Annual Research Report

2016

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Contents

Page

List of Tables

List of Figures

List of Plates

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A. REPORT BY THE DIRECTOR OF RESEARCH

Director of Research, Dr Luc Bonneau

July 2017

A.1. Context

As reported last year, the 2016 crop budget presented was optimistic for the estate and over-optimistic for the smallholders with 8.7% and 8.3% more crop forecasted respectively than the one achieved in 2015 (1 full month of production extra). But, 2016 has seen very depressed yields in comparison to 2015 certainly due to the El Nino of 2015 and is the second worst year after of 2013 (too wet) of that decade (Table 1) and the worst from the smallholders. However, it is important to note that the yields observed in 2016 were equally affected to their budget (-12%) for both nucleus and smallholders (see 2015 annual report).

Table 1 FFB production (MT) by the oil palm industry donors to PNGOPRA between 2011 and 2016*

Year	Milling companies	Smallholders + Outgrowers	Total	Versus 2011	Versus 2012	Versus 2013	Versus 2014	Versus 2015
2011	1,844,783	871,394	2,716,177	n/a				
2012	1,702,393	887,981	2,590,374	95%	n/a			
2013	1,558,522	776,406	2,334,928	86%	90%	n/a		
2014	1,794,404	832,297	2,626,701	97%	101%	112%	n/a	
2015	1,832,222	771,442	2,603,664	96%	101%	112%	99%	n/a
2016	1,767,166	737,593	2,504,759	92%	97%	107%	95%	96%

The industry, in comparison to the previous year saw an appreciation of the CPO price throughout the year from a low 530USD/T in January to close to 800USD/T in late December 2016, unfortunately at the time of writing the price have plummeted again below 700USD/T.

As for PNGOPRA, lower volume meant lower revenue from FFB (-12% of budget) and budget control had to be enforced throughout the year. Nonetheless, PNGOPRA remained cash positive while engaged in the largest capital expenditure of its existence by the construction of its Plant Pathology Laboratory at Dami (K1.45 million). On that note the Director of Research thank the Section heads for their understanding when restriction were enforced during 2016 and the reconstruction of cash reserve in the first part of 2017, but also the milling company in being flexible with our debts which allow us to retain sufficient free cash throughout the year.

NBPOL Group, has also changed financial calendar in 2016 from calendar to July to June, rendering the budgeting exercise un-timed with the other PNGOPRA Members. We hope for the reverse of that decision as it renders information processing smoother.

Following the production level achieved in 2016 in comparison to 2015 there were no changes of voting rights not in 2016 (Table 1 & Table 2). The board of director remained unchanged to previous year and there was no change of Chairmanship with Mr Graham King General Manager of Hargy Oil Palm Limited remaining Chairman of the Board.

Table 2 FFB production in 2016 and voting right in 2017 per OPRA associate members

MEMBER	FFB Produced in 2016	VOTES Number	VOTES %
New Britain Palm Oil Limited	812,918	**9**	31.0
Smallholders (OPIC)	737,593	**8**	27.6
Kula Palm Oil Ltd (ex CTP (PNG) Ltd)	499,681	**6**	20.7
Hargy Oil Palms Pty Ltd	287,926	**3**	10.3
Ramu Agri-Industries Ltd	166,641	**2**	6.9
Director of Research[1]	n/a	**1**	3.4
TOTAL	2,704,759	**29**	100

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

In 2016 the hectares planted have decreased by 257 ha in comparison to 2015 (Table 3) mainly due to Popondetta projects which has adjusted its smallholder from 13,547ha to 10,974ha. Despite the replant continuing, NBPOL WNB has retain a moderate area as immature hectares because of a young age profile due to last decade extensions, while MBE and HOP have seen a decline of their immature as the massive replant programme initiated in 2011 reach a declining pace and no major extension have taken place yet. In another note POL has now a third of its area immature due to replant activities only. As for Bialla, the hectares planted remained quasi constant, but the immature proportion has greatly diminished by about 900ha as Bialla is also facing shortage of extension areas.

