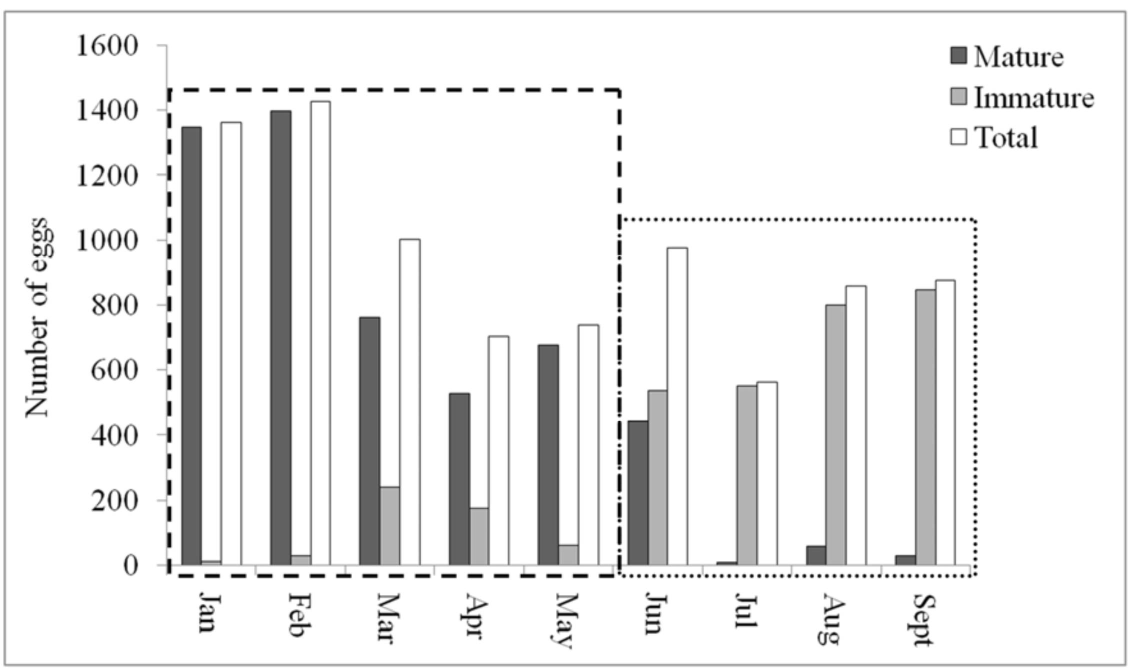

Figure 60 Number of mature and immature eggs found in dissected females from January to September 2013

The number of *M.anisoplae* infected male beetles released at Lakurumau fluctuated across the months throughout the year, but was considerably increased towards the back end of the year (Figure 61). This trend of increased release will be maintained in 2014.

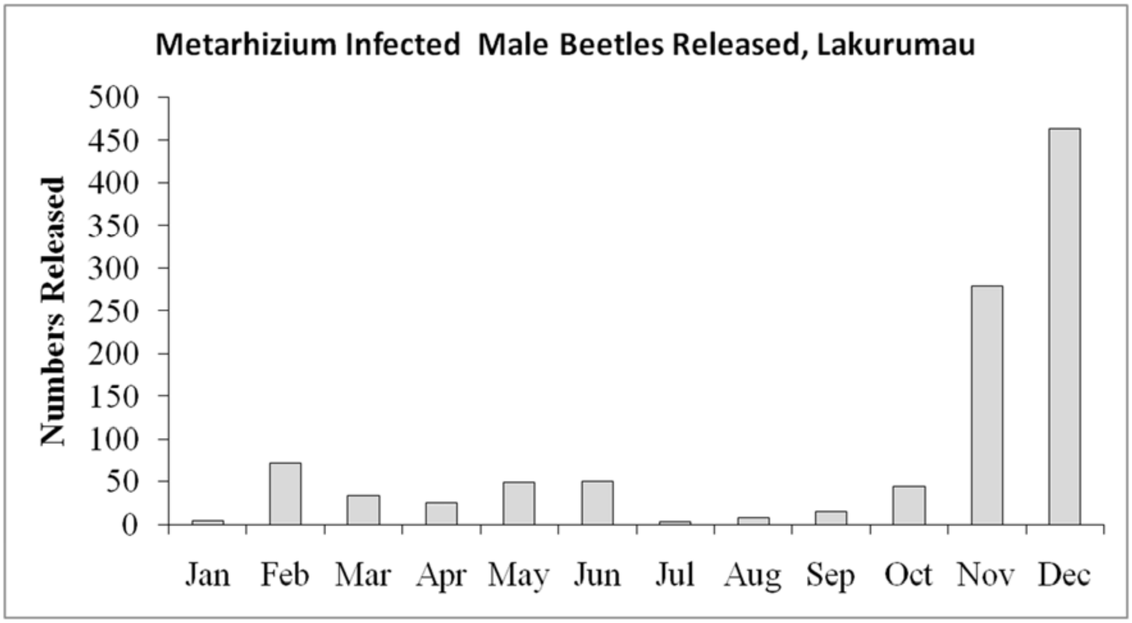

Figure 61 Number of *Metarhizium anisoplae* infected male *O.rhinoceros* beetles released at Lakurumau in 2013

The preliminary genome analysis results showed that the *O.rhinoceros* species from PNG is similar to the Pacific-Like genotype but not the Guam-Like genotype (Table 88). This result will be further confirmed through analysis of more specimens collected from different parts of the country.

The Polymerase Chain Reaction (PCR) results indicated that high percentages of beetles in PNG were infected with virus, and that the virus is present on beetles from both NI and WNB (Table 88). Further analysis will confirm the exact strain of the virus. The following abbreviations in the table stand for **COI** = Cytochrome Oxydase, **RFLP** = Amplified Fragment Length Polymorphism, **PCR**= Polumerase Chain Reaction, and **OrV**= Oryctes Virus.

Table 88 Preliminary results of the beetle genotype and the viral infection

Date	Location	Number received (n)	Number tested (n)	Guam like Oryctes (COI RFLP result)	PCR OrV+	% OrV+
Jan-13	Series A (Lakurumau)	10	10	0	3	30
Jan-13	Series B (?)	10	10	0	5	50
Jul-13	Kimbe	5	5	0	4	80
Jul-13	Lakurumau	28	9	0	7	78
Jul-13	Luburua	50	12	0	9	75
Jul-13	South Seas	13	9	0	7	78

Discussion and Conclusion

The drop in the number of beetles from Luburua Plantation is highly likely the result of the replant palms growing out of susceptible age as they are 2011 planting. A rapid palm census will be conducted in this plantation and, if no fresh damages are observed, the trapping will be terminated, but some palms that have recovered from damage will be marked and monitored for impact on production over the next 3-5 years once harvesting resumes. The number of beetles trapped from Lakurumau Plantation is still high and the palms are still at susceptible stage, as they are 2012 planting (Figure 58).The trapping will continue in 2014, but a more effective trapping programme will be devised particularly with respect to the positioning of the traps in the field as more replanting is expected in the province in the coming years. In these new replants, if beetle damages are still encountered (which is highly likely), pheromone trapping and release of *M.anisoplae* infected male beetles will still continue. Once the effective strain of virus is either identified locally or imported from overseas, it will be used to infect adult males and released in the fields to complement the pheromone trapping and fungus infection release programmes.

The egg load results indicate that pheromone trapping is disrupting the reproduction cycle of the beetles. The switch from having to find more mature eggs to more immature eggs in dissected females over the months of trapping (Figure 60) shows that more beetles are being trapped before the eggs mature to continue the reproduction cycle. It is not clear, how long it takes from fertilization to oviposition, but an individual female is able to survive for 4-9 months and produce approximately 50 eggs. Once the females were trapped and killed before the eggs were laid, the chances of the female beetles surviving the full expected life span (4-9 months) and laying the expected number of eggs (around 50 eggs) was disrupted thereby reducing the number of offspring produced.

The release of *M.anisoplae* infected males will continue in 2014, but an attempt will also be made to conduct post release surveys in areas where the fungus is released to assess the infectivity rate of the beetles. Some infected beetles will be retained in the laboratory to assess the progression of infection rate on the beetles.

The preliminary result from the PCR analysis is showing that the virus is commonly present in both NI and WNB infecting the beetles, but has not been virulent. Although, the virus strain is yet to be identified, there is a high possibility that the beetles have adapted to the virus, hence it is not killing them. The trapping will continue (with collection extended to East New Britain Province) for further gut analysis. If the analyses results from the later samples all show the same ineffective strain, arrangements will be made to import a more virulent foreign strain to introduce into NI to control *O.rhinoceros* infestation there.

Arthropod Survey Program for Stream Health Monitoring (Smallholder Agricultural Development Project- SADP)- (RSPO 4.4; 8.1)

Introduction

Work on the SADP Arthropod Survey Program for Stream Health monitoring began in 2012 with the hiring of an aquatic biology specialist. The project was undertaken with the goal of developing a means of effectively and expeditiously monitoring water quality in freshwater occurring within smallholder oil palm areas in West New Britain and Northern Provinces. The project began slowly due to logistical complications stemming from lack of required equipment, but began to gain momentum in June of 2012.

The Project occurred in three phases namely the research phase, the analysis phase and the dissemination/training phase. The research stage occurred during both 2012 and 2013 during which time streams were surveyed using techniques developed by the aquatic biology specialist for the Project. This phase involved the collection and subsequent enumeration of representative macroinvertebrate assemblages from streams in West New Britain and Northern Provinces displaying relatively pristine conditions as well as from streams showing obvious adverse signs of human impacts, especially with regard to habitat quality and availability. In addition to stream surveys, the research phase included the compilation and review of pertinent literature and taxonomic resources necessary for the identification of collected macroinvertebrates.

As described in the PNGOPRA Annual Report 2012 (PNGOPRA, 2012), the following assumptions guided Project activities through to the dissemination/training phase:

- That streams which are minimally impacted by human activities including oil palm production (that is, they are representative of '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 macroinvertebrate taxa present.
- That streams showing adverse conditions as a result of human activities will produce a higher proportion of macroinvertebrates which are relatively tolerant of poor water quality and in-stream habitat and that these streams will show less diversity with regard to macroinvertebrate taxa present.
- That variations in values of metrics of water quality in the above noted two conditions between streams will allow for development of meaningful criterion by which water quality at a given stream reach can be measured.

The analysis phase first focused on the identification of macroinvertebrates collected from research phase stream sites. Enumeration of specimens occurred from December 2012 through September 2013 when the final set of specimens collected during sampling in Northern Province were enumerated and tallied. Once all specimens were identified to at least the Family level (in all but a small number of groups which were identified to the level of Order), data were subjected to analysis using metrics of water quality based on macroinvertebrate assemblages.

The dissemination/training phase culminated in the development of the "*Protocols for the Rapid Assessment of West New Britain Province and Northern Province Streams using Aquatic Macroinvertebrates as Indicators of Stream Health"* (Kiely, 2014). This stand-alone document (electronic copies are available for distribution) provides a step-wise guide to the collection of aquatic macroinvertebrates from a stream site, their identification, and methods by which assemblages occurring in a given stream site can be used to draw inferences about water quality. In addition to the development of this document, the dissemination/training phase involved classroom and hands-on training concerning the background, development, and use of the protocols. These training sessions were offered to, and well attended by, selected industry personnel.

The primary focus of the present reporting is to describe the methods by which stream sites were selected for the research phase, the methods by which aquatic macroinvertebrates were collected at said stream sites, and the analyses and metrics employed to develop the set of protocols for use by Industry personnel to rapidly assess water quality. Results of analysis of data using aquatic macroinvertebrate metrics of water quality are also presented along with a discussion of overall findings and Project outcomes.

Materials and Methods

Site Selection

During the research phase, two types of stream reaches (or sections along a given stream's length) were sought for subsequent assessment of their macroinvertebrate assemblages using the standard operating procedures (SOP) developed for the Project. The first type of stream sites were classified as reference sites (RS), while the second type were classified as adversely impacted sites (AISS).

Reference conditions, as observed at RS, represented as closely as possible the natural state of a stream. In preparation of protocols for the assessment of water quality using macroinvertebrate assemblages or other variables, the natural condition of streams occurring within a landscape must be understood (Herbst, 2004)so that poor conditions resulting from alteration of the stream or surrounding landscape, especially the riparian or buffer zone, can be discerned. RS were chosen in both West New Britain and Northern Provinces based the following factors:

- Position in landscape: RS were to be as close as possible to areas that were not significantly impacted by human activities including oil palm production, based on observation of both in-stream and riparian conditions.
- Presence of riparian buffer: in all cases, the presence of a riparian buffer zone was considered a necessary component of reference site suitability. The ideal buffer vegetation was considered to be primary or secondary native forest.
- Presence of diversity within in-stream habit: because these sites will ultimately form the basis for the identification of 'healthy macroinvertebrate assemblages' in smallholder and company oil palm areas, they were chosen based on the availability of a variety of in-stream habitat types including riffles, runs, and pools. Additionally, the presence of non-embedded substrates, the amount of exposure (i.e. amount of shade to stream channel) and the presence of woody debris and vegetation (emergent and/or submerged) were also considered indicative of more natural conditions.
- The absence of significant human activity along the stream reach to be sampled (e.g. the absence of washing areas).
- Relative ease of access for sampling- sites had to be accessible both in terms of sampling and movement of sampling equipment to the sample reach.

AISS were selected for sampling of macroinvertebrate assemblages based on their observable dissimilarity to ideal or observed RS. Adversely impacted sites were chosen for a variety of reasons including their occurrence within landscapes altered by human activities such as logging, oil palm growing, or urbanization. Other factors leading to a site being designated an AISS include the presence of embedded substrates as a result of transport of soil into the stream from the surrounding landscape, the relative lack of in-stream habitat suitable for colonization by macroinvertebrates, and the absence of adequate natural buffers comprising primary or secondary forest. Plate 10 shows a typical reference site (i) and a typical adversely impacted site (ii) occurring within the same landscape.

Plate 10 Stream sites in West New Britain Province displaying (i) typical conditions of RS and (ii) typical of AISS

Certain selection criteria were enforced for the selection of both reference sites and adversely impacted sites. Specifically, all streams selected were no greater than 20 m in width, and none were influenced by ocean tides. The protocols developed through this project will direct users to refrain from surveying ponds, salt marshes, wetlands, and large rivers.

Stream Reach Sampling

SOPs were developed by the aquatic biology specialist for use during research phase stream surveys of RS and AISS. Stream reaches were a minimum of 100m in length and were selected such that their downstream terminus was at least 50m upstream of road crossings and bridges where constrictions of the stream channel were likely to affect stream flow.

Reaches were sampled using a multihabitat approach tailored to the Project, but derived from the general protocols described by (Barbour, Stribling, & Verdonschot, 2006). The method utilised involved first assessing the entire ~100m stream reach and identifying the proportion of various in-stream habitat types occurring along its length. Once assessed, sampling effort comprising 10 collections of macroinvertebrates using a 500 micron kick net was expended according to the proportion of each in-stream habitat type present. Thus, if suitable macro-invertebrate habit within the sample reach comprised 40% riffles, 30% runs, and 30% emergent vegetation the sampling effort per habitat type would be 40% (4 kick net samples), 30% (3 kick net samples), and 30% (3 kick net samples) respectively.

Plate 11 Kick net being used to collect macroinvertebrates clinging to a submerged root mass

The 10 kick net samples (Plate 11) taken from each stream length were combined and processed in the field. From each site surveyed using the above described technique collected macroinvertebrates were preserved in 70% ethanol and placed into a sealed plastic container until such time as they were returned to the laboratory for further processing and eventual identification and enumeration of constituent macroinvertebrate taxa.

In addition to the collection of macroinvertebrates, water quality tests were performed at each site using a Yellow Springs Industries (YSI) brand water quality monitoring device. Parameters measured in this fashion were temperature, dissolved oxygen, and pH. Stream habitat, riparian vegetation, average depth, average width, the composition of the substrata, and the weather conditions at the time of sampling were also recorded at each location. A minimum of two photos were taken at each sampled stream reach.

A total of 15 RS were sampled in West New Britain, while 7 RS were sampled in Northern Province. Nine (9) AISS were sampled in each Province.

Sample Processing

Macroinvertebrate samples collected in the field were further processed in the laboratory. Initial laboratory processing involved removing at random a minimum of 200 animals from each sample. Once removed, the animals were identified to the taxonomic level appropriate for each group. The Family level forms the basis of most SIGNAL II values (termed 'tolerance values' in certain literature), and was thus the level to which the majority of specimens were identified (Stark, Boothroyd, Harding, Maxted, & Scarsbrook, 2001). For certain groups including the chironmids (Diptera), atyids (Class Decapoda), sphaerids (Class Gastropoda) and scorpionflies (Order Mecoptera) the sub-family level, class level, class level, and ordinal level were used respectively. All taxa were tallied for each site and the data entered into spreadsheets for analysis.

Data Analysis

Macroinvertebrate assemblage data were analysed using a number of metrics of water quality based on criterion such as the mode of feeding employed by a given taxon, the overall taxa richness (total number of distinct groups) of a site, and a number of metrics based upon SIGNAL II scores. In addition, temperature, pH and dissolved oxygen values were analysed across sites.

SIGNAL II scores, derived through field and laboratory studies for taxa occurring throughout Australia, represent a given taxon's ability to endure environmental stressors including:

- Increased turbidity due to the introduction of soil into the aquatic environment
- Decreased dissolved oxygen such as occurs during the decomposition of algae following algal blooms
- Degraded and/or limited in-stream habitat
- Increased nutrient loads (in some cases leading to algal blooms)
- Fluctuations or persistent alteration of water temperature

SIGNAL scores range from 1 to 10 (Chessman, 2003). Taxa receiving a score of one have been shown to be highly tolerant of one or a combination of the adverse conditions listed above while taxa receiving a score of 10 have been shown to be highly intolerant of such conditions. Thus, the SIGNAL II system represents a gradient of tolerances from highly tolerant to highly intolerant.

Owing to the paucity of freshwater research and published literature pertaining to Papua New Guinea, tolerance values do not exist for taxa which may be unique to this country (especially with regard to genera and *species*). While some differences are to be expected, it is posited that application of Family level SIGNAL II scores to PNG taxa is possible owing its regional proximity to Australia (Boyero, Ramirez, Dudgeon, & Pearson, 2009). Thus SIGNAL II scores derived for Families occurring in Australia (note: all Families observed during this study are found in Australia) formed the basis for analysis using the following metrics:

- Percentage of intolerant taxa (within a sample from a given site)
- Percentage of tolerant taxa

Additional metrics were analysed including the percentage of specimens representing the Orders Ephemeroptera and Trichoptera (ET) and the overall taxa richness occurring within a given sample (stream reach).

Results

West New Britain Province

A total of 50 distinct taxa were observed across the RS surveyed in West New Britain Province while 37 taxa were observed across AISS. Figure 62 shows the percent composition of taxa observed in both RSs and in West New Britain.