Table 3 Planted mature area (ha) in December 2016

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (*NBPOL, Mosa*)	**35,395**	**24,659**	540	60,594
Popondetta (*NBPOL, Kula Group*)	9,153	10,623	-	19,776
Milne Bay (*NBPOL, Kula Group*)	9,664	1,679	-	11,343
New Ireland (*NPOL, Kula Group*)	3,703	2,643	-	6,346
Ramu (NBPOL, *RAIL*)	11,492	-	432	11,924
Bialla (*Hargy Oil Palms*)	11,253	11,499		22,752
TOTAL	80,660	51,103	972	132,735

Table 4 Planted immature area (ha) in December 2016

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (*NBPOL, Mosa*)	3,110	**3,020**		6,130
Popondetta (*NBPOL, Kula Group*)	937	351		1,288
Milne Bay (*NBPOL, Kula Group*)	1,162	268		1,430
New Ireland (*NPOL, Kula Group*)	1,860	173		2,033
Ramu (NBPOL, *RAIL*)	1,999	0	212	2,211
Bialla (*Hargy Oil Palms*)	**2,368**	2,421		4,789
TOTAL	11,436	6,233	212	17,881

Nonetheless, the total hectares planted by the OPRA members at the end of 2015 reached 150,616 ha with 2,088 additional hectares planted in 2016 (+2.2%) by the nucleus and a reduction of 2,417 in the smallholders. NBPOL West New Britain remains the biggest site and NBPOL Poliamba the smallest (Table 5). While all sites have seen a reduction of their surface, WNB and Ramu were the only site to increase with an additional 1,292ha and 622ha respectively (+2.0% and +4.6%).

Table 5 Total planted area (ha) in December 2016

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (*NBPOL, Mosa*)	**38,505**	**27,679**	540	**66,724**
Popondetta (*NBPOL, Kula Group*)	10,090	10,974		21,064
Milne Bay (*NBPOL, Kula Group*)	10,826	1,947		12,773
New Ireland (*NPOL, Kula Group*)	5,563	2,816		8,379
Ramu (NBPOL, *RAIL*)	13,491		644	14,135
Bialla (*Hargy Oil Palms*)	13,621	13,920	**0**	27,541
TOTAL	92,096	57,336	1,184	150,616

It is noted that NBPOL POL has the highest proportion of its estate as immature with 24.3% of the total area planted (Table 6) while NBPOL WNB has the lowest with just above 9.2% of immature as total hectares for both estates and smallholders. Overall the immature hectares have reduced which signal a shift from the last 4 decade trend that our members as a whole struggle to find new area to continue extension. However, RAIL, HOP and WNB are investigating new perimeters to expend their operation significantly.

Table 6 Proportion of immature palms in December 2016

Project Area	Plantation	Small holders	Outgrowers	Total
Hoskins (*NBPOL, Mosa*)	**8.1%**	**10.9%**	0.0%	**9.2%**
Popondetta (*NBPOL, Kula Group*)	9.3%	3.2%		6.1%
Milne Bay (*NBPOL, Kula Group*)	10.7%	13.8%		11.2%
New Ireland (*NPOL, Kula Group*)	33.4%	6.1%		24.3%
Ramu (NBPOL, *RAIL*)	14.8%		32.9%	15.6%
Bialla (*Hargy Oil Palms*)	17.4%	17.4%		17.4%
TOTAL	12.4%	10.9%	17.9%	11.9%

Furthermore, in PNG Overall, Dami Seeds reports another 1.3million seeds sold to non-PNGOPRA members, cumulating 12,5million seeds sold to outsiders in the last 10 years, equating to 60,000 Ha+

worth of planting material. While all new outsider projects have not materialized some have built and are building mills: Tzeng Plantation Ltd and Memalo holding already operating 1 mill each, Tzeng Plantation Ltd, Wewack Agriculture and Bewani building 1 each. It is anticipated that 5 mills will be operating from those new projects by the end of 2017, putting under pressure[1] the traditional stakeholders of the PNG oil palm sector. With current pace of growth, traditional members of PNGOPRA could be outpaced by 2025 and PNGOPRA recommends that communication regarding Pest and Disease[2] should be encouraged between the two sides of the industry.

PNGOPRA continued to be financed by a levy paid by all associate oil palm growers and also by external grants (Project funding). The total budgeted operating expenditure for PNGOPRA in 2016 was higher than the previous year at K7,41 million and is budgeted to decrease in 2017 to K5.87 million all inclusive (OPEX, CAPEX and donor funded). The total spending in 2016 cumulated at K6,96 million (6% below budget) due to the large capex exercise (K2.23 million).

The Association Member levies financed 97.5% of this expenditure while external grants have decreased at 2.5%. The share of the external grants has been sustained at 2.6% in 2017 budget. As a result of financial stress and closure of POC levy collection, the Member's levy was raised back at a rate of K2/tonne of FFB for all growers and was applicable on first January 2017. The Palm Oil Council finances remain administrated by PNGOPRA and the situation is unchanged as the remaining funds are still used by Tola Investment, the company of Sir Brown Bai in relation to his expenditure linked to the oil palm industry.

In 2016, expenditure by PNGOPRA was under spent from budget for the fourth year in the row and only K531,174 (3.4 weeks of budget) were carried forward (K2 million less than previous year). In the 2017 budget the expenses of Agronomy, Plant Pathology and Entomology increased while those of SSR were reduced.
In 2017 Research Operational Expenditure budget was distributed as follows: Agronomy research, 49.4%, Entomology research, 19.4%, Plant Pathology research 14.4%, (2016 = 13.5%), Socio-economics 16.7% for a total of K5.47 million levy funded.

A.2. Man power

In 2016 PNGOPRA has not seen changes in its management. Dr Luc Bonneau was appointed PNGOPRA Director of Research and NBPOL Group Head of Research in 2015 after joining Dami in 2012.
The distribution by age of employees is presented in Figure 1 and Figure 2. The executive succession plan needs to be addressed in the coming years for Plant Pathology and Agronomy. However the succession plan is not taking place partially due to the lack of flexibility in accommodation available on site and lack of funding due to stagnant production from the members and ever increasing labour charges.

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 remained at 36% female, 64% male.

[1] Poaching of experienced people, Sustainability credential of PNG oil palm sectors and government relations.
[2] Common pest, fining of new parasitoids and use of chemicals, phytoplasmas.

Figure 1 Distribution of the 10 executive staff employed by PNGOPRA per age group

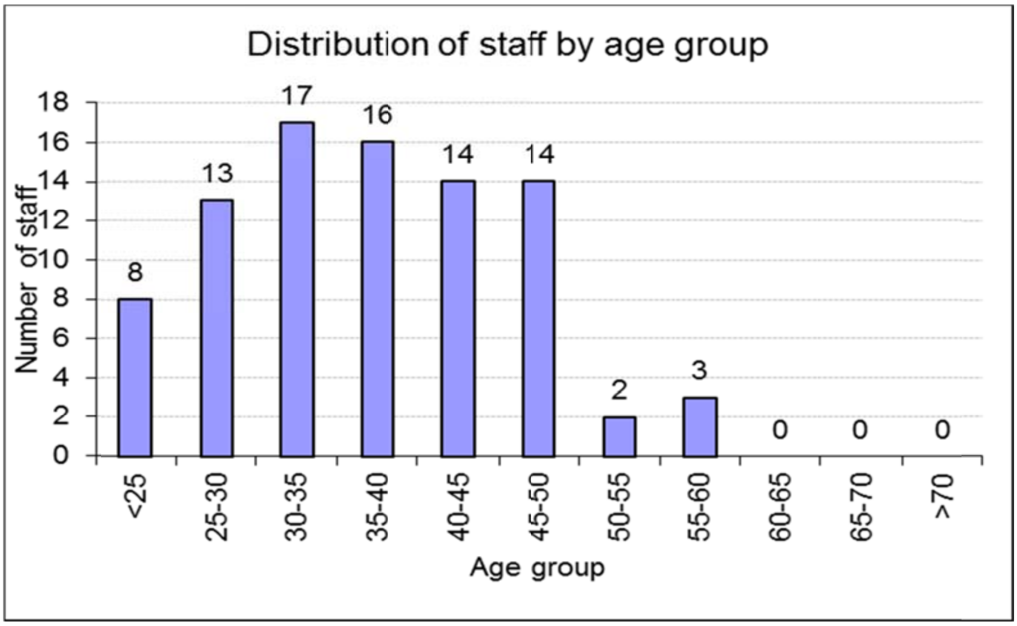


Figure 2 Distribution of the 87 non-executive staff employed by PNGOPRA per age group

- Emmanuel Gorea has returned from Australia from his MRes studies and rejoined the team in Dami. Sharon Agovaoa has completed her Bachelor degree from Unitech in Lae and is now the Officer in Charge at MBE after the relocation of Dr Carmel Pilotti.