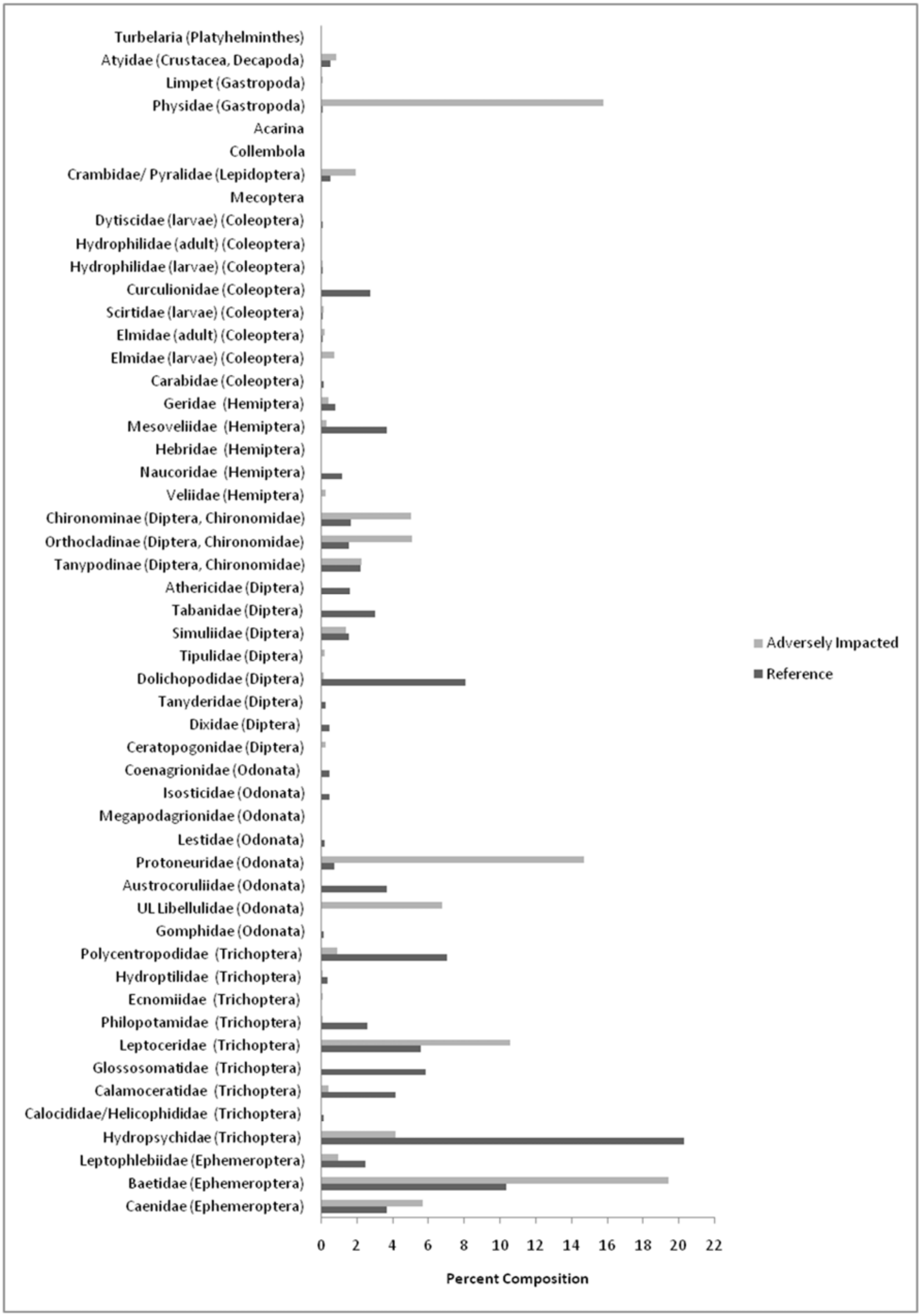

Figure 62 Percent composition of taxa observed in West New Britain RS and AISS

Comparison of macroinvertebrate metrics of water quality are presented in Table 89. Metrics showing the greatest observable difference in values between RS and AISS were those based on SIGNAL II values of relative tolerance to changes in water quality. Specifically, the average percentage of intolerant taxa was 52.28 for RS compared to 18.74 for AISS. For the purposes of the present study, relatively intolerant taxa were defined as those with SIGNAL II scores equal to or greater than 6.

Table 89 Summary of average values for aquatic macroinvertebrate based metrics of water quality for West New Britain Province RS and AISS

	N	% Intolerant (CV%)	% Tolerant (CV%)	% ET (CV%)	Taxa Richness (CV%)
RS	16	52.28 (35.67)	11.35 (54.81)	54.97 (30.82)	21.20 (21.99)
AISS	12	18.74 (74.40)	8.44 (34.27)	44.18 (53.20)	16.55 (27.70)

The average values for the percent tolerant metric, defined as the percentage of taxa with combined samples with SIGNAL II values equal to or less than 3 was slightly higher in RS (11.35%) versus AISS (8.44%). This result was unexpected, especially when compared to the average percent intolerant taxa values. However, the relatively low overall percentage of tolerant taxa in both RS and AISS was overshadowed by the presence of a high proportion of intolerant taxa in RS.

The average percentage of taxa representing the orders Ephemeroptera and Trichoptera (%ET on Table 89) was higher for RS (54.97%) than AISS (44.18%). These orders are accepted as being generally less tolerant of poor water quality, and are associated with relatively higher water quality in Australia, the United States, and Europe.

Taxa richness, or the overall diversity (distinct taxa) of macroinvertebrates at a site showed a greater average value in RS (N = 21.20) versus AISS (N = 16.56).

Table 90 summarizes the average dissolved oxygen level (DO mg/L), pH and temperature for West New Britain Province RS and AISS. Average DO was 7.43 and 6.66 for RS and AISS respectively. Average pH was 7.99 for RS and 7.34 for AISS. Average temperatures observed in RS were lower than those observed in AISS, with values of 25.86 and 26.62℃ respectively.

Table 90 Summary of average dissolved oxygen (DO mg/L), pH and temperature for West New Britain Province RS and AISS

	DO (CV%)	pH (CV%)	Temperature (CV%)
RS	7.43 (6.30)	7.99 (5.37)	25.86 (3.76)
AISS	6.66 (20.26)	7.34 (5.64)	26.62 (3.94)

Northern Province

A total of 40 distinct taxa were observed across the RS surveyed in Northern Province while 38 taxa were observed across AISS. Figure 63 (following page) shows the percent composition of taxa observed in both West New Britain RS and AISS.

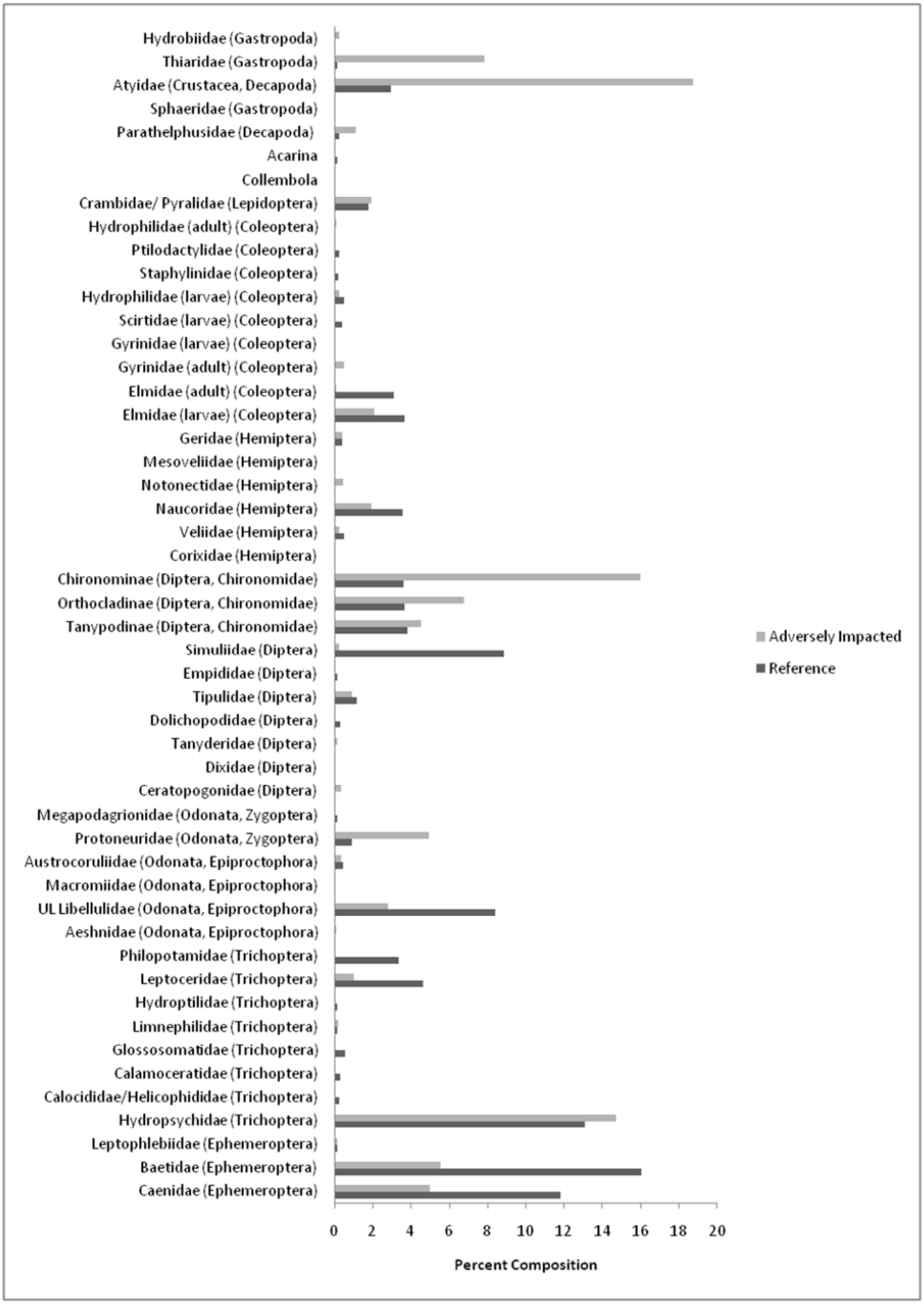

Figure 63 Percent composition of taxa observed in Northern Province RS and AISS

Comparison of macroinvertebrate metrics of water quality are presented in Table 91. The percentage of members of the Families Ephemeroptera and Trichoptera was markedly higher in RS compared to AISS with values of 55.14% and 25.49% respectively. The values for percent tolerant taxa more closely followed the expected pattern than did those for West New Britain sites. Specifically, the percentage of tolerant taxa was higher in AISS (22.12%) than for RS (10.32%). Conversely, the percentage intolerant taxa was higher in RS (32.85%) displaying more natural conditions than for sites which showed obvious signs of adverse impacts from human activity (17.61%). The taxa richness values for RS and AISS were 19.43 and 18.22 total taxa respectively.

Table 91 Summary of average values for aquatic macroinvertebrate based metrics of water quality for Northern Province RS and AISS

	N	% ET (CV%)	% Intolerant (CV%)	% Tolerant (CV%)	Taxa Richness (CV%)
RS	7	55.14 (21.89)	32.85 (20.98)	10.32 (48.36)	19.43 (18.52)
AISS	9	25.49 (53.97)	17.61 (78.74)	22.12 (56.49)	18.22 (18.36)

Table 92 summarizes the average dissolved oxygen level (DO mg/L), pH and temperature for Northern Province RS and AISS. Average DO was 6.91 and 6.65 mg/L for RS and AISS respectively. Average pH was 8.59 for RS and 7.36 for AISS. Average temperatures observed in RS were lower than those observed in AISS, with values of 26.32 and 26.56℃ respectively.

Table 92 Summary of average dissolved oxygen (DO mg/L), ph and temperature for Northern Province RS and AISS

	DO (CV %)	pH (CV%)	Temperature (CV%)
RS	6.91 (14.56)	8.59 (3.63)	26.32 (5.54)
AISS	6.65 (32.74)	7.36 (3.49)	26.56 (5.47)

Discussion and Conclusions

The SADP Arthropod Survey Program for Stream Health Monitoring constitutes the second major assessment of aquatic macroinvertebrate assemblages in West New Britain and Northern Province freshwater streams. The first, undertaken by Douglas Environmental, surveyed 38 stream sites between the two Provinces, and presented their data in a report published in 2007 (Douglas Environmental Services, 2007). The assemblages collected and analyzed under the latter project, unlike the former, did not utilize SIGNAL II tolerance values. Thus, the SADP Arthropod Survey Program for Stream Health Monitoring is the first known application of tolerance values to macroinvertebrate assemblages in West New Britain and Northern Provinces, and, at the time of producing the present report, the first reported such endeavor in Papua New Guinea.

The guiding assumptions of the project, especially with regard to the establishment of reference conditions, were for the most part, confirmed through analysis of macroinvertebrate assemblages and application of metrics. On average, streams selected as RS in both West New Britain and Northern Provinces showed a higher percentage of relatively intolerant taxa than did AISS in each Province. This phenomenon was more pronounced in West New Britain Province (percent intolerant was 52.28 and 18.74 for RS and AISS respectively), but was still observable in Northern Province (percent intolerant was 32.85 and 17.61 for RS and AISS respectively).

The percentage of tolerant macroinvertebrates was lower for both RS and AISS sites in both Provinces. The percent tolerant metric did not align with what was expected at the beginning of the project in West New Britain Province. Specifically, the combined RS showed a higher percentage of tolerant macroinvertebrates (11.35%) than did AISS (8.44%). Such a result is not unusual when one considers that tolerant organisms are able to thrive in high quality aquatic environments, while the opposite condition is not true. That is, intolerant organisms are limited by water quality and/or habitat availability in low quality aquatic environments.

The percentage of taxa in the Orders Ephemeroptera and Trichoptera also showed a marked difference between RS and AISS, especially in Northern Province. This metric was found to have values of 54.97% and 44.18% for West New Britain Province RS and AISS respectively. In Northern Province, these values were 55.14% and 25.49% for RS and AISS respectively. These orders and generally intolerant of poor water quality and would be expected to occur in greater abundance in RS with relatively good water quality and in-stream habitat.

Both RS and AISS in both West New Britain and Northern Provinces possessed, on average, a relatively high number of taxa with the AISS surveyed in West New Britain displaying the lowest value of 16.56 distinct taxa. The most diverse macroinvertebrate communities occurred in West New Britain Province RS where the average taxa richness was 21.20 distinct groups.

The end user protocols developed through this project directs users to base assessments of water quality on four metrics namely, percent intolerant taxa, percent tolerant, percent Ephemeroptera and Plecoptera (ET) and taxa richness. The interpretation of each metric is described below:

- Percent Ephemeroptera and Trichoptera (ET): ET values will be higher in streams showing good to excellent water quality. Based upon the reference streams and streams showing obvious signs of disturbance surveyed during the research phase, values and cut-off points which follow were identified as a means of grading stream health. Values greater than 50% indicate very good to excellent water quality. Values falling between 20% and 49% indicate an aquatic environment that has moderate to good water quality. Values falling between 0% and 19% indicate that some type of disturbance is likely to be present within the sample reach (Table 93).

Table 93 Interpretation of the ET metric

0% - 19%	20%- 49%	>50%
Disturbance Likely; Potentially Poor Water Quality and/or Habitat	Moderate to Good Water Quality	Excellent Water Quality

- Percent Tolerant: Percent Tolerant values will increase as streams become more impaired. Values greater than 20% indicate streams be moderately to severely impaired. This metric is most indicative of overall water quality when compared with the Percent Intolerant metric. When streams show a higher percentage of tolerant macroinvertebrates relative to those that are intolerant some type of disturbance is present. Values observed in streams surveyed in preparation on the present protocols were highest in streams showing obviously degraded habitat and overall poor in-stream conditions. These streams, primarily located in Northern Province had percent tolerant values exceeding 20%. Streams surveyed with percent tolerant values between 15% and 20% are likely experiencing some type of disturbance which should be elucidated through further investigation.

- Percent Intolerant: Values for this metric are expected to be higher in sites showing good to excellent water quality versus those showing obvious or potentially degraded water quality and/or in-stream habitats. West New Britain RS, which displayed the highest quality stream conditions, specifically the presence of multiple in-stream habitat types, especially riffles as well as extensive buffer/riparian zones of native forest showed an average percent tolerant value of over 50%. Streams which are experiencing disturbance will often show a much higher percentage of tolerant versus intolerant macroinvertebrates. Interpretation of this metric should be based upon the categories delineated in **Table 94**.

Table 94 Guide to the interpretation of the percent intolerant metric

0% - 10%	11%- 20%	30%- 50%	>51%
Disturbance Likely; Potentially Poor Water Quality and/or Habitat	Moderately Poor Conditions	Moderately Good to Good Water Quality	Excellent Water Quality

- Taxa Richness (total number of distinct groups observed- Families, Orders in the case of Mecoptera, and Classes in the case of Acarina): In general, healthier streams will contain a greater number of quality in-stream habitat types, and thus will support a greater diversity of macroinvertebrates. This metric should always be considered with respect to the ET, percent tolerant, and percent intolerant metrics. Sites showing a diverse macroinvertebrate community (i.e. higher taxa richness) will often show values for these metrics in the ranges indicative of good to excellent water quality.

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DONOR FUNDED PROJECTS

There were no donor funded project reports compiled during the year. The report on the short unfunded extension to the joint Entomology-Pathology ACIAR funded Bogia Syndrome (BCS) is provided under Plant Pathology (Dr Carmel Pilotti). The *Oryctes rhinoceros* management project in collaboration with AgResearch New Zealand (NZ) and the Secretariat of the Pacific Community (SPC) resumed during the year but will not conclude until end of 2015. Progressive results from the project are provided under applied research.

PUBLICATIONS

Ero M.M, Manjobie T. and **Dewhurst C.F.** (2013). Oil Palm Foliage Damage by *Segestes decoratus* Redtenbacher (Orthoptera: Tettigoniidae: Mecopodinae) in West New Britain, Papua New Guinea. *The Planter, Kula Lumpur***, 89**(1048): 481-490.

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Woruba, D.N., Priest, M.J., **Dewhurst, C.F.**, Gitau, C.W., Fletcher, M.J., Nicol, H.I. and Gurr, G.M. (2013).Entomopathogenic Fungi of the Oil Palm Pest, *Zophiuma butawengi* (Fulgoromorpha: Lophopidae) and the Potential for Use as Biological Control Agents. *Austral Entomology*, DOI.

OTHER ACTIVITIES

Training, Field Days and Radio Talks- (RSPO 1.1, 4.8, 8.1)

In-house and external training for staff remains an integral part of the Entomology Section, and is an ongoing activity. Each year staff are selected according to training needs and sent to attend the training whenever opportunities arise. A number of trainings (5) were attended by staff from the section last year (Table 95). Tabitha Manjobie's MPhil studies at Unitech started in 2013 and she is expected to complete the study in 2014.

Apart from the trainings that the section staff receives, the section also provides trainings on pests to member companies (NBPOL, HOPL) and smallholder growers (growers as well as OPIC staff). We also are involved in field days and radio talks organized by OPIC. There are about 20 different trainings, and radio programmes that the section provided (Table 95). Unfortunately, no field days were organized by OPIC in 2013.