- In 2016, 3 PNGOPRA workforces were still registered as students, Dr Luc Bonneau doing his distance Learning MBA with Bradford University in UK, Emmanuel Guermis doing is Master studies in socioeconomics in Perth at Curtins University Australia, and Richard Dickrey doing his Bachelor Degree in Agriculture with Unitech in Lae, PNG.

- In 2017, additional 2 staff members are to rejoin the student pool.

- Susan Tomda has resigned and Paul Simin is due for promotion as executive OIC in Bialla mid 2017.

A.3. Research in 2016

In 2016 the research performed by PNGOPRA remains in the same lineage and spirit as previous years. Below each section head put together their respective section in the annual report and brief items are highlighted below.

- The agronomy section has now entered a transitional period as its new generation of fertiliser trials using the latest OPRS semi-clonal material now used by the industry : SuperFamily™. At the time of writing, most new trials have been planted only 2 are still in the nurseries. The strategy for Agronomy is to keep up the advance in breeding to supply bespoke information to the industry palm nutritionists, hence new series of trials will be programmed every 6-7 years.

- The CRB-G still the biggest threat to our industry, with to date no effective control measure being identified. Some collaboration work with SPC (Fiji), Ag Research (NZ), and NRI (UK) have been on going to mine and find a solution. The work is continuing actively in 2017. Meanwhile it is expected that CRB-G will continue its progression in PNG along the south coast of the mainland. Note that it has already been reported to start to be a sizeable nuisance in the NBPOL operation of Solomon Island both in immature and mature areas.

- In 2016 the pesticide Dimehypo was approved for a 5 year period. Companies are now using Dimehypo as generic to combat leaf eating insects (sexava, stick insect, CFM and bagworms) but are yet to clear completely their metamidophos as the product cannot be used under the SAN standard for which all are members are gradually joining in.

- The production of parasitoids has been greatly affected mainly by the incapacity by our teams to collect vast amount of eggs and insects from the wild. A review of our processes is organized for 2017.

- A study on beneficial plants has shown interesting results while combat against *Mimosa pigra* has continued.

- Plant Pathology, has relocated to Dami late 2016 and no significant findings were accounted for as in the last few years that can significantly change plantation practices. Despite the relocation, records continued and work is now peaking up the pace in the new laboratory. We hope for more collaboration with the Dami breeding programme as this will serve our associate members better.

- The SSR activities have now grown to a steady pace and very well accepted by the stakeholders, whether those are the nucleus estates, the smallholders, the number of BMP block has increase and two events a week are organized by the association to demonstrate and educate smallholder in oil palm husbandry. OPIC has continued to underperform and internal politics have not been solved with current General Secretary under investigation and the absence of a formal Board of Directors. As such PNGOPRA do not see any reduction of its extension service in any foreseeable future, as it is of moral duties to assist the association members wherever it is most needed. But PNGOPRA acknowledge the effort of Hargy Oil Palm in privatising most extension services to its associate smallholders which have been left unmanaged by OPIC over many years.

- In general smallholder's blocks are in critical need of N and K fertilizer and financial arrangement need to be found to resolve this one of many contribution factors to the steady fall in yield from the smallholder sector nationwide, especially in Higaturu Oil Palm.