Table 95 Number of trainings attended and provided by Entomology Section in 2013

Date	Division/Department	Event/target	Conducted	Received by	Area/Location	Comment
01/01/13	OPRA	MPhil		TM	Unitech	Begin 2013 ends 2014
08/01/13	NBPOL	Male Inflorescence Census	SS		Lolokoru	Follow up
06/02/13	NBPOL	Male Inflorescence Census	SS		Lolokoru	Follow up
11/02/13	Hargy	Male Inflorescence Census	SS		Barema	First training
12/02/13	Hargy	Male Inflorescence Census	SS		Barema	Continued
20/02/13	OPRA	First Aid		SS	Mosa	
21/02/13	OPRA	First Aid		SS	Mosa	
08/03/13	NBPOL	Male Inflorescence Census	SS		Lolokoru	Follow up
23-27/01/13	OPRA	Dissection & Sampling	TJ (AgResearch, NZ)	SS, EK	Poliamba	Oryctes beetles
29/02/13	OPRA	First Aid		SS	Mosa	
19/08/13	OPRA	Pest ID & reporting	SS		Nahavio	Hoskins Project Infill Growers
20/08/13	OPIC	Pest ID & reporting	SM		Nahavio	Hoskins Project Infill Growers
28/05/13	OPIC	Water hyacinth	SS, SM		Radio WNB	Radio programme
08/02/13	OPIC	Pest ID & Monitoring	CD, SM		Dami	Talasea Division
21/08/13	NBPOL	OPM Training	SB	SS	Dami	Brief into use of OMP
13/08/13	OPRA	Refresher training	SS, ME	SN	Bialla	Pest Infestation Visits and reporting
01/03/13	OPIC	Pest Monitoring& Reporting	SS, SM, CD			All Divisions
10/02/13	SHA, NBPOL	Use of TTIDR	SS	EM	Bebere	Brief run through of use of TTIDR
05-06/08/13	NBPOL Bebere	Use of TTIDR	SS	AU, TU	Lolokoru	Detailed run through on treatment forms
05-06/08/13	NBPOL Bebere	Sexavae collection training	SS	AU, TU	Lolokoru	Adults and eggs
21/08/13	OPRA	Dissection & Sampling	SS	RD	Dami	Oryctes beetles
24/08/13	SDA	General presentation on insects	ME	SDA Church Adventurers	Wandoro SDA Church Camp Grounds	
17/10/13	NBPOL Mosa Group	P& D Monitoring & Reporting	ME, SS, LK	Mosa group	Dami	Joint training by Entomology & Pathology
31/10/13	NBPOL Malilimi Group	P&DMonitoring & Reporting	ME, SS, LK, SM	Malilimi group	Malilimi	Joint training by Entomology & Pathology
23/10/13	NBPOL Mosa Group	P&DMonitoring & Reporting	ME, SS, LK	Mosa group	Dami	Joint training by Entomology & Pathology
05/11/13	Poliamba Radio Program	New Ireland Growers	RD	NI listeners	Kavieng	Pest Monitoring & Reporting

AU= Alex Umbina, CD= Charles Dewhurst, EK = Erwin Kea, EM= Esther Muta, LK= Lazarus Kewaka, ME= Mark Ero, RD=Richard Dikrey, SB= Severina Betitis, SM= Simon Makai, SN= Seno Nyaure, SS= Solomon Sar, TM= Tabitha Manjobie, TU= Tobias Uva, TJ = Trevor Jackson.

OPIC Pest and Disease Meeting- (RSPO 8.1)

The OPIC pest and disease meeting at Nahavio continued throughout the year. Both OPIC DMs and Smallholder Affairs Department (NBPOL) representatives attended the meeting throughout the year. From PNGOPRA, it was attended by Head of Entomology and Plant Pathology Field Officer. The discussions during the meetings resulted in vigilant monitoring and reporting of pests for timely damage assessment and treatment application where necessary.

International Conference Attendance

No international conferences were attended by staff from the section during the year.

Student Training

No long-term (6 months) training was provided for students at the main Entomology lab in Dami, however, 2 students from Moramora Technical School had a 3 week short-term exposure training with the Entomology Section at Hargy PNGOPRA Sub-Centre, Bialla.

IPM Working Group Meeting with Hargy Oil Palms Ltd (HOPL)- (RSPO 8.1)

No IPM Working Group Meeting was held during 2013, although email correspondences were exchanged to get the group up and running during the year.

Visitors to Entomology Section (Dami Head Office) in 2013

A total of 67 visitors pass through the Entomology Laboratory at Dami during 2013. The visitors were from various organizations within the country as well as abroad, and the organizations from which they came from are listed below.

ACIAR
AgResearch, NZ
CSIRO
James Cook University
Hargy Oil Palms Ltd
Kimbe International School
Liamo Resort
LJMU
NBPOL
OPIC, Popondetta Project
OPIC, Hoskins Project
OPIC, Popondetta Project
Papua Mining
PNGOPRA, Higaturu
Rea Kaltim
SADP Project
Serene Developments Ltd
Sumitomo Chemicals, Australia

Entomology Staff Strength in 2013

The Entomology team comprised 11 staff in 2013. These included 3 executives (including the Head of Section), 3 Technical Supervisors and 5 Recorders.

3. PLANT PATHOLOGY SECTION

HEAD OF SECTION III: DR CARMEL A. PILOTTI
Emmanuel Gorea, Lazarus Kewaka, Agnieszka Mudge, Derick Rama

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. All data has been corrected except where indicated and only infections for 2013 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 higher than in 2012 for most Divisions in 2013 (Figure 64). The mean for plantation was 1.6% and most Divisions had disease incidences below this level. Exceptions were Bomata (3.76%), Giligili (2.1%), Maiwara (6.9%), Salima (2.4%) and Tamonau (3.9%) Divisions. The number of suspect palms recorded continues to exceed the number of palms confirmed with Ganoderma by the presence of brackets (data not shown).

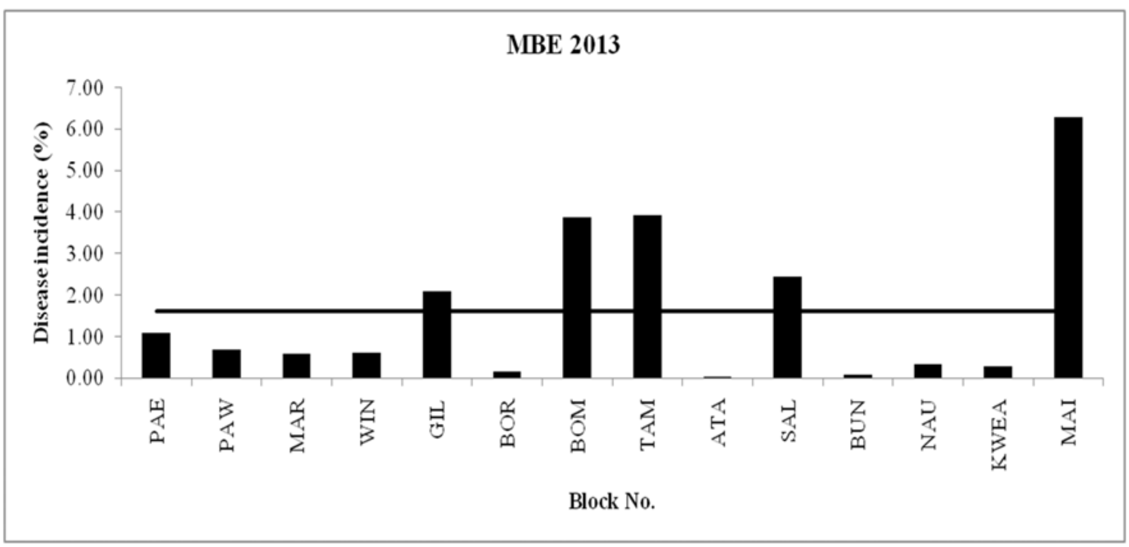

Figure 64 Disease incidence (Ganoderma) in Milne Bay Estates plantations in 2013. Unaudited data supplied by MBE. Horizontal line is the mean for the plantation (n=260)

Disease incidence within each of the Divisions was variable. Replanted blocks at Kwea had disease incidences ranging from 0.070 to 0.095% with palms with Ganoderma brackets already being identified in two fields (Figure 65). Palms in Kwea were planted in 2007, 2008 and 2009.
Bunebune blocks replanted in 2010 recorded higher disease incidences than Kwea replants in 2013 with a range from 0.02 to 0.25% when suspect palms were included in the data (Figure 66). At Maiwara, disease incidence ranged from 0.4-0.7% in 2005, 2006, 2007 and 2008 replants (Figure 67).

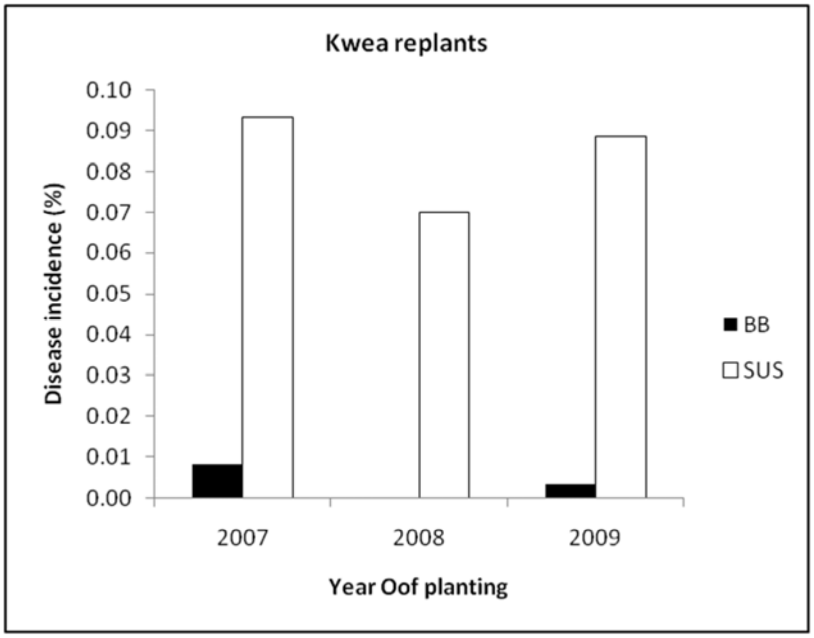

Figure 65 Disease incidence for replanted blocks in Kwea in 2013. BB= confirmed Ganoderma; SUS=suspected Ganoderma

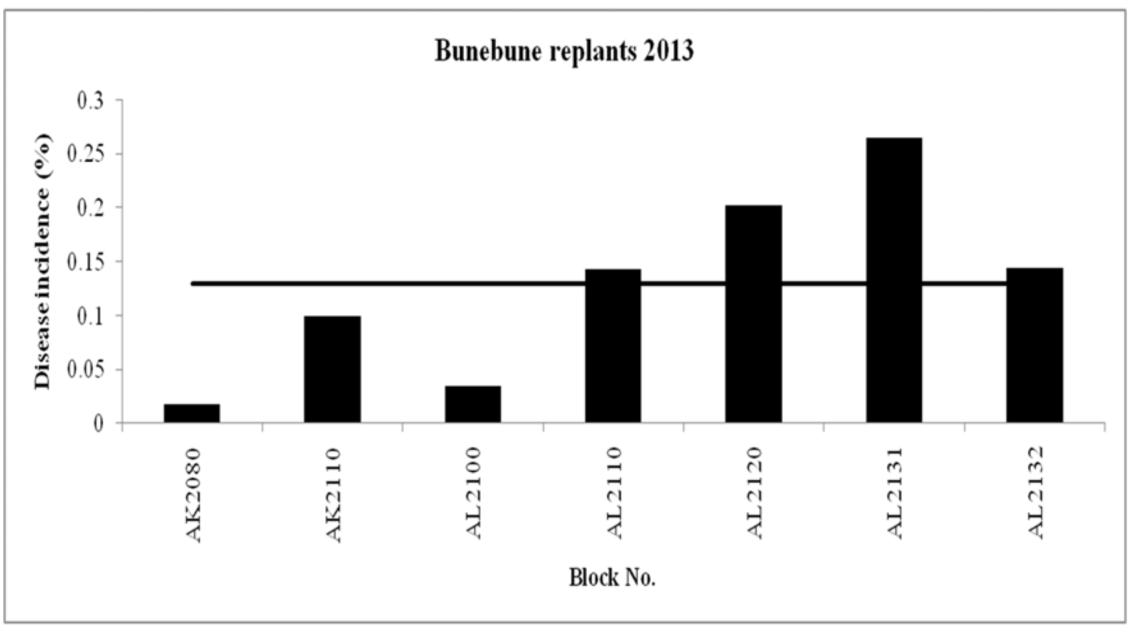

Figure 66 Disease incidence (Ganoderma) for 2010 Bunebune replants in 2013. The horizontal line is the mean for the blocks shown

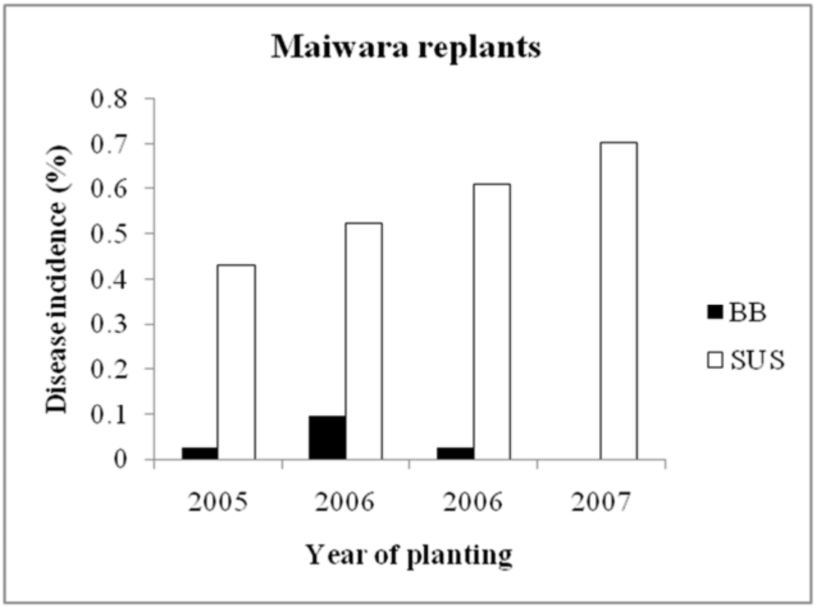

Figure 67 Disease incidence (Ganoderma) for replanted blocks at Maiwara in 2013. BB=confirmed Ganoderma; SUS=suspected Ganoderma

VOP Ganoderma surveys – Milne Bay

Disease surveys were completed for VOP blocks in 2013. An updated list of blocks surveyed and their mapping status is also presented in Table 96. A small percentage of blocks were inaccessible and therefore were not surveyed. Isometric maps were completed for all the surveyed blocks in 2013. These maps are in the process of being digitized so that new infections in replants can be followed.

Table 96 Status of *Ganoderma* surveys and mapping in VOP blocks in Milne Bay Province at the end of 2013.

Area	Total blocks	Total GPS	Status	Disease maps (manual)	Inaccessible blocks
Rabe	35	34		33	2
Waema	46	43		41	5
Leasehold	6	6	completed	6	0
Yaneyanene	46	0		46	0
Gabugabuna	34	6		31	3
Laviam	37	37	completed	37	0
Lautewatewa	24	24	completed	24	0
Kerakera	23	9		22	1
Delama	19	15		19	0
Diudiu	11	11	completed	11	0
Lauhaba	23	23	completed	23	0
Naura	40	40	completed	37	3
Kapurika	25	25	completed	25	0
Marayanene	23	9		22	1
Gumini	28	8		25	3
Kilakilana	30	0		23	7
Ata'ata	37	6		34	3
Iwame/Dayoge	24	16		23	1
Wella/Bwauna	10	0		10	0
Mila	36	0		34	2
Tamonau	38	11		35	3
Siasiada	54	0		46	8
Ipouli	42	0		40	2
Figo	30	24		23	7
Borowai	71	21		43	28

Poliamba Ltd.

Mean disease incidence at Poliamba was 0.97% in 2013 (Figure 68). All estates recorded below average disease incidence except for Noatsi Estate where disease incidence (2.2%) was more than double the plantation mean. Means for the other estates were Kara (0.53%), West Coast (0.59%), Nalik East (0.90%) and Madak (0.69%).

Disease survey data for Kara Estate is shown in Figure 69. The mean for this estate was 0.53% and 17 (out of 25) blocks recorded above average disease levels. Block AA0010 warrants further scrutiny as the disease level in this block (2.3%) is well above the mean.

Blocks within Nalik East Estate also showed a large variation with the highest incidence being recorded in Block AB0570 (6.7%) (Figure 70). Several other blocks in this estate recorded above average levels of infection but these are generally below or on par with the plantation mean.

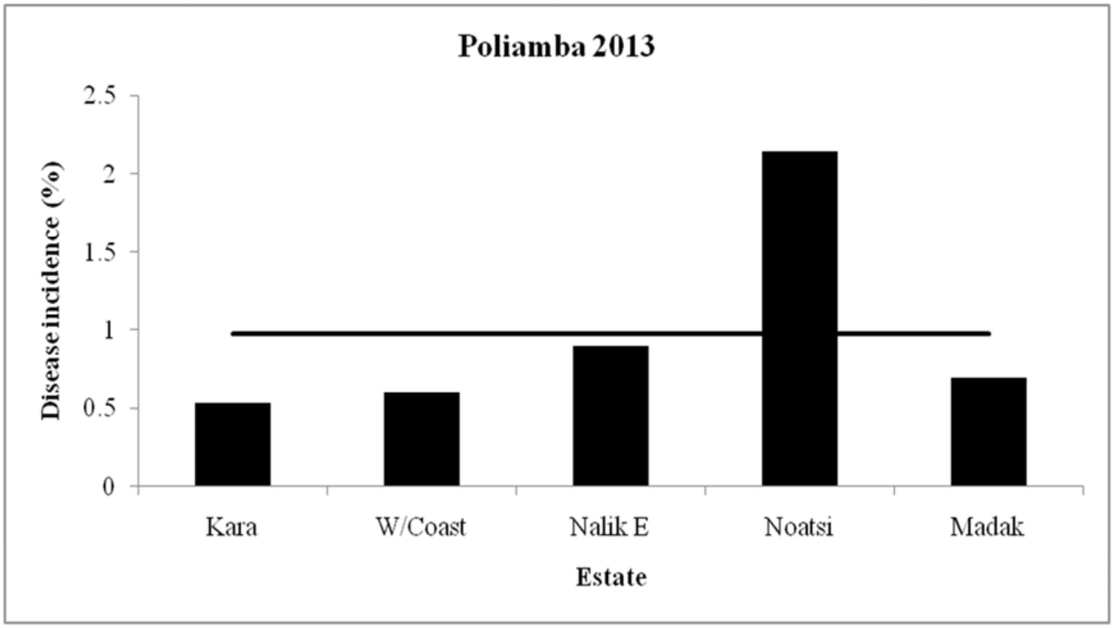

Figure 68 Disease incidences (total *Ganoderma*) for each Estate at Poliamba Ltd. in 2013. The mean for the plantation is shown by the horizontal line (n=169)

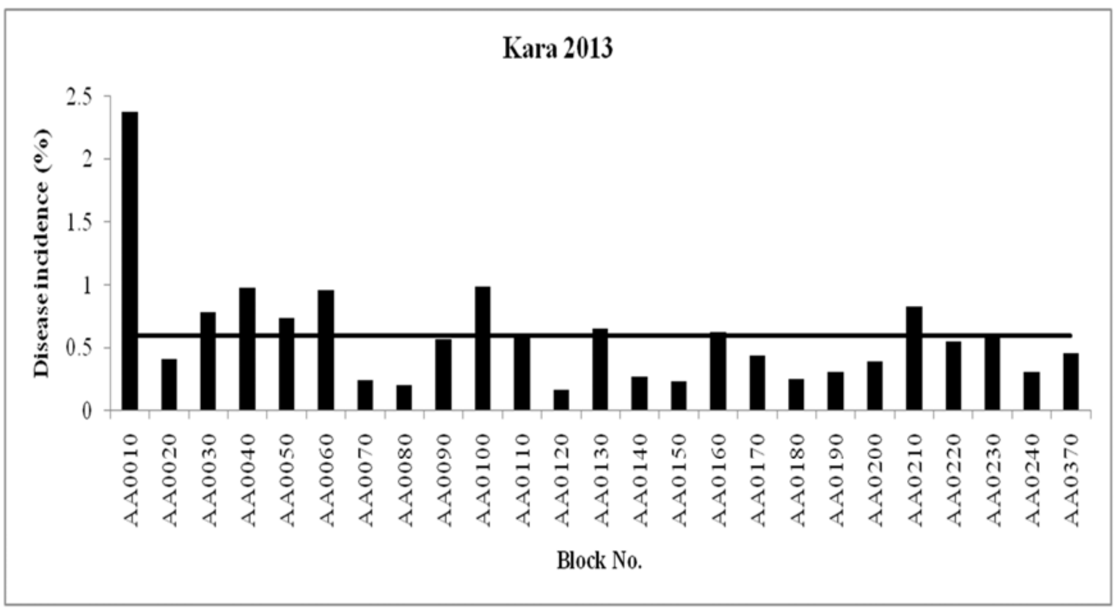

Figure 69 *Ganoderma* disease incidences for blocks within Kara Estate, Poliamba Ltd. in 2013. The horizontal line is the mean for all blocks surveyed in this Estate

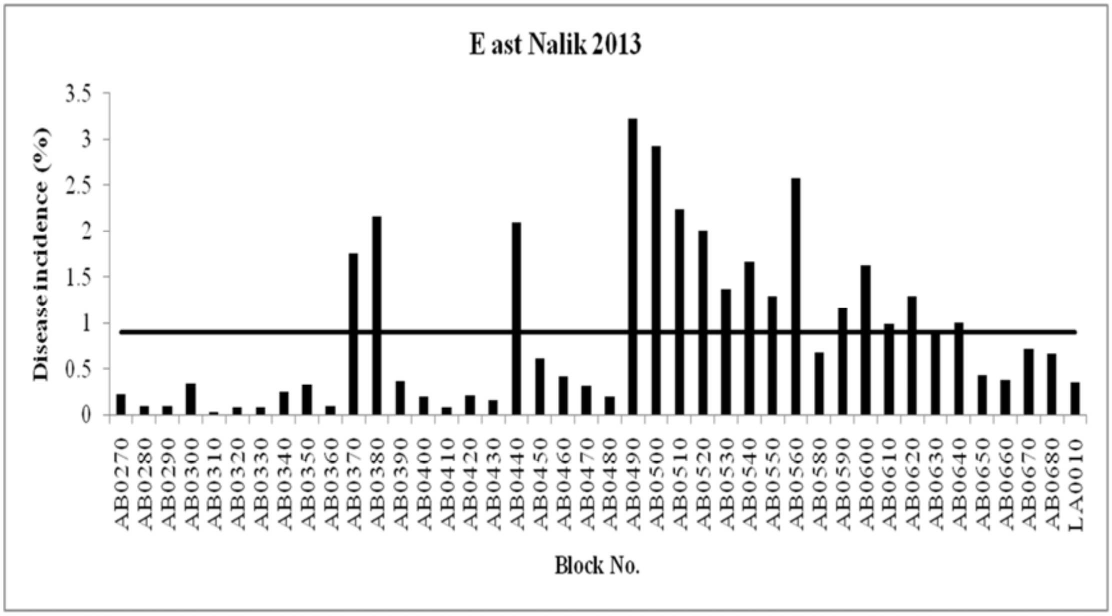

Figure 70 *Ganoderma* disease incidences for blocks due for replant in 2013/14 in Nalik East Estate, Poliamba Ltd. in 2013. The horizontal line is the mean for all blocks in this Estate

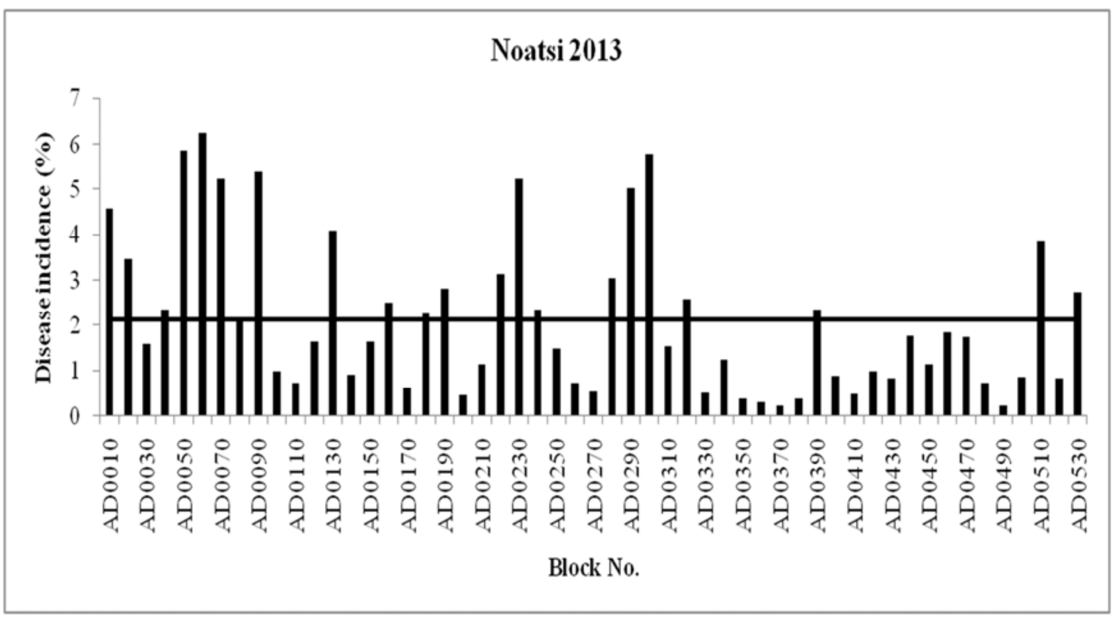

Figure 71 *Ganoderma* disease incidences for blocks in Noatsi Estate, Poliamba Ltd. in 2013. The horizontal line is the mean for all blocks in this Estate

Blocks within Noatsi Estate continue to record high levels of Ganoderma infection in 2013 (Figure 71). The mean for this estate was 2.2% and 22 blocks (out of 43) recorded higher than average infection levels. The mean for Noatsi blocks was more than twice the plantation average. Most of these blocks are older plantings that were supposed to be replanted in 2014 or 2015. Sanitation rounds within these blocks were not completed in 2013 (data not shown) and this may have a bearing on the infection levels in the blocks when they are replanted.

Madak Estate has the youngest plantings in Poliamba (oldest planting date 1996) and disease levels in this Estate are generally lower than the other estates and lower than the mean for the plantation

(Figure 72). Despite this 17 blocks recorded above average levels of Ganoderma and several blocks (LE0020, AE0210 and AE0eight0) had comparable incidences to blocks in other estates.
The majority of blocks on the west coast recorded lower than the mean disease incidence (0.72%) and eight blocks recorded higher than average levels of disease (Figure 73). Two of these recorded above 2.5% Ganoderma incidence and these were the older (1997) plantings.

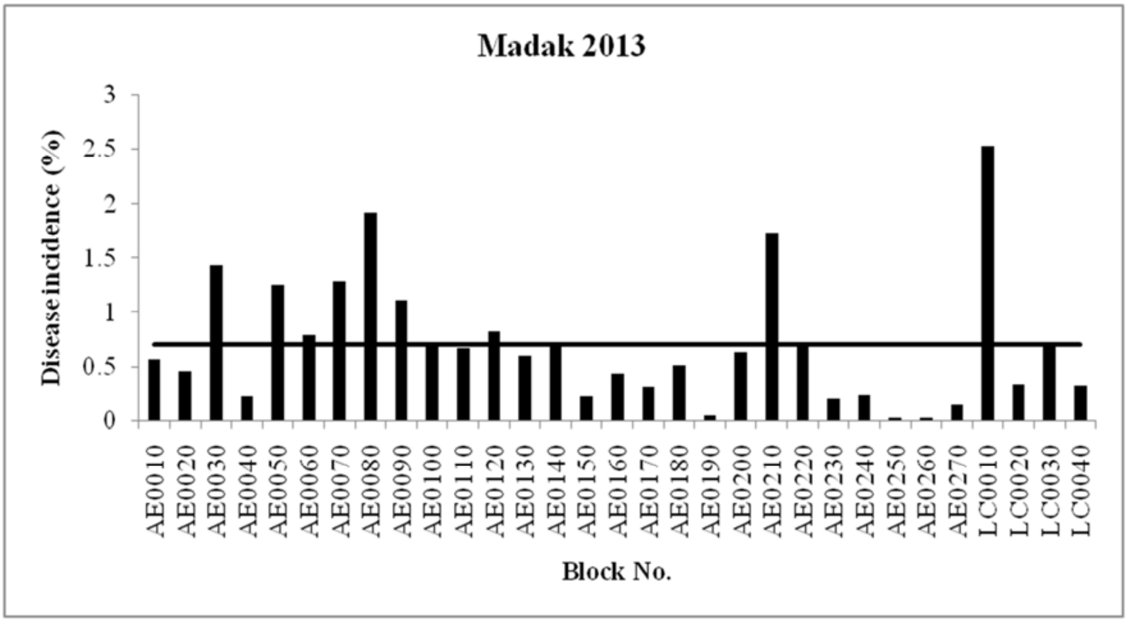

Figure 72 *Ganoderma* disease incidence recorded for blocks in Madak Estate, Poliamba Ltd. in 2013. The horizontal line is the mean for all blocks in this Estate

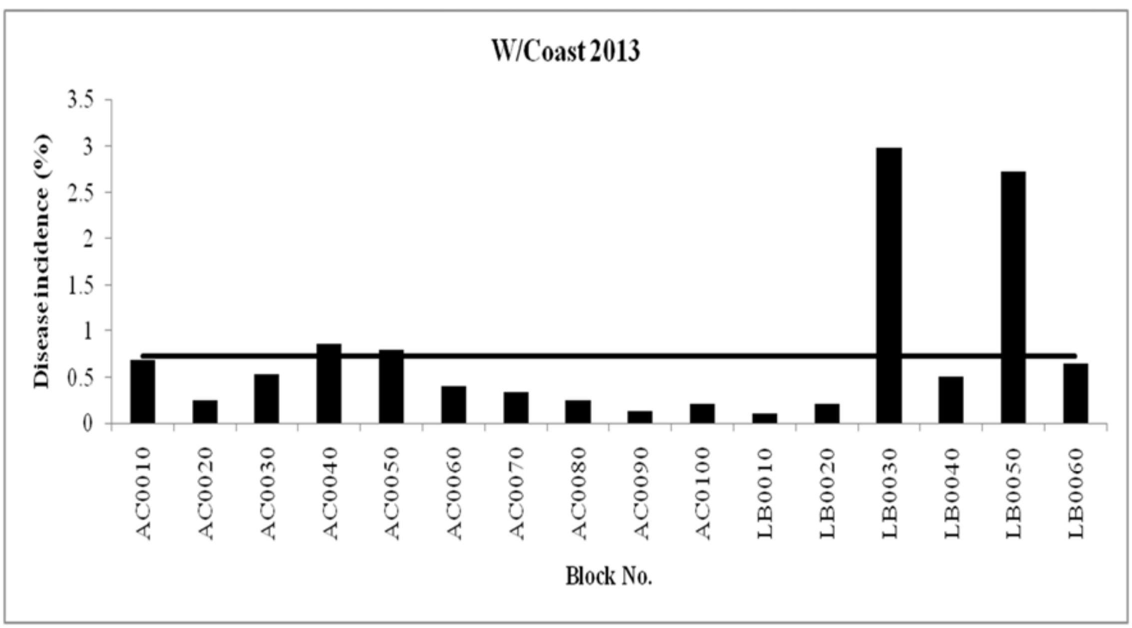

Figure 73 *Ganoderma* disease incidence recorded for blocks in Nalik West Estate, Poliamba Ltd. in 2013. The horizontal line is the mean for all blocks in this Estate

Higaturu OP Ltd.

The mean disease incidence for Higaturu Estate in 2013 was 0.33% (Figure 74). Sumberipa Estate recorded twice the average infection levels whilst the other three Estates were below the average for the plantation. Embi recorded the lowest levels of disease in 2013.
Disease data for individual Estates are shown in Figures 14-17. Blocks at Embi are shown by planting date and all ages of palms had infection levels below the average for the plantation with the 1999 and 2000 plantings recoding higher than the mean for this estate of 0.23% (Figure 75).

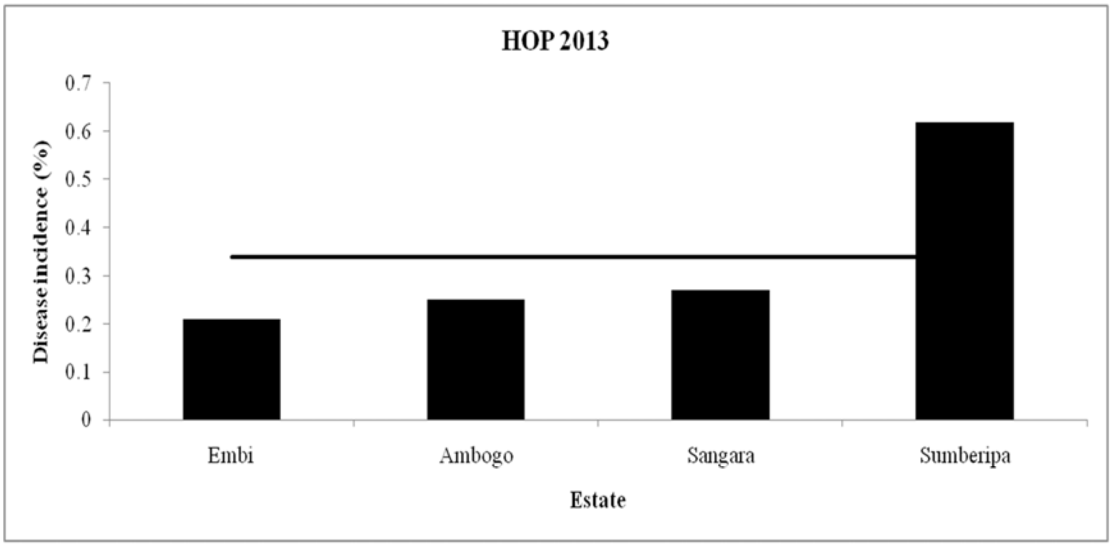

Figure 74 Mean *Ganoderma* disease incidence recorded for each Estate at Higaturu OP Ltd., 2013. Data supplied by TSD Section (unaudited). Higaturu OP Ltd. Horizontal line = plantation mean. n=174

The mean disease incidence for Ambogo was 0.23%, slightly below the plantation mean (Figure 76). Blocks planted in 1990 had the lowest incidence of Ganoderma (0.29%) and 2001 and 2002 plantings also had comparable disease levels (0.26%). The lowest disease levels of 0.19% were obtained for the oldest (1990) plantings at Ambogo.

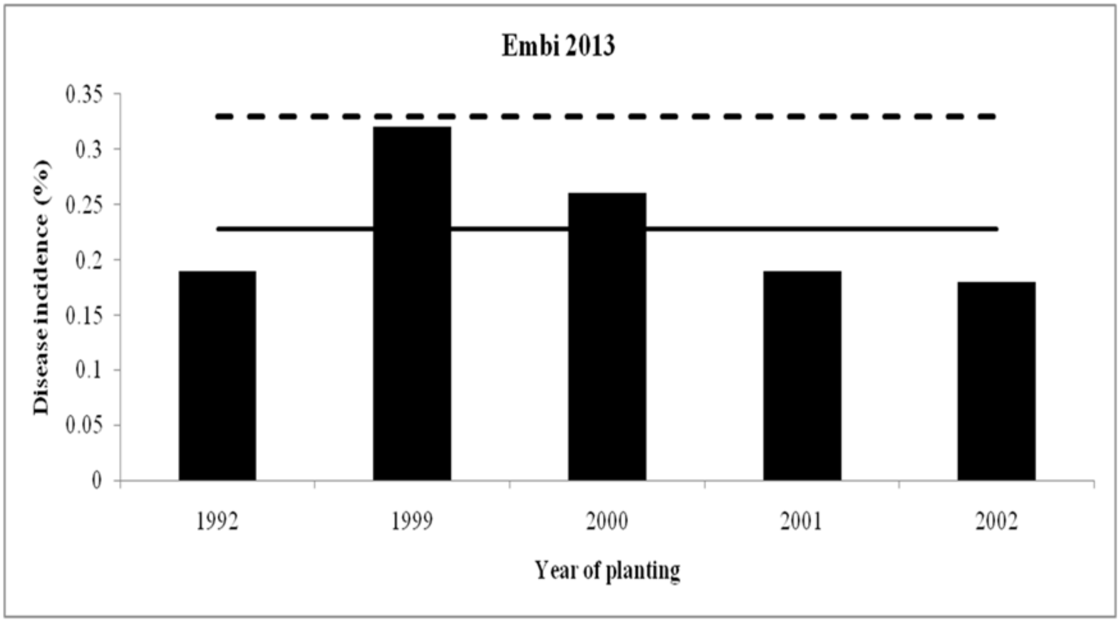

Figure 75 *Ganoderma* disease incidences for surveyed blocks at Embi Estate, Higaturu OP Ltd. in 2013. Data supplied by TSD Section. Higaturu OP Ltd. YOP = year of planting. The dashed line is the mean for the plantation (n=175) and the solid line is the mean for this Estate (n=40). Unaudited data

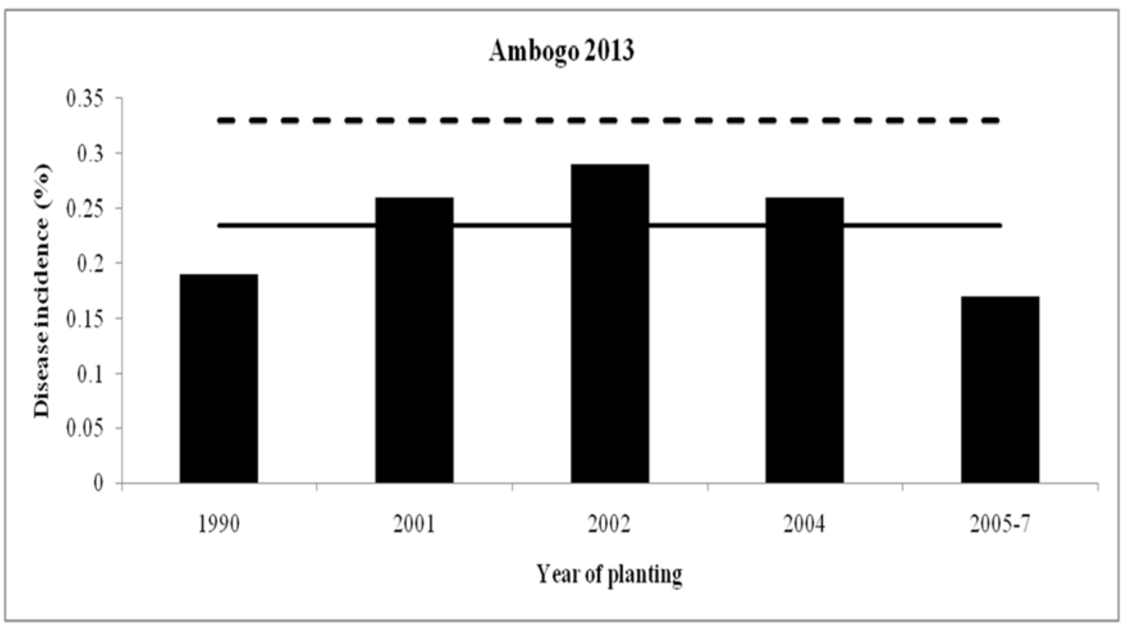

Figure 76 *Ganoderma* disease incidences for Ambogo Estate, Higaturu OP Ltd. in 2013. YOP = year of planting. The dashed line is the mean for all blocks (n=175) and the solid line is the mean for this Estate (n=45). Unaudited data