B. AGRONOMY SECTION

HEAD OF SECTION I: DR. MUROM BANABAS

B.1. Agronomy overview

The main task of PNGOPRA Agronomy Section is to determine the optimum nutrient requirements for oil palm plantations, from the analysis of nutrition trials and the understanding of the processes within the soil which influence and regulate plant nutrient uptake; ultimately communicating the information to the oil palm industry. In addition, Field 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. Trial types vary between the different areas and depend on where the gaps in knowledge are and differences in soil type. Although the number of trials has generally been reduced in the NBPOL plantations, there new trials have been designed for future recommendations. Two new fertiliser trials were planted in 2015 in NBPOL-WNB and similar progeny seedlings were planted at RAIL, HOP, MBE, GPPOL and HOPL nurseries in 2016 for field planting in 2017. These new trials are planted with consideration of probable progeny effects on the oil palm responses to fertilisers. Yield data collection has started in Trial 154 at Bebere Plantation in 2016.

Across all sites, there was continued involvement with the industry in training. PNGOPRA was involved in training the plantations on leaf sampling techniques, processing and consignment for analysis. A workshop was also held for the TSD sections for the industry to cover all aspects of agronomic aspects of oil palm and related activities in the industry. Fertiliser trial data were compiled for fertiliser recommendations for both NBPOL and Hargy Oil Palms.

In 2016, Susan Tomda, Agronomist at Bialla resigned and new assistant agronomist, Stanley Yane was recruited to be stationed at Dami. The Agronomy team at Dami moved into the new office building while in Milne Bay the agronomy team moved into the MBE TSD office and field laboratory facility.

Abbreviations

AMC	Ammonium chloride (NH_4Cl)
AN	Ammonium nitrate (NH_4NO_3)
ANOVA	Analysis of variance (Statistical test used for factorial trials)
BA	Bunch ash (burnt EFB)
BNO	Number of bunches
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, $MgSO_4$)
LAI	Leaf area index
l.s.d	Least significant difference
mM	(millimoles per litre)
MOP	Muriate of potash (KCl)
n.s	See Sig.
p	Significance (probability that treatment affect is due to chance)
SBW	Single bunch weight
s.d	Standard deviation
s.e	Standard error
s.e.d	Standard error of the difference of the means
Sig.	Level of significance (n.s. not significant, * $p<0.05$, ** $p<0.01$, *** $p<0.001$
SOA	Ammonium sulphate ($(NH_4)_2SO_4$)
SOP	Potassium sulphate (K_2SO_4)
TSP	Triple superphosphate (mostly calcium phosphate, $CaHPO_4$)

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 K_2PO_4 followed by ICP-OES
Total P	Nitric/perchloric acid digestion, by ICP-OES
Exch. Ca, Mg, K & Na	IM NH_4 acetate extraction (pH7), meas. By ICP- OES
Exch. Al	IM KCl 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 HCl extraction, det. AA,exch. Mg subtracted
Total N	Dumas combustion
'Available' N	7 day anaerobic incubation, 2M KCl extraction of NH_4^+
Organic S	0.02 M K_2PO_4 extraction followed by ICP-OES for total S, then subtraction of sulphate-S
Sulphate-S	0.02 M K_2PO_4 extraction followed by ion chromatography
Hot water soluble B	0.01IM $CaCl_2$ extraction, det. By ICP-OES
Organic matter	Dumas combustion. Calculated at 1.72 x total carbon

B.2. New Britain Palm Oil - Dami

Stanley Yane and John Wange

B.2.1. Trial 154: Nitrogen fertiliser response trial on Tenera clonal materials at Bebere Plantation

(RSPO 4.2, 4.3, 4.6, 8.1)

B.2.1.1. *Summary*

N fertiliser levels did not affect yield and leaf tissue nutrient contents but there were visual differences between the different four clone lines for FFB, Leaf color and sizes. The trial will continue to year 10.

B.2.1.2. *Introduction*

The plantation industry is currently planting new selected clonal materials and this may continue into the future if it is the chosen strategy. There is expectation that the materials are high yielding and therefore high in nutrient demand to meet the crop growth and crop production demand. This fertilizer trial was established with the aim to add high N fertilizer rates with other nutrients none limiting to see how high the yields from these selected materials can be achieved. The information gained from this trial will be used for assisting fertilizer recommendations. Trial information is presented in Table 8.