Ganoderma incidence in Sangara Estate was close to the mean for the plantation (0.27) in 2013 (Figure 77). The oldest plantings (1996) had the highest disease incidence (0.32%). The youngest plantings (2002) plantings had a disease incidence of 0.3% which is probably not significantly different. All ages of palms in this Estate recorded disease levels below the plantation mean for 2013.
Sumberipa estate continues to show elevated levels of disease in 2013 (Figure 78). Mean incidence for this estate was higher than the plantation mean at 0.59%. Blocks containing 2000, 2004 and 2005

plantings were well above the Estate mean and exceeded the plantation mean by almost 3 times. Palms planted in 2001 and 2002 also recorded disease incidences above the plantation mean

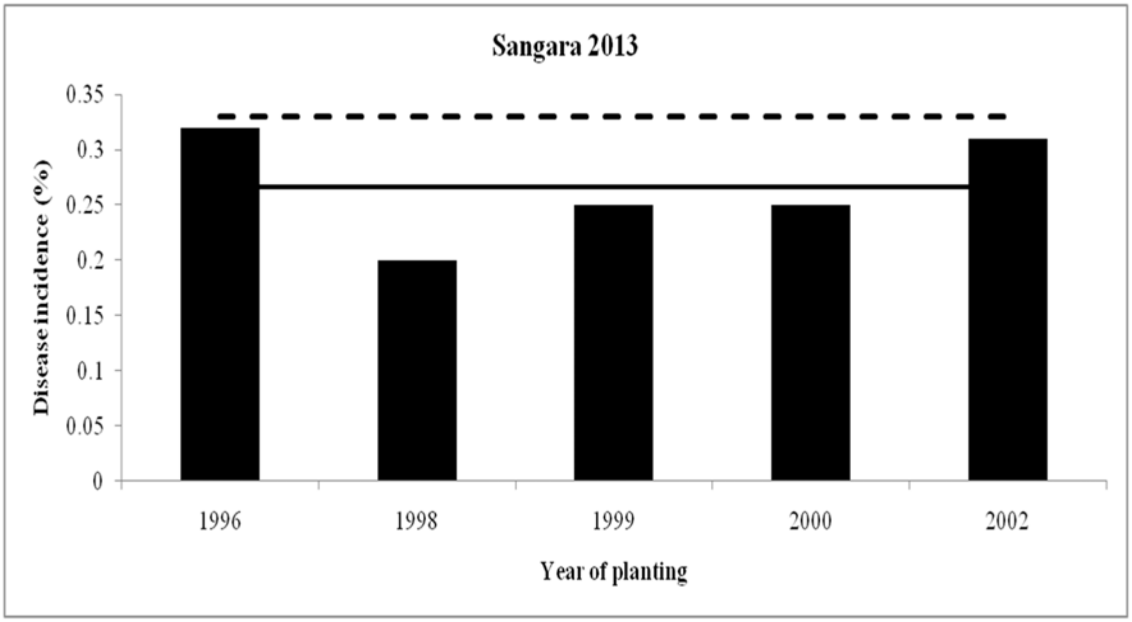

Figure 77 ***Ganoderma*** **disease incidences for Sangara Estate, Higaturu OP Ltd. in 2013. The dashed line is the mean for all blocks (n=175) and the solid line is the mean for this Estate (n=43). Drawn from unaudited data**

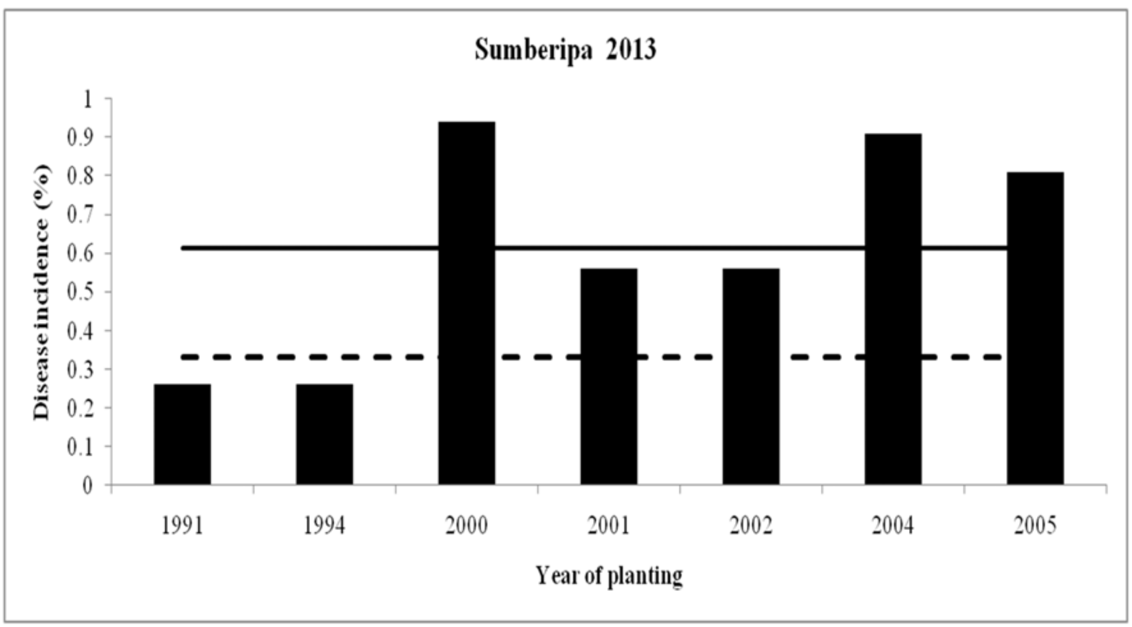

Figure 78 ***Ganoderma*** **disease incidences for Sumberipa Estate, Higaturu OP Ltd. in 2013. YOP = year of planting. The dashed horizontal line is the mean for the plantation (n=175) and the solid line is the mean for blocks in this Estate (n=44). Unaudited data**

NBPOL West New Britain

Monthly monitoring of disease levels in Fields E4 and E5 continued in 2013 (Figure 79). Field E5 averaged 60 new infections per month (Figure 80) and Field E4 mean was 38 new infections per month (Figure 81).

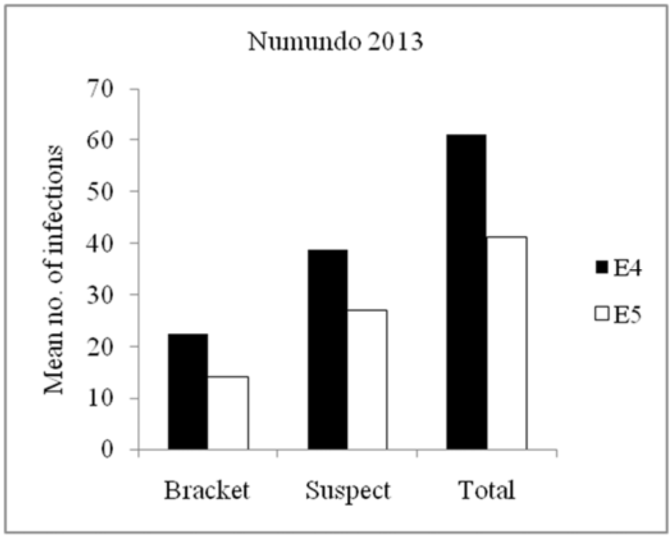

Figure 79 Total number of infected palms identified in Fields E4 and E5, Numundo in 2013

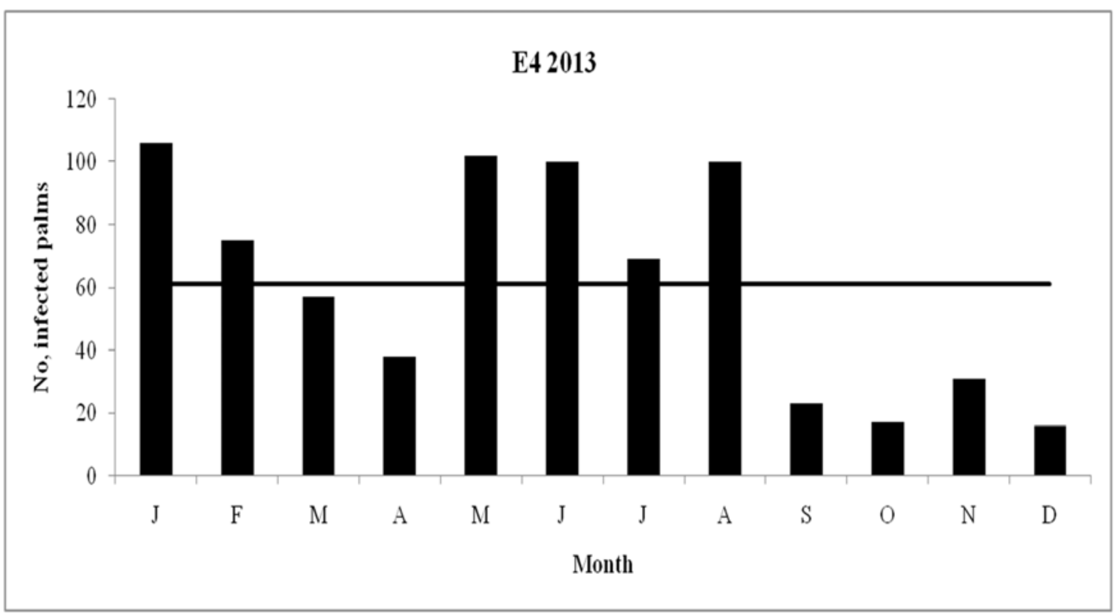

Figure 80 Monthly (*Ganoderma* and suspect) infections recorded in Fields E4, Numundo Plantation, New Britain Palm Oil Ltd. in 2013

Figure 81 Monthly (*Ganoderma* and suspect) infections recorded in Fields E4, Numundo Plantation, New Britain Palm Oil Ltd. in 2013

YIELD STUDIES IN GANODERMA-INFECTED FIELDS

Objective

To assess yield loss in Ganoderma-affected fields and to quantify that loss for future reference and to attempt to model the yield loss with Ganoderma disease progression in individual palms.

Field E5

Yield data was collected over 26 months (fortnightly harvests) in Field E5 with a final Ganoderma incidence of 35% in 2013. Average bunch weights over 26 months are depicted in Figure 82. Bunch weights for Ganoderma palms in total were not vastly different from healthy palms however, the differences were significant?

The monthly yield in tonnes was also variable with the diseased palms showing a depressed yield overall (Figure 83).

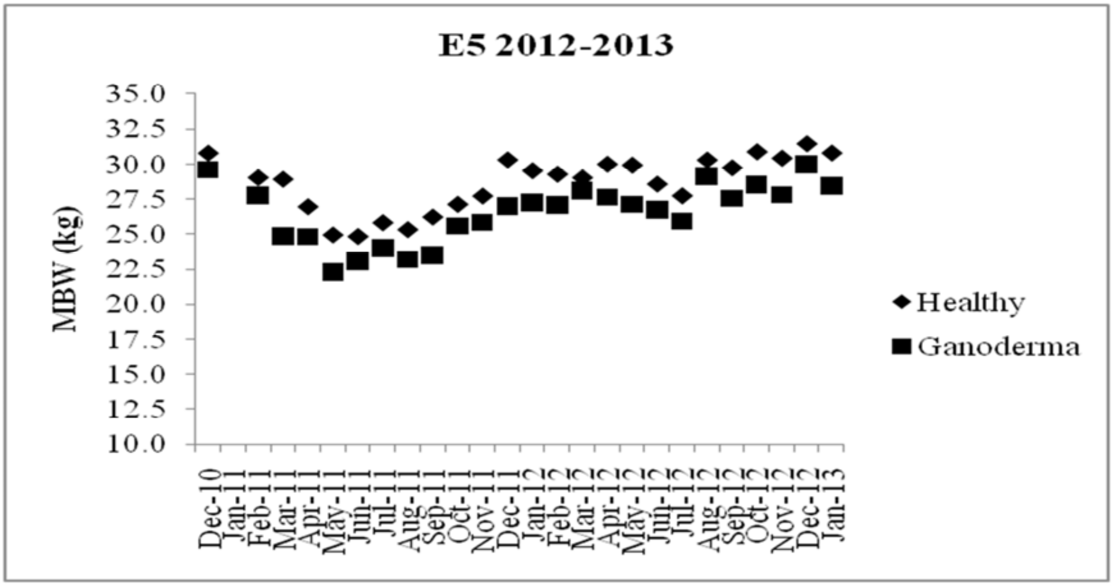

Figure 82 Bunch weights for healthy and diseased palms (all stages of Ganoderma infection) in Trial E5, WNBP, over a period of 26 months

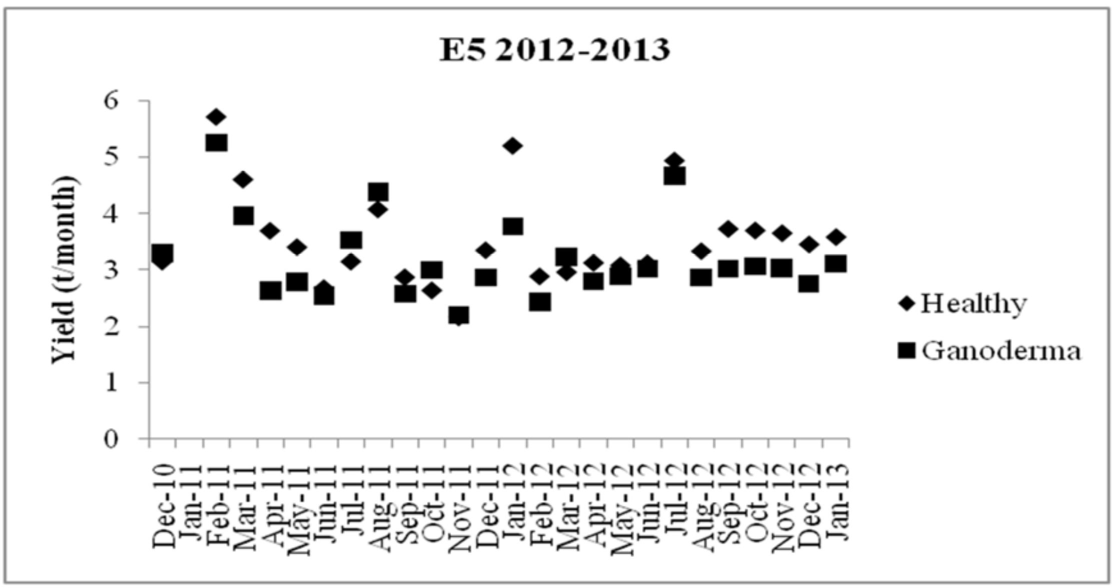

Figure 83 Monthly production (tonnes) for healthy and diseased palms in Trial E5, WNB over 26 months

The annual yields for the period 2011-2012 for all palms (diseased and healthy) combined were significantly different with an average of 28t/ha in 2011 and a drop in production in 2012 to 25t/ha. (Figure 84). This represents a difference of only 3t/ha/yr loss at infection levels between 30-35% which is a surprising result and indicates that palms are still producing reasonable yields at high disease incidence. The summarized data includes palms in the early stages of the disease when yields are not necessarily depressed so further analysis will be required to assess the yield loss with disease progression. The small difference may also be due to natural a natural peak in production towards the end of 2012 or increased production overall due to seasonal effects or improved nutrition. Further analysis of this data is underway.

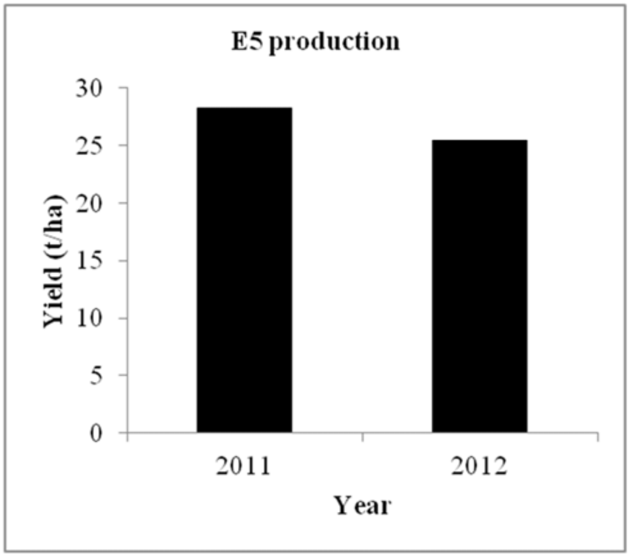

Figure 84 Mean yields (t/ha/yr) for all (healthy and Ganoderma-infected) palms in Trial E5, WNBP (n=52). The difference in the means is significant (p<0.01)

Field F2a

Yield recording began in this field in March 2013. Data for Field F2a for 2013 is still undergoing auditing and analysis hence results are not available.

SCREENING FOR *GANODERMA* SUSCEPTIBILITY

Introduction

This research incorporates the ACIAR *Ganoderma* Projects PC-2007/039 and PC-086-2012 "The control of basal stem rot caused by *Ganoderma* in Solomon Islands" a collaborative project between PNG OPRA and the University of Queensland.
The aim of this project is to develop a reliable and less artificial nursery test for screening of Dami breeding lines and to apply this test to assess genetic diversity with regard to resistance and/or susceptibility amongst parents and progenies. In addition, the nursery results are to be correlated with field resistance of progenies. A further aspect of this research is to attempt to identify molecular markers associated with resistance or susceptibility in the progenies being tested in the nursery and the field.
To facilitate the establishment of robust markers, a reliable nursery screening protocol has been established using non-trial progenies bred at Dami Research station, PNG. The development of the screening technique involved research into the environmental conditions required for infection of oil palm seedlings by *Ganoderma.*
A modification of this technique will be used to screen trial progenies when they become available in mid- 2014. These results are critical for any future screening programme of oil palm germplasm which will be used in the development of markers for disease resitance or susceptibility.

Nursery screening

Screening of Dami progenies planted in GPPOL trials

Eighty-one families prepared by Dami OPRS were planted in field trials in Solomon Islands. These progenies are to be tested for resistance or susceptibility in the nursery as a basis for assessing field resistance.
Seed from these families is still being prepared by OPRS and nursery screenings were not able to be completed as anticipated in 2013 on GPPOL trial progenies. Thirteen crosses prepared in 2013will be

screened in 2014. It is envisaged that further crosses will be made in 2014 and the remaining families will be tested in 2015. The results of these nursery screenings will be fed into the ACIAR Project where attempts will be made to genotype the phenotypic traits observed.

Screening of Dami 'SuperFamilies'

Seed was received in November 2013 and two nursery trials were established in December 2013 when palms were 2 -3 weeks old. The trial design is a randomized complete block with 3 replicates and 5palms/progeny/block for Trial 1 and 3palms/progeny/block for Trial 2 with only 13 progenies under test for the latter. Results are as yet, unavailable.
Nursery testing will be carried out multiple times (at least twice) on the same families in 2014. The aim of the multiple testing is to validate the rankings amongst the families and determine the precision of the nursery assay.