Table 8 Trial 154 background information

Trial number	154	**Company**	Bebere Plantation - Division 1
Estate	Bebere Div 1	**Block No.**	Bebere MU 1111-06C
Planting Density	120	**Soil Type**	Volcanic
Pattern	Triangular	**Drainage**	Freely draining
Date planted	Feb 14	**Topography**	Flat
Age after planting	3 years	**Altitude**	
Harvesting Start	Nov 15 (20 month)	**Previous Land-use**	Oil palm 3rd generation
Treatment start	2016	**Area under trial soil type (ha)**	
Progeny	Known*	**Assistant Agronomist in charge**	Stanley Yane
Planting material	Dami DxP (clonal)		

B.2.1.3. *Methods*

Experimental design and treatments

The trial was established at Bebere Plantation in WNB in OPRS Progeny Field Trial 332. The MU was planted with four known Tenera clone lines (T-lines), T038, T118, T120 and T123. The materials were planted from road to road with varying number of rows each and replicated within and across 3 blocks. There were four fertiliser treatment levels. The first level was the standard fertilizer rates recommended for the age of palms in the plantations while the other 3 were high rates at increasing amounts (Table 9). The other same T-lines not treated with increased fertilizer rates were treated as control and identified as Fert level 1. These plots received the plantation recommended plantation fertilizer rates. The treatments were allocated to each of the 4 T-lines and were duplicated resulting in 24 plots. The plantation applied the recommended fertilizer rates and PNGOPRA applied the difference to top it up to the treatment rates.

Table 9 Trial 154 Treatment fertilizer levels

Treatment	Fertilizers and rates (kg/palm/year)				
	Urea	TSP	MOP	Kie	Borate (g)
Fert level - 1	0.45	0.6	0.2	0	0
Fert level - 2	1.2	2.0	1.0	2.0	100
Fert level - 3	2.3	2.0	1.5	2.0	100
Fert level - 4	4.7	2.0	2.5	2.0	100

Data collection

Yield data was collected by OPRS Breeding Section and required data for the experimental plots were extracted from the OPRS data. In addition to yield recording, physiological growth parameters were measured and leaf tissue sampling were collected for nutrient contents analysis.

Trial data was analysed to see the effects of treatment levels on the measured parameters, differences between the progenies and possible combine effects.

B.2.1.4. ***Results***

Yield and yield components

Yield and yield components were analysed as unbalanced ANOVA because the control was single data set from combined data from the similar clone T-lines that were in the plots and from within the same MU which were getting recommended plantation fertilizer rates. There was no effect of fertiliser levels on the FFB yield and yield components, however there were differences (p=0.008) in yield from the four different T-lines (Table 10). Although there was no effect of fertilisers on FFB yield production, there was a trend in yield and yield components increasing with fertiliser levels. FFB yield in T-line T038 and T123 were greater than the other 2 T-line by 2-4 tonnes (

Table 11).

Table 10 Trial 154 effects (*p values*) of treatments and T-lines on FFB yield and its components in 2016

Source	2016		
	FFB yield	BNO	SBW
Fert levels	0.779	0.849	0.539
T- lines	**0.008**	**0.047**	**<0.001**
Fert x T-lines	0.873	0.888	0.909
CV %	23.1	17.0	9.1

Table 11 Trial 154 main effects of N rate treatments on FFB yield, bunch number and single bunch weight in 2016

Treatments	2016		
	FFB yield (t/ha)	BNO/ha	SBW (kg)
Fert level - 1	9.1	2798	3.1
Fert level - 2	9.7	2932	3.3
Fert level - 3	10.1	3039	3.2
Fert level - 4	10.4	3017	3.4
l.s.d$_{0.05}$			
Clone - T038	**11.3**	**3185**	**3.5**
Clone - T118	**9.0**	**2937**	**3.1**
Clone - T120	**7.4**	**2534**	**2.9**
Clone - T123	**12.2**	**3300**	**3.7**
l.s.d$_{0.05}$	*2.273*	*600.9*	*0.38*
GM	10.0	2989	3.3
SE	2.29	504.4	0.30
CV %	22.8	17.0	9.1