Field (disease) trials- Solomon Islands

Phenotypic data collection

Bunch and flower counts and palm status recordings were continued to March 2013 when yield recording began. The final flower counts for 2013 are not presented here.
The mean bunch weights for 4 year old trial palms in Field 12 for a 5 month period are shown in Figure 85. The mean bunch weight was 5.2kg and the progenies were scattered around this weight. Highest yielding progenies for Field 12 were family 22 and family thirty eight.
Mean bunch weights for palms in Field 13 were slightly higher at 5.5kg (Figure 86). Family 38 again recorded the highest bunch weights and Families 41 and 44 also had comparable bunch weights of over 6kg.
Bunch weights translated to yield in Field 12 and Family 22 had the highest yields of all the progenies with 10.8t/ha over the 5 month period (Figure 87). Mean (total) yield for Field 12 was 7.9t/ha over 5 months. In Field 13. Family 33 recorded the highest yields of 13.5t/ha (Figure 88). Yields were generally higher in Field 13 (mean 9t/ha) but data on palm vigour in each of the fields has not been taken into account and hence, comparisons should be made with caution.
Yield data for each field over 5 months in 2013 is shown in Figure 89. Yield from each harvest appear to have been in decline in the latter half of the year. Yield recording is continuing and this pattern should change over the next 12 months.

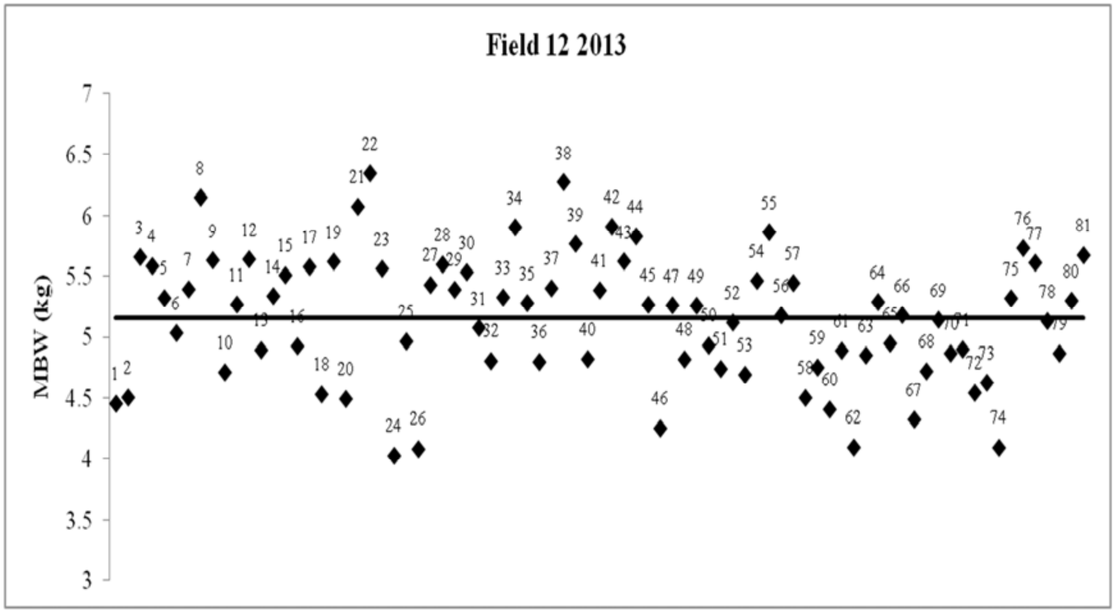

Figure 85 Bunch weights recorded for 4 year-old palms from 81 Families planted in trial blocks in Field 12 (Trial 1, Ngalimbiu) over a 5 month period from March 2013 to July 2013. The horizontal line is the overall mean for all blocks. Data labels are progeny numbers

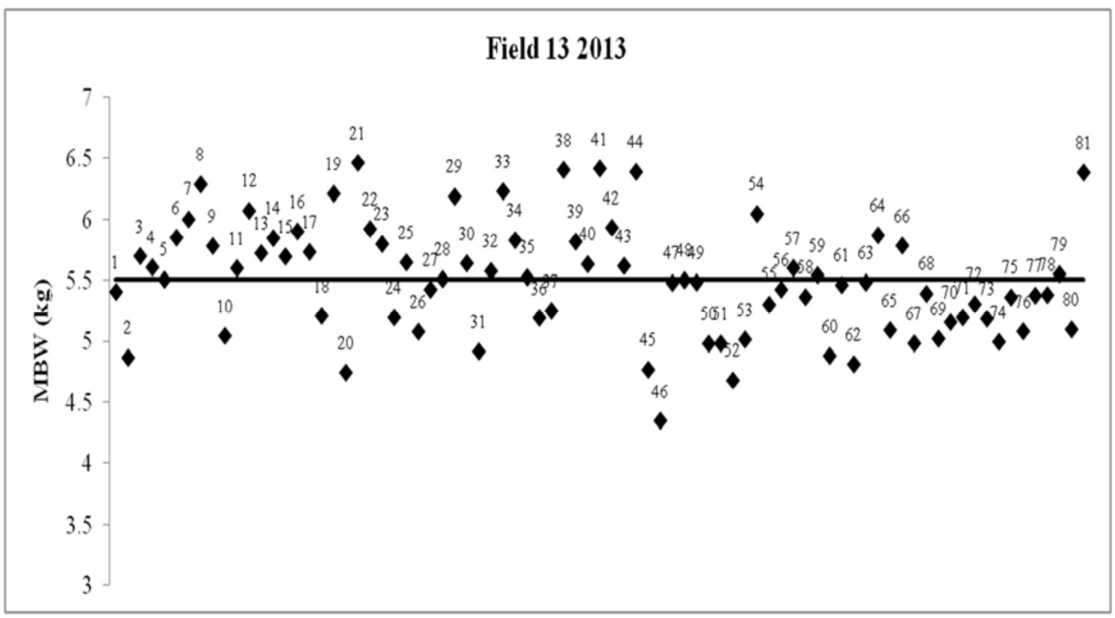

Figure 86 Mean bunch weights recorded for palms from 81 families planted in trial blocks in Field 13 (Trial 2, Ngalimbiu) over a 6 month period from March 2013 to August 2013 (n=14). The horizontal line is the mean for all blocks. Data labels are progeny numbers. Palms are 4 years old

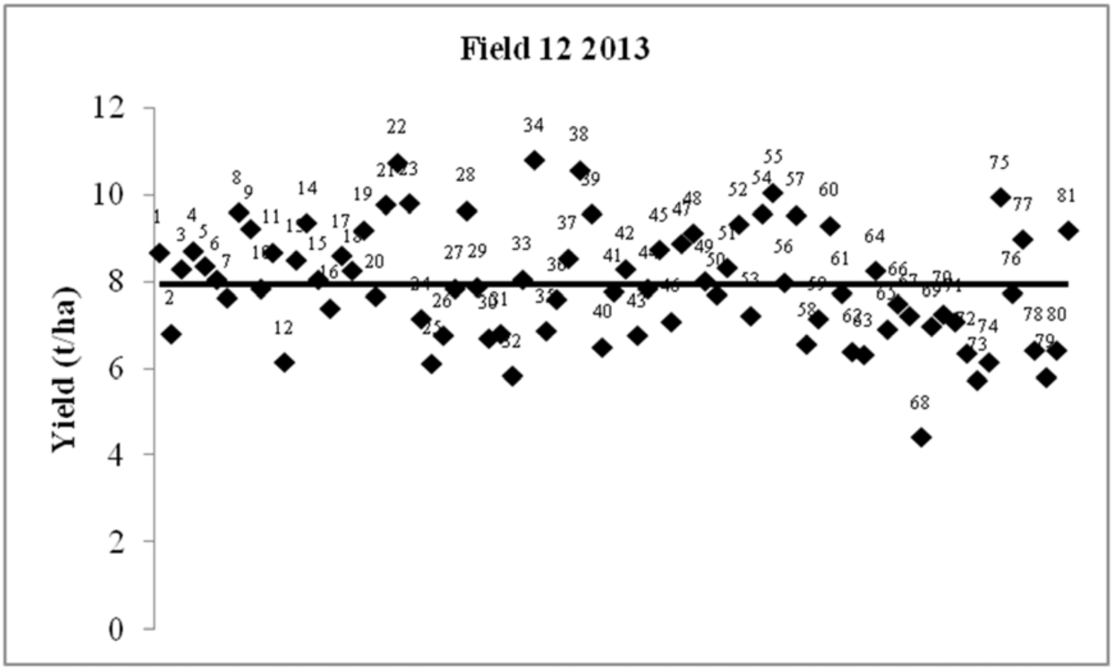

Figure 87 Total yields (t/ha) recorded for palms from 81 families (n=14) planted in trial blocks in Field 12 (Trial 1, Ngalimbiu) over 5 months from March 2013 to July 2013. The horizontal line is the mean for all blocks. Data labels are progeny numbers. Palms are 4 years old

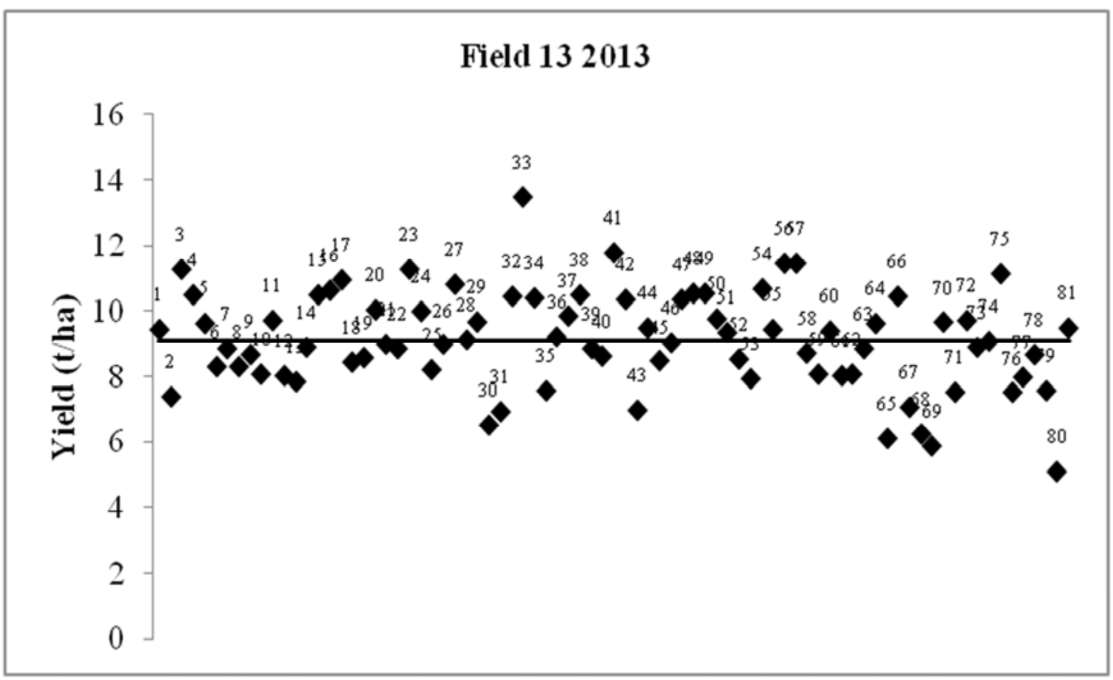

Figure 88 Total yields (t/ha) recorded for palms from 81 families (n=14) planted in a trial in Field 13 (Trial 2, Ngalimbiu) over 6 months from April 2013 to August 2013. The horizontal line is the mean for all blocks. Data labels are progeny numbers. Palms are 4 years old

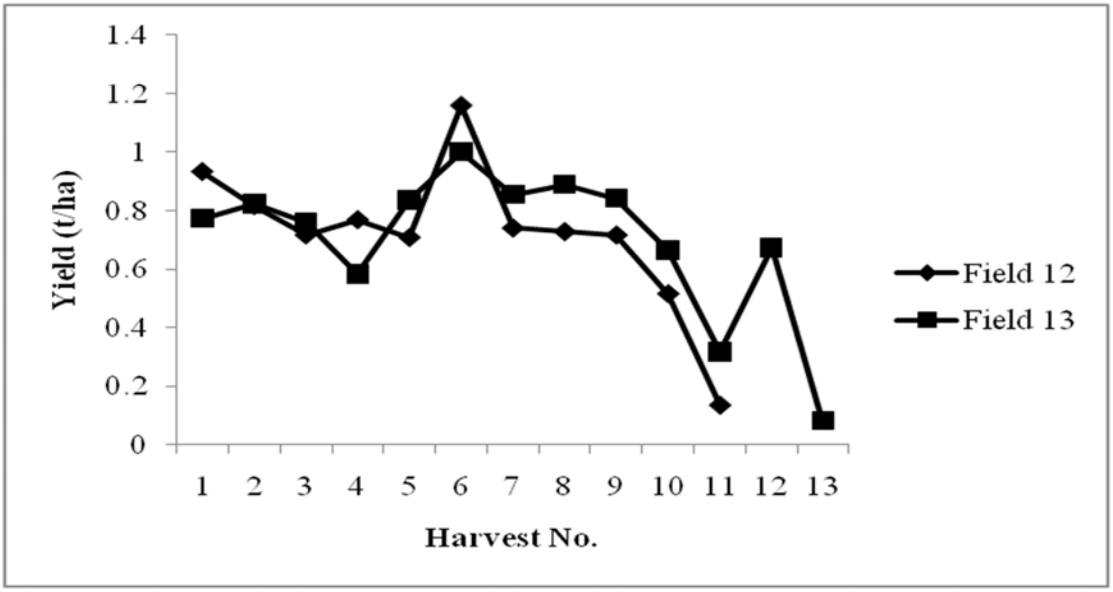

Figure 89 Mean yields (t/ha) per harvest produced by all progenies planted in Trials 1 and 2 at Ngalimbiu Plantation, GPPOL in 2013 (n=1134). Palms are 4 years old

Genotyping of trial progenies

Microsatellite markers developed by (Bilotte, 2005) for *Elaeis guineensis* have been used in this study to provide a basis for separation of the Dami families under test in the field trial in SI. Eighteen markers were found to be useful in an initial study and were used to genotype test plants from all families.

Leaflets of all 2268 palms planted in the field trial were sampled for microsatellite analysis. The mean expected heterozygosity (He), or level of genetic diversity, among the 81 families is 0.617. The highest He found is 0.621 and lowest is 0.559. For all families represented in the field trial 88% of the molecular variance is within families and only 12% between families Patterns of allele segregation and inheritance in the progenies were also assessed. It was detected that some of the male parents and one female parent appear to have a higher level of non-transmission of alleles to their progenies, and the resultant progenies have higher level of indels (insertion or deletion mutations) and non-Mendelian inheritance patterns (Table 97). An example of the segregation of five of the microsatellite markers is shown for one cross in Table 98. Re-sampling of all parental lines will be done in the next phase of this project in order to verify these results. The presence of insertions and deletions does not necessarily imply a detrimental effect on selections in the future. These alleles will simply not be used for selection. There is still sufficient variation amongst the offspring to be able to separate the families. Thus, from these 18 markers the Dami populations in the field trials can be successfully fingerprinted. Indications are that as few as 12 markers can be utilized without loss of resolution (A. Mudge pers. comm.) All of this data is still under analysis and the results will be reported at a later date.BSR disease is slow to establish, and at this stage we have not detected definite BSR symptoms in the field trial population which means that markers associated with susceptibility &/or resistance to BSR cannot be identified at present. These markers will be tested initially on the populations undergoing screening in the nursery. If susceptible or tolerant phenotypes can be identified, these can be used in crosses to develop populations segregating for markers linked to the genes for susceptibility or resistance. These results will be some years away unless we can fast-track the development of these populations. Even if only susceptible phenotypes can be identified and co-dominant markers linked, these can be used to remove susceptible lines from a breeding program.

In the next phase of this research, other markers such as (RADs) will be tested to complement the SSR markers already identified to expand the chromosome maps. This will also be complemented by transcriptome analysis of key genes in the oil-palm-Ganoderma interaction pathway.

Table 97 Inheritance of microsatellite markers amplified from GPPOL trial progenies (families). Not all families are represented.

Family	Cross	Total no. of indels & nonM	% of alleles with Indels & nonM
F5	P1 / P24	33	20.6
F11	P2 / P23	19	11.9
F25	P5 / P20	62	38.8
F37	P7 / P22	55	34.4
F42	P8 / P22	20	12.5
F38	P8 / P17	15	9.4
F55	P11 / P26	2	1.3
F58	P12 / P19	0	0.0
F65	P13 / P19	1	0.6
F8A	P13/ P28	1	0.6
F3A	P13 / P21	6	3.8
F64	P13 / P17	13	8.1
F10A	P15 / P20	21	13.1
F12A	P15 / P23	9	5.6
F15A	P16 / P20	27	16.9
F19A	P16 / P24	27	16.9
F18A	P16 / P26	2	1.3
F17A	P16 / P22	14	8.8

Table 98 Inheritance of 5 microsatellite markers from a small sample of progenies from a cross between Parents 1 and 24 from a Dami breeding population. Highlighted cells are insertions and deletions of the alleles.

Sample	M14	M14	M15	M15	M18	M18	M19	M19	M20	M20	M5	M5
P1	180	182	82	88	104	104	118	118	278	289	353	353
5.1	176	180	82	82	104	120	118	118	289	289	338	353
5.2	182	190	82	86	104	120	114	118	278	289	338	353
5.3	180	190	82	86	104	120	114	118	283	289	338	353
5.4	180	190	86	88	102	104	118	118	278	289	342	353
5.5	180	190	82	88	102	104	118	118	278	283	342	353
P24n	176	190	82	86	120	120	114	114	283	289	338	342

BOGIA COCONUT SYNDROME

Introduction

This syndrome (BCS) is currently manifested in coconuts in Madang Province (Kelly, 2011). There is also some evidence that it is also present in bananas in other Provinces (Davis, 2012). The presence of a phytoplasma belonging to the LY group in dying coconuts is of immediate concern to the oil palm industry since many coconut diseases and pests are transmitted to oil palm (e.g. fan blight, Finschhafen Disorder, Sexava). In addition, the presence of an LY group phytoplasma, if found transmissible to oil palm, will be detrimental for oil palm seed exports. There is also a possible threat to the new oil palm developments in the Ramu Valley (Ramu Agri-Industries) which are close to the border with Madang Province.

A BCS Technical Committee was set-up in 2009 and PNG OPRA representatives on this Committee are Dr Carmel Pilotti and Charles Dewhurst/Dr Mark Ero. The involvement of PNG OPRA was necessary to ensure that the industry is kept abreast of developments in any containment or eradication programme set-up by quarantine authorities. The performance of this Committee has been hampered by inadequate funding support for eradication operations as well as research. Because of this, in 2012 PNG OPRA sought funding from ACIAR to identify possible vectors of the phytoplasma, the outcome of which would at least inform the oil palm sector of the threat of insect populations in proximity to plantations. This study was a collaborative effort between the Entomology Section and Plant Pathology. Prior to the insect study, collaborative surveys, sampling and testing were implemented in conjunction with CCI and NAQIA to assess the presence and proximity of the BCS phytoplasma in coconuts, in areas where oil palm is also grown (Morobe, Oro and Milne Bay Provinces).

In 2013, the remaining analysis and results of the vector sampling survey carried out from August to October 2012 in Madang Province were collated and compiled in a report to ACIAR. A summary of these results is provided here.

BCS surveys and testing

Collection and testing of coconut samples

Coconut samples collected from coastal Provinces (except Western) 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 DNA product.

To date, no other Province has been found to have coconuts with the BCS phytoplasma but further surveys will be required inorder to monitor the status of coconuts in Provinces close to NBPOL and HOPL plantations in PNG.

BCS vector study- ACIAR funded

Plants and insects were collected by Entomology Section staff (SM, SS and CD), CCI and RAIL and from August-October 2012 and analysis was completed in April 2013. A selection of the positive samples tested in Milne Bay were sent to New Zealand for sequencing.

The final results of this investigation are presented here.

A paper has been drafted and submitted for publication.

Sample preparation

Individual insects were removed from alcohol solution and placed on paper towel for a minimum of 1 hour to permit evaporation of the alcohol to take place. DNA was extracted using the Qiagen DNeasy Blood & Tissue Kit (Qiagen Inc.) and then immediately frozen.

Plant samples were collected at Furan Village and Vidaro Village (Madang Province) by either drilling (palms) or by destructive dissection (bananas, taro).

Samples were frozen soon after collection and then carried to PNGOPRA Milne Bay laboratory by hand.

All plant samples were lyophilized and ground in a mortar and pestle. Ground samples were extracted using a Qiagen DNeasy Plant Mini Kit (Qiagen Inc.) and DNA was immediately frozen until analysis. The quality of the extracted DNA was checked prior to molecular analysis. An example is shown in Figure 90.

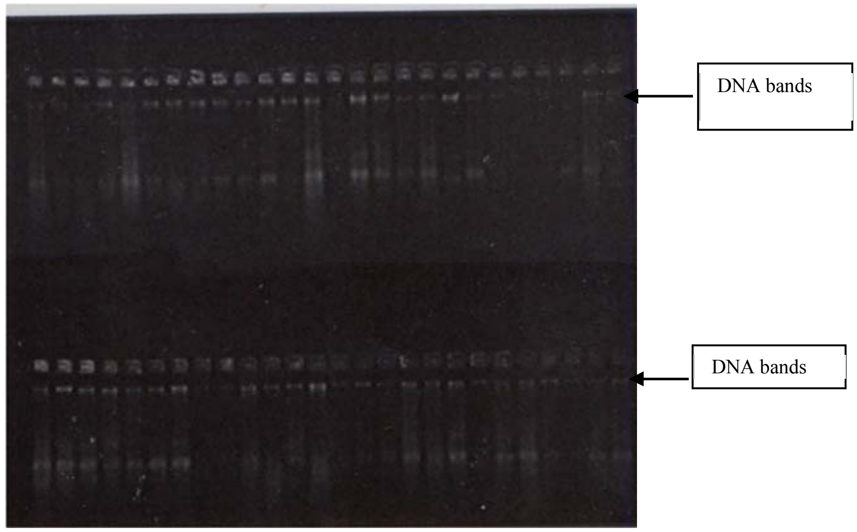

Figure 90 Gel electrophoresis of DNA after extraction from various insects

PCR analysis

Nested PCR reactions were carried out in 25ul volumes in 0.6ml tubes and PCR was run using a Techne gradient thermal cycler. A positive and negative control was included with each batch of samples analysed. The positive control used was kindly supplied by Dr Nigel Harrison, University of Florida. 10µl of each sample was run on a 1.2% agarose gel and stained with ethidium bromide for viewing and photography.
A typical gel is shown in Figure 91.

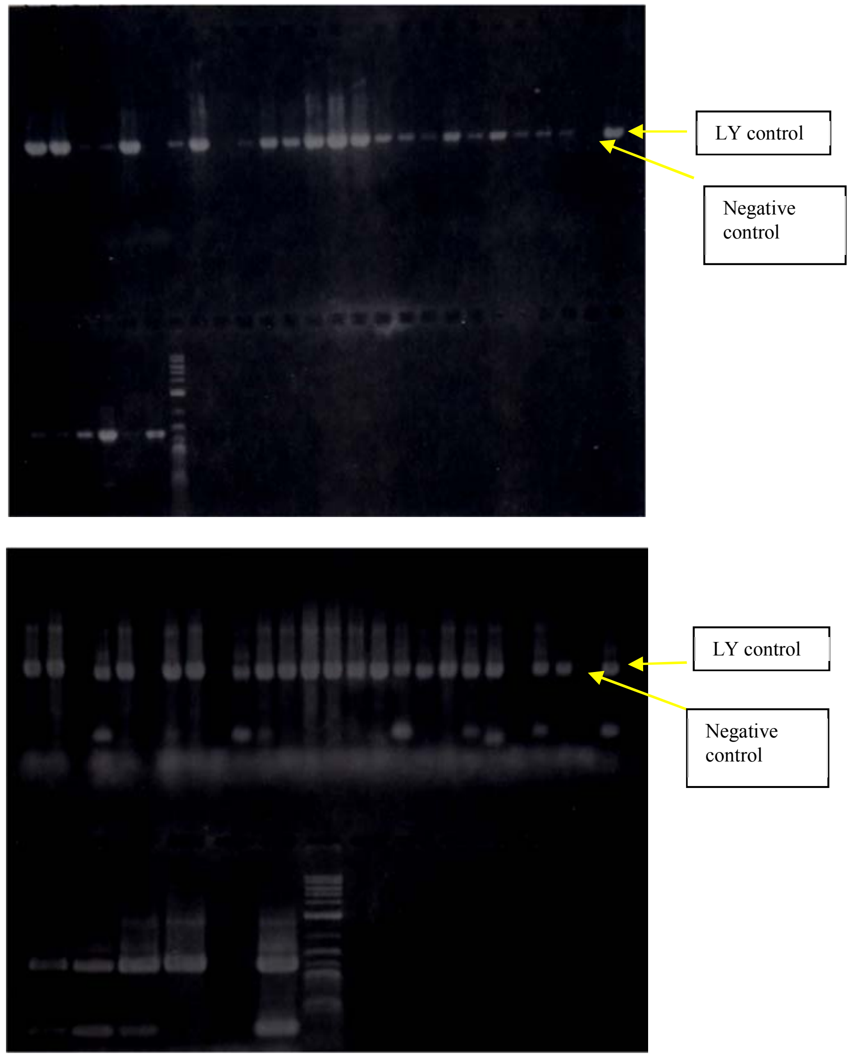

Figure 91 A gel showing the DNA products from some of the insects collected in the vector survey

Top: First round PCR
Lower: Second round (nested) PCR products. The sample on the far right of each photo is the positive (LY) control.
A selection of 35 samples were sent for sequencing in New Zealand

Insect screening

Samples were deemed positive for phytoplasma if the nested-PCR produced a detectable band. Samples which produced a product in the first-round PCR but not in the nested-PCR were considered to be negative with the cause likely due to other bacteria. The presence of phytoplasmas cannot be confirmed until sequencing of these products is performed.
Analyses of approximately 125 insects were not fully processed and tests will need to be run again, as one set of primers had become degraded by the end of the project, and nested–PCR products could not be verified. These samples have Now been restested but the data is not shown here.
Of the total number of 268 samples analysed in the initial study, more than 25% were tentatively recorded as positive.
The insect group that returned the most positive results (40% of samples) was the leafhopper *Zophiuma pupillata* (Hemiptera: Lophopidae), with 16% of the total positive results. The growth stage of the insect appeared irrelevant as nymphs as well as adults tested positive.

A large proportion of the positive samples from coconut hosts were collected from the Omuru coconut seed garden owned by CCI. Unfortunately, the status of the coconut host plants at Omuru was not recorded, although a yellowing of fronds was observed in a number of mature palms in the plots. More than 90% of the *Z. pupillata* collected from Omuru tested positive for phytoplasma.

The largest number of *Z. pupillata* were collected from coconut and betel nut hosts, but a high proportion were also collected from banana. The apparently broad host range of this species makes it a potential candidate as a carrier of phytoplasma, as it was also recorded from Cocoa bushes inter-planted with coconut some distance away (M. Makai, *pers. comm.)*. Positive *Z. pupillata* insects were obtained from both symptomatic and asymptomatic betel nut.

For many of the specimens collected from an initial visit in April 2012 (SS and SM), the host or host status was not recorded, and therefore any correlation of results with host status cannot be reported with confidence. Host plant status was recorded during the October collections.

Coleoptera were collected from Sago palms and most of the Ricaniidae were collected from *S. campanulata*. Many Flatidae were collected from *Terminalia* trees and a single *Z. pupillata* specimen was collected from *Pandanus* sp. A summary of the insect species collected and their analysis is provided in Table 99.

Representatives of the Delphacidae recorded 27% positive PCR assays.

Derbidae also returned a significant proportion of positive results (15%) after nested-PCR. The majority of the positive samples were from insects collected on banana plants at Furan (Sites 1 & 2). Only a few Derbidae were collected from young coconut palms and a single collection was made from an *Areca* (betel nut) palm. These were the most abundant insects found in the Furan area after *Z. pupillata*.

Other Orders/Families with individuals testing positive were Hemiptera (Flatidae, Ricaniidae, and Pentatomidae), Orthoptera, (Tettigoniidae, *S. decoratus* or *S. novaeguineae*). Many insects carry bacteria as symbionts or saprophytes and this may be the reason for the positive results from these insects. The results of sequencing will confirm the identity of the bacteria present in these samples.

Twenty one plant samples from Furan and 11 from Vidaro were analysed by PCR. Of the 7 samples sent to NZ for sequencing, only 2 were confirmed positive and therefore were the only samples processed for sequencing. Results of sequencing indicated that the phytoplasma had 99% homology to the banana wilt-associated phytoplasma (BWAP) which is identical to the LY group phytoplasma found in coconuts in Madang Province.

Two other samples (one each from Furan and Vidaro) have been dispatched and are yet to be sequenced in New Zealand.

Table 99 Frequencies of insect groups and phytoplasma-positive (nested PCR) samples from all hosts at Furan Village, Madang Province.

Taxon	Total no. of specimens tested	Total no. PCR positive	No. of hosts
Cicadoidea	1	1	1
Cicadellidae	6	0	4
Chrysomelidae	1	0	1
Coleoptera	4	0	2
Curculonidae	1	1	1
Delphacidae	22	5	3
Derbidae	40	6	3
Diptera	3	0	1
Flatidae	18	3	5
Fulgoridae	2	0	2
Hemiptera	6	1	unknown
Hymenoptera (*Indet*.)	1	0	1
Isoptera	4	0	unknown
Lepidoptera	1	0	1
Lophopidae	117	47	4
Membracidae	1	0	1
Pentatomidae	3	1	1
Ricaniidae	45	1	6
Termitidae	1	0	1
Tettigoniidae++	21	2	2

++ Although not indicated, these were either *S. decoratus* (Madang) or *S. novaeguineae*

DISEASE REPORTS

The number of disease reports received and attended to in 2013 by staff in Milne Bay and West New Britain are shown in Table 100. All reports were investigated and recommendations made.

Table 100 Disease reports received by the Plant Pathology section from OPIC and plantations in 2013

Site	Area	No. reports received	Description
Milne Bay	All areas	19	Nursery diseases
			Nursery – pests
			Leaf miner
			FInschhafen Disorder
West New Britain	All areas	90	Ganoderma
			Crown disease
			Upper stem rot
			Wet stem rot
			Bunch rot
			Fractured crown
			Wilting

PUBLICATIONS, CONFERENCES AND TRAVEL

Publications

Draft paper titled “A survey for potential vectors and plant hosts of a phytoplasma associated with coconuts in Madang Province, PNG”. Draft submitted to Australasian Plant Pathology Journal, currently under review.

Draft paper titled " Further investigations into a lethal decline of coconut palms in Madang Province PNG". Draft awaiting reviews.

Conferences

No conferences were attended by staff of this Section in 2013.

Travel

Travel was undertaken by the Head of Plant Pathology (HoPP) for plantation site visits and ACIAR projects activities.

OTHER ACTIVITIES

Project administration

Annual reporting for the ACIAR Ganoderma Project and the final report for the ACIAR Vector SRA was accomplished.

LPC meetings

The Head of Plant Pathology attended LPC meetings held throughout the year in Milne Bay.

TRAINING

Most training activities in 2013 were field-based for OPIC and plantations.
Monthly disease training and awareness sessions were held throughout 2013 for VOP growers in Milne Bay by the Plant Pathology Section. Awareness was also carried out in West New Britain.

ACKNOWLEDGEMENTS

The support of ACIAR with the *Ganoderma* Project in PNG and SI is gratefully acknowledged. The assistance of GPPOL with the field trial activities in SI is also acknowledged. Ganoderma survey data supplied by the TSD Sections of member companies is also greatly appreciated.

4. SOCIOECONOMIC RESEARCH

HEAD OF SECTION IV: EMMANUEL GERMIS
& Merolyn Koia

GENERAL INTRODUCTION

The focus on smallholder research is becoming more important with the rapidly changing socio demographic context of smallholder production. The high rate of under-harvesting amongst smallholders, shifting production strategies and land tenure disputes may affect patterns of production, income distribution, farmer decision making and the overall quality of life. In 2013 the socioeconomics research team worked on the following project activities:

CUSTOMARY LAND USAGE AGREEMENT (CLUA) (RSPO 1.1, 1.2, 2.2, 2.3, 5.1, 6.1, 6.2, 6.4, 7.5, 7.6, 8.1)

Introduction

The acquisition of customary land by non-clan members and outsiders for the purpose of oil palm development in West New Britain started in the mid 1990's. Earlier studies have identified land issues as a key factor currently affecting smallholder FFB production. These issues cause problems and major challenges for future viability and sustainability of the smallholder oil palm sector. Much of land demand is created by LSS settlers from populated blocks, private sectors and government employees who have spent their working lives and raised their children in WNB see the "purchase" of a Customary Rights Purchased (CRP) block as a way to secure a livelihood. The CRP blocks purchased in the middle to late 1990's were developed before the CLUA system came into function and have no proper records of customary land use while the first CLUA document was introduced around the year 2000.

The purpose of the study was to find out how many growers have not signed and how many have signed a CLUA form prior to and beyond the year 2000, how many growers have signed the first version of the CLUA that was introduced in 2000, how many growers have signed the new CLUA version that was introduced after 2010 and to advise OPIC to encourage all growers (existing & intending) to sign a new CLUA form.This preliminary report was based on two follow up research activities (focus group awareness & block surveys) in late 2012 and early 2013. The research study was done in Waisisi CRP blocks at Siki division Hoskins project area.

Methodology

Focus group awareness and block survey were the two research activities used to assess the progress of the CLUA since its first establishment. Two follow up (focus group) awareness were conducted with OPIC Siki and Waisisi land owners and CRP growers. Four leading questions were introduced while growers and land owners raised their doubts and gave their views on each leading question while explanations were given with minutes taken followed by a block profile survey of the 45 blocks at Waisisi CRP area.

Results

The two tables (Table 101, Table 102) below explains the two follow up research activities regarding CLUA status conducted (focus group awareness, block surveys & visit to OPIC Siki) at Siki division and their outcomes in late 2012 and 2013.

Table 101 First CLUA monitoring and evaluation activities conducted in late 2012

Date	Attendees	Activity	Outcomes
03.07.12	61	First CLUA awareness with OPIC Siki, Waisisi Land owners & Waisisi CRP growers	Land owners & CRP growers were advised of their rights and landowners were advised to decide who to sign CLUA forms for fixed term.
02.09.12 - 04.09.12	45	Visited the 45 Waisisi CRP growers	Found out that 10 blocks purchased prior to 2000 have not signed their CLUA forms. Found out that 8 blocks purchased during 2000 lost their old CLUA forms

Table 102 Second CLUA monitoring and evaluation activities conducted in 2013

Date	**Attendees**	**Activity**	**Outcomes**
09.04.13	**54**	**Second follow up awareness**	**New CLUA Signatories nominated by landowners. All existing & intended blocks to sign a New CLUA**
10.10.13		**Followed up visit to Siki OPIC Office regarding CLUA status of Waisisi CRP growers**	**Confirmed 61 growers (36 existing & 25 intending) signed new version of CLUA form.**

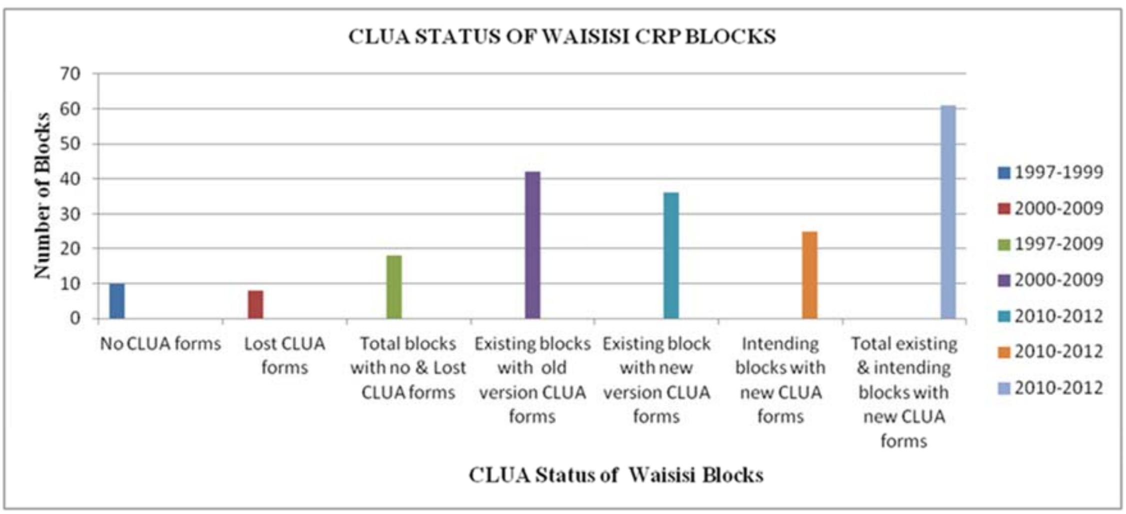

Figure 92 Status of CLUA (old & new version) for land purchase prior and after the year 2000 (n=61)

The graph(Figure 92) shows status of blocks purchased in Waisisi CRP prior to 2000 when the CLUA system was not introduced, blocks purchased during 2000 to 2009 when the first version of CLUA (old CLUA form) was introduced and the introduction of the second version of CLUA (new CLUA form) in 2010-2012.

Discussion

The research activities that were conducted in 2012 and 2013 were focus group awareness with OPIC Siki division, Waisisi CRP growers and land owners, block profile survey of the existing growers (Table 101 and Table 102) and visit to OPIC Siki division for confirmation of growers' CLUA status

(Figure 92). From the two CLUA follow up awareness (Table 100,Table 101) conducted in late 2012 and 2013.
A list of what needs to be done to get the new CLUA form to serve its purpose are:

- All signatories of the new CLUA must be appointed by the majority of clan or village members.
- Detailed document that draws the rights of both the growers and the land owners
- The terms and conditions required by CLUA to be discussed in village meetings
- Land owner signatories for the new CLUA to be agreed and appointed by majority
- Purposely for oil palm development
- Stakeholders to be notified if there are changes to CLUA signatories and
- Land owners have rights on their land and growers have purchase rights

During the survey conducted, it was evident that blocks purchased in the late 1990s'(1997-1999) have not signed CLUA forms while those who obtained blocks from and after 2000 signed the old one page CLUA (first version). It is important that all growers must sign a new CLUA form to avoid future inconveniences. With the introduction of the new CLUA version, more growers (existing & intending) are coming forward because from the advices received, the growers knew that they will be more secured to settle and do oil palm business effectively to contribute to high FFB production and income to sustain their livelihood and so as the customary land owners. The customary land owners will still have ownership over their land. The new CLUA has attracted a lot of CRP (existing & intending) growers. The land disputes and illegal land sales will be minimized as all stakeholders will be involved in the agreement of land sales for oil palm developments while increasing FFB production.

Recommendations

Below are the proposed activities that the smallholders have to accomplish under the guidance of OPIC for the effective and convenience of CRP block development to maximize yield, production and income in the smallholder oil palm industry.

- All VOP and CRP growers to sign a copy of the New CLUA form,
- The signing of the new CLUA form will date back to the first Block development,
- All Customary Land Owners must organize themselves into Customary Land Owning Groups,
- Land owner groups must have set of guidelines to make decisions on CLUA requirements and
- CLUA document to be kept confidential in respective OPIC Divisional Offices while copies kept by grower and in OPIC Lands Office.

MOBILE CARD PRELIMINARY REPORT (OPIC BIALLA & HARGY OIL PALM LIMITED 2012-2013)

Introduction

The Mobile card (MC) is an option for oil palm income diversification on smallholder LSS blocks in Bialla project. In 2012 PNGOPRA Socio-economic Section did a Mobile card (MC) concept assessment and rate of uptake in smallholders. The purpose of the awareness was to assess the uptake of the MC scheme by smallholders in the project, identify areas that needs improvements and who are the stakeholders that will be involved to make the improvements and to assess whether the MC payment scheme is making general progress or not. The feedbacks from the study are discussed below.

Method

A follow up visit to the OPIC Bialla project and smallholder department of Hargy Oil Palms whereby OPIC Project Manager, extension officers and the HOPL Smallholder Manager were interviews. Apart from that, follow up study was carried out by conducting 4 Mobile Card (MC) awareness programs in Wilelo, Tiauru, Barema, Soi Land Settlement Scheme (LSS) and at Baubata for OPIC officers. One hundred and thirty two LSS Oil Palm Growers and 20 OPIC staffs attended the awareness.

Results

The progress of the MC payment scheme in Bialla Oil Palm Project as registered by OPIC and HOPL are shown in
Table 103 and Table 104. In 2012, only 21 blocks were registered for MC scheme by the OPIC Field Manager, whilst the extension officers of OPIC and SHA of HOPL did not register any blocks under the MC scheme. Surprisingly, the number of de-registered growers by extension officers and OPIC Field Manager did not match and this call for proper coordination of this scheme if we want to make it work (
Table 103). Despite this, both OPIC and HOPL have given their support towards the scheme in 2012. HOPL allowed 100 % split income while OPIC facilitated bank documents MC users to HOPL. Other support were also proposed by the OPIC and HOPL to be considered in the future (Table 104).

Table 103 Mobile Card Payment Scheme progress 2012 -2013

Contact Areas	Year	MC Registered growers	MC De-registered growers	Comments
Ext. officers	2012	0	5	Improper records of MC De-register records not same as FM
OPIC F/ Manager	Nov 2012	21blks	3	De-register records not same as ext. officers
SHA Manager HOPL	2012	0	0	No data on hand To retrieve from the payment system (IT department)

Table 104 Improvement of Mobile Card Scheme by HOPL and OPIC

Contact areas	Support given to MC scheme	Support to be given to MC scheme
HOPL	Allow 100% split income on whole block	Separate indication of FFB tonnage/income generated by MC users
OPIC	Some extension officers facilitate bank documents for MC users to SHA HOPL	Include into LPC reporting

Discussions

Generally there was no progress of the MC payment scheme after the 4 awareness's conducted. The assessment revealed improper records of the MC proceedings at all levels (
Table 103). The record of MC (registration & de-registration) do not correspond to each other meaning that there was a lack of understanding and corporation between the concerned stakeholders. HOPL payroll system works well with 100% split on whole block and was understood by growers. MC scheme is practical if block owners live on the block. Title transmissions must be done in deceased blocks to allow MC usage for maximum FFB crop recovery to increase production and income to evenly distribute within households on the blocks. Few extension officers facilitated bank account documents for MC users. OPIC to include MC reporting in LPC meetings and HOPL to indicate how much FFB is produced from mobile card. Standard Operating Procedures (SOP) and MC contract termination form to be in placed to avoid inconveniences. Pre-commitment of extension officers, slow administering of documents led to improper records and delayed in MC proceedings.

Recommendations

Below are the proposed activities that the concerned stakeholders should work together to serve the purpose of the MC concept so that it is effective and convenient to the growers to maximize yield, production and income in the smallholder oil palm industry.

- Audit into all MC records in both OPIC and SHA HOPL regarding the MC concept
- Conducting surveys/interviews on MC user blocks and non MC user blocks
- MC concept into C-card scheme as in Hoskins LSS.

HARGY PLANTATION WORKERS STUDY BIALLA (RSPO 1.1, 4.8, 8.1)

Summary

There was less study conducted on the general work force of the plantation industry in the past to assess the socioeconomic status of the workers. Qualification was not a requirement for general employment that encourages more people to be recruited. The general social services that Hargy Oil Palm Limited (HOPL) provided to its workers attracted a lot of people to be employed. The purpose of the research survey was to find out the factors that influence the people to be employed by HOPL, the workers views on the services provided by HOPL and what they thought about their current type of work that they do and what would be the best approach HOPL would take up to address some of their issues that will directly or indirectly influence their productivity.

Methodology

The survey was conducted in 2012 at Urumaili plantation of Hargy Oil Palm Limited (HOPL). Seventy plantation employees (79% male and 21% female) participated through a one on one survey interview. Those interviewed were the harvesters, wheelers, sprayers, loose fruits pickers, security guards, and drivers. Preferences were allocated to harvesters.

Results

Plantation workers and their number of sick days

Table 105 shows the number of general workers and the number of sick days they acquired in 2012. More than half of the plantation workers (about 83%) relocated to Area 08 because of free health services by HOPL, while 11% felt that free health services did not have a greater influence on their move. From the sick, 57% said they were given day off based on recommendations from the medical officers. About 9% said despite sickness, they continued working because they have already used up their sick days leave.

Table 105 Plantation workers and their number of sick days (n=78) Source: (Study, 2012)

Number of sick days (frequency)	Number of plantation workers
0	25
1	32
2	11
3	1

Plantation workers and the nature of their work

Error! Reference source not found. shows the list of work carried out by male and female workers. Work allocation to each gender is based on general observation where all male workers do heavy and risky duties while females attend to female oriented duties.

Table 106 Plantation employees and their nature of work (in gender). Source (Study, 2012)

Gender	Nature of work the most represented
Female	Loose fruits collectors Compound cleaners/Janitors
Male	Harvesters, Wheelers, Sprayers, Drivers, Security guards

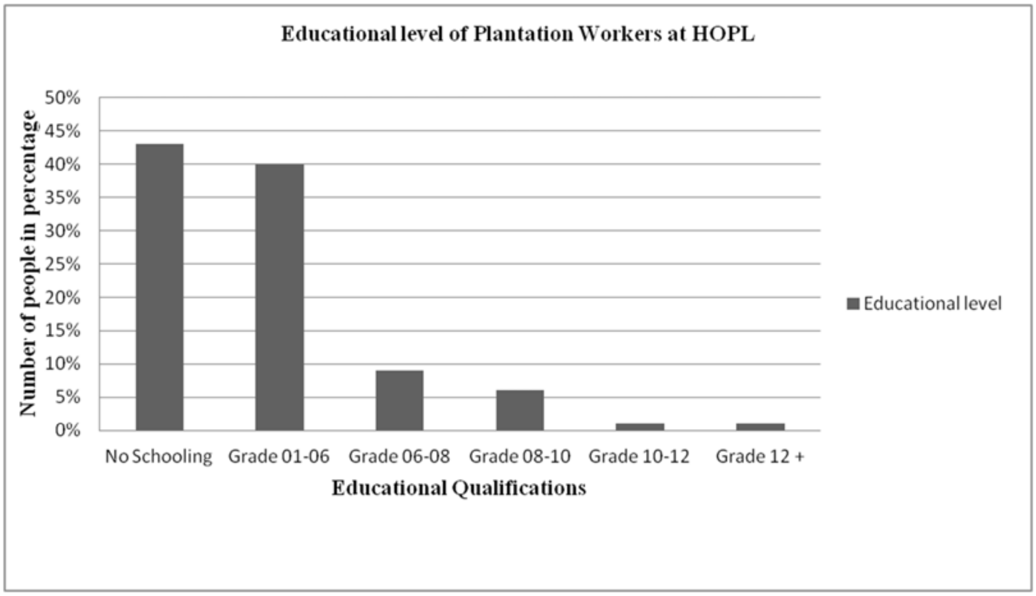

Figure 93 Education level of plantation workers. Source: (Study, 2012)

Above is the graph (Figure 93) showing the educational level (qualifications) that the general workers possesses. Most of them have no or limited literacy skills and this influences the type of work they do. The quality and quantity of work done were based on their years of work experiences. The educational qualifications of plantation workers are reflected on their allocated work. Most of them are semi-skilled employees. Survey findings revealed low level of literacy amongst plantation employees. About 43% of the plantation employees have no formal education, 40% of them completed grade one to six, 9% completed grade six to eight and 6% completed grade eight to ten, 1% completed grade ten to twelve and tertiary education. More than half, 58% of the plantation employees indicated that educational qualification was not necessary when HOPL recruited them. However, 42% view educational qualifications is important.

Discussions

General plantation employment in HOPL as indicated in the 2012 survey was not based on literacy or educational levels. Consequently many low literate populations take the advantage to earn a life in the plantation compounds. The basic social infrastructures that HOPL provided met the basic necessities that the general work force were looking for. Many workers moved to Area 08 because of good health services that kept the workers and their families healthy as long as possible at minimum cost. The frequency of sick days revealed that there are good health services that cater for the workers. The work allocations were assigned according to gender and skills that each worker is able to perform (e.g. harvesting of FFB) while producing the maximum productivity. Generally males do heavier and risky tasks that need skills and experiences while females were assigned to females dominated duties of household and gardening related tasks.

FOOD SECURITY PROJECTS (MARKET & SHOP SURVEYS) (4.2, 4.8, 5.1, 6.1, 8.1)

Summary

The supply and demand for food crops currently in the markets around Kimbe town (open market) generally depends/fluctuates with the prices of goods in the shops and similarly the prices of goods in the shops increases steadily with the influence of FFB price. The purpose of the market survey was to monitor the trend in the market prices of food crops in relation to monthly oil palm FFB prices, to justify if Food Security is a concern in LSS blocks and also other smallholder oil palm schemes, to compare the prices of marketed goods/food crops against store goods that most income from FFB is spent on, to identify reasons why some smallholders do marketing instead of attending to their oil palm blocks, compare sellers gender, locality, ethnicity and how they do their marketing in terms of the quality and quantity of their produces and monitor and compare the supply and demand for certain foods cultivated and sold.

Methodology

The socioeconomics section conducted several market surveys along Hoskins, Bialla and Kimbe highways. Weight of food crops were recorded depending on the price and quantity of produce. A small market survey was conducted to weigh the food crops, interviewing the sellers and collecting prices of store goods in Kimbe town. The prices of the store goods were collected according to market sellers' preferences. The data were captured in survey forms in both the market (record of fresh weights and interview of sellers) and shops.

Results

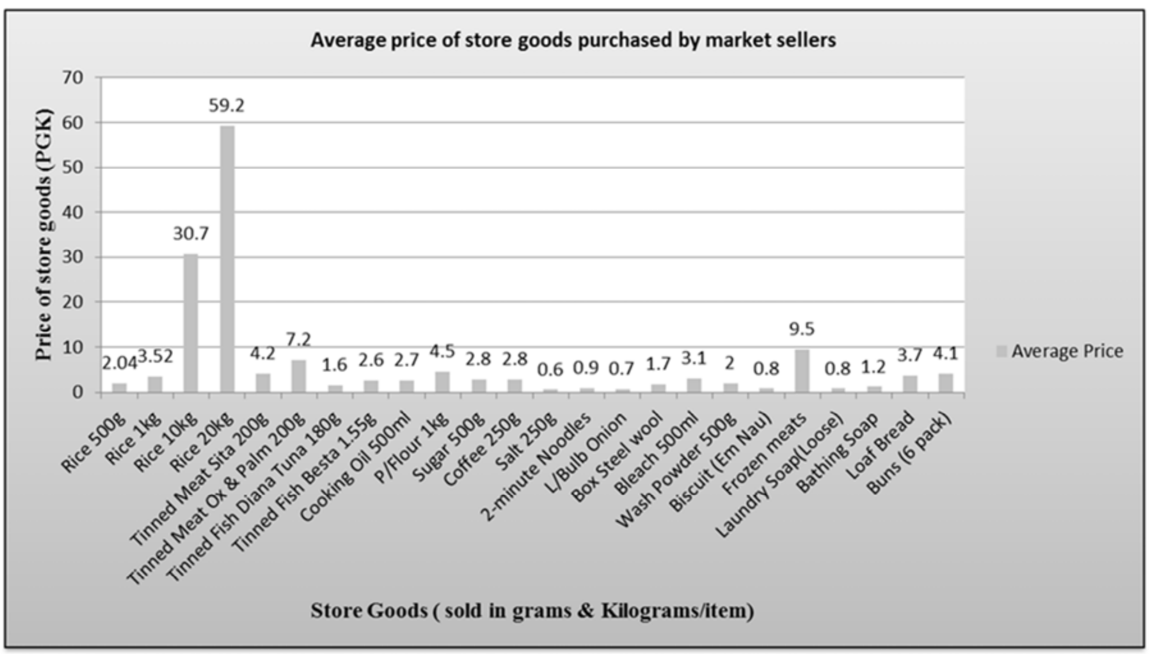

Figure 94 Average price of basic store goods purchase by 14 market sellers in 5 shops in & around Kimbe town in July 2012

Average price for basic goods (household items) purchased in five shops in and around Kimbe town by fourteen market sellers in the first FFB fortnight of July 2012 is shown in Figure 94. Goods were bought based on the quantity (in grams & kilograms) against the price instead of the quality.

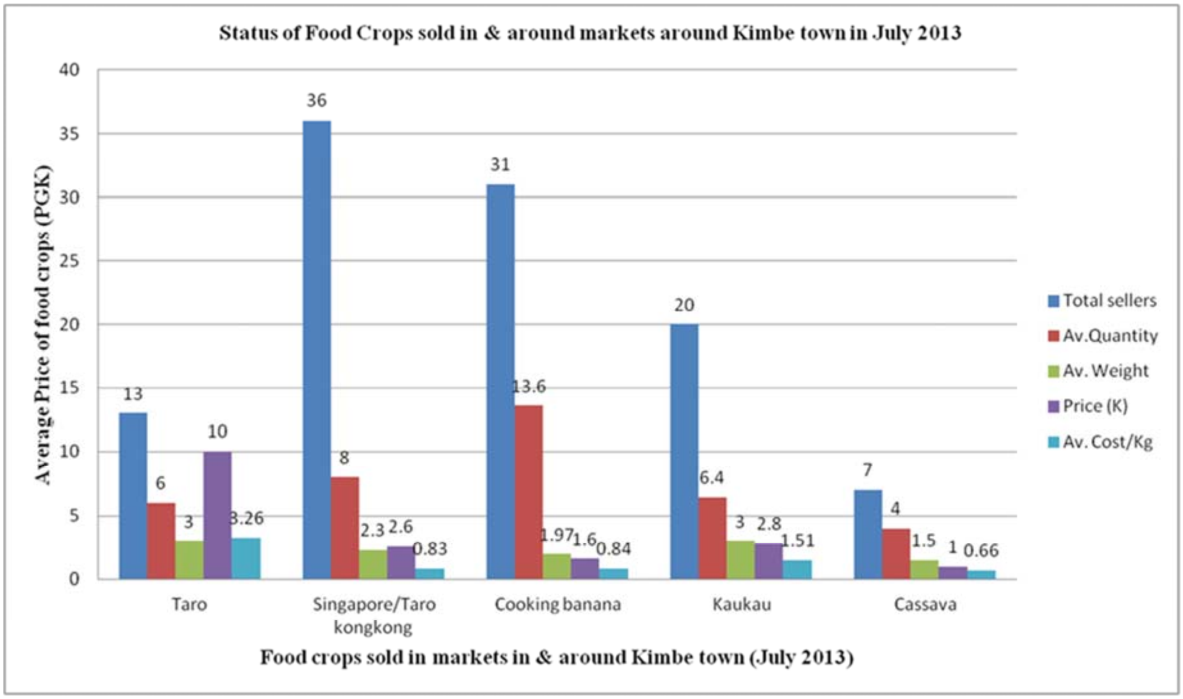

Figure 95 Food Crops sold in markets in and around Kimbe town in July 2013

Figure 95 shows the status of food crops sold in and around Kimbe town. Taro was identified as the most expensive food crop while banana was least expensive but together with Singapore has the highest supply. The sellers mentioned that marketing is done once, twice or three times a month. Sellers revealed that food crops sold quickly during company and smallholder FFB fortnights than public servant fortnights. Preferred marketing days are Mondays', Thursdays' and Fridays' as crop sales are fast. The average market income is K70 per day and with frequency of twice a month is K140. Mondays and Thursdays generates more income than the other four days as Thursday is the fortnight day and Monday is the day after the weekend of the fortnights. Store goods purchase by sellers depends on income of each marketing day.

Discussion

The price of food crops at the market are also increasing with the price of processed food in the shops, therefore oil palm growers who make gardens can earn extra income by selling food crops at the local markets. Crops that can be easily cultivated like singapore, cooking banana and kaukau are always sold cheaply in large quantities while crops like taro which are difficult to grow fetches high price at the market. The survey also revealed that certain days of the week are good for marketing because the sellers experience fast sales of food. Unfortunately, money earned from sales of food crops at the market are eventually used to purchase processed food like rice and tinned fish.

SOCIOCONOMIC RESEARCH POSTER (RSPO 1.1, 4.8, 8.1)

The Socioeconomics section has developed an extension tool for information dissemination to the smallholder and industry populations on how to sustain themselves under the oil palm tree. The Poster is currently in printing stage and will be distributed to all oil palm smallholder and industry sites in the country. It will be produced in both English and pidgin versions.

OPIC RADIO EXTENSION PROGRAM (RSPO 1.1, 4.8, 8.1)

The ongoing program with OPIC to broadcast on updated activities and disseminate extension information and advices. Two programs were broadcasted on CLUA awareness for customary land use for smallholder oil palm cultivation and financial savings option for smallholders. The radio programs were broadcasted in pidgin version.

CROSS-CUTTING ISSUES HIV & AIDS PROGRAM (RSPO 1.1, 4.8, 8.1)

PNGOPRA had gone through the HIV & AIDS workplace training through Emmanuel Germis in July 2012. In July 10^{th} 2013, Emmanuel was confirmed as a national HIV & AIDS Trainer of Trainees (TOT) from a trial work place training session with 17-OPRA employees in Dami conference room by BAHA National Training Coordinator from Port Moresby. The basic HIV & AIDS training was incorporated into 3-tranings conducted and will continue to be incorporated into any field and workplace trainings with the smallholder and industry populations.

5. ROUND TABLE FOR SUSTAINABLE OIL PALM RSPO

RSPO Principles are regularly updated and those are available on Web Site. Early 2014 the National Interpretation Working Group (NIWG) of RSPO decided unanimously to adopt the RSPO new criteria and principles without any amendment.

http://www.rspo.org/
www.rspo.org/file/PnC_RSPO_Rev1.pdf

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