Leaflets and rachis nutrient contents

Leaf samples were not collected from the palms in the MU which were not treated with increased fertilizer rates, that is the palms treated as control. Therefore results from only the plots other than the control are discussed. There was no effect of fertilizer treatment levels on leaf nutrient contents, however there were statistically significant differences between the progenies (Table 12 and Error! Reference source not found. **). The leaflet N, P, Ca and S were higher in progenies T038 and T123 than in the other 2 progenies (rial 154 effects (*p values*) of fertilizer levels and progenies on rachis nutrient contents in 2016**

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Fert levels	0.731	0.859	0.145	0.174	0.481	0.561
T-lines	0.426	0.598	**<0.001**	**0.032**	**0.001**	0.061
Fert x T-lines	0.111	0.803	0.223	0.408	0.518	0.431
CV %	8.6	16.5	8.2	8.7	8.0	12.8

Table 14). The high nutrient contents in the two progenies also correlated well with high yields reported for the two progenies in

Table 11. There were also differences in rachis P, K and Mg contents of the progenies but could not related well to the differences in yield (

Table 15). It was also observed that leaflet Mg contents in T038 and T123 were 0.20 %DM and 0.17 %DM respectively and could be considered deficient in these 2 progenies compared to the other progenies. These differences could influence yield responses to high N and K fertilizer rates in the future.

Table 12 Trial 154 effects (*p values*) of fertilizer levels and progenies on leaflet nutrient contents in 2016

Source	Leaflets nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fert levels	0.793	0.661	0.560	0.627	0.938	0.136	0.529	0.545	0.515
T-lines	0.288	**0.006**	**0.009**	0.093	**0.001**	**0.013**	0.337	0.134	**0.006**
Fert x T-lines	0.261	0.774	0.547	0.070	0.126	0.712	0.405	0.837	0.579
CV %	3.5	6.0	3.3	6.0	8.5	4.0	14.7	17.7	4.1

Table 13 Trial 154 effects (*p values*) of fertilizer levels and progenies on rachis nutrient contents in 2016

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Fert levels	0.731	0.859	0.145	0.174	0.481	0.561
T-lines	0.426	0.598	**<0.001**	**0.032**	**0.001**	0.061
Fert x T-lines	0.111	0.803	0.223	0.408	0.518	0.431
CV %	8.6	16.5	8.2	8.7	8.0	12.8

Table 14 Trial 154 main effects fertilizer levels and progenies on leaflet nutrient contents in 2016

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fert level - 2	15.1	2.90	0.158	0.59	0.21	1.11	0.44	30	0.217
Fert level - 3	15.0	2.90	0.159	0.59	0.20	1.11	0.44	34	0.217
Fert level - 4	15.1	2.83	0.156	0.58	0.21	1.15	0.47	31	0.213
l.s.d$_{0.05}$									
Clone - T038	15.0	**2.96**	**0.163**	0.62	**0.20**	**1.19**	0.42	35	**0.223**
Clone - T118	14.9	**2.83**	**0.156**	0.59	**0.22**	**1.10**	0.48	30	**0.212**
Clone - T120	15.4	**2.63**	**0.151**	0.56	**0.22**	**1.09**	0.43	35	**0.204**
Clone - T123	14.9	**3.08**	**0.161**	0.59	**0.17**	**1.12**	0.47	28	**0.225**
l.s.d$_{0.05}$		*0.220*	*0.00655*		*0.0223*	*0.0581*			*0.01135*
GM	15.1	2.88	0.158	0.59	0.21	1.12	0.45	32	0.216
SE	0.534	0.173	0.00516	0.0349	0.0175	0.0467	0.0661	5.64	0.00893
CV %	3.5	6.0	3.3	6.0	8.5	4.1	14.7	17.7	4.1

Table 15 Trial 154 main effects fertilizer levels and progenies on rachis nutrient contents in 2016

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Fert level - 2	5.36	0.350	0.118	1.93	0.116	0.81
Fert level - 3	5.51	0.346	0.116	2.02	0.122	0.83
Fert level - 4	5.34	0.362	0.108	1.85	0.117	0.78
l.s.d$_{0.05}$						
Clone - T038	5.12	0.342	**0.100**	**1.73**	**0.112**	0.76
Clone - T118	5.47	0.378	**0.135**	**1.92**	**0.113**	0.88
Clone - T120	5.55	0.356	**0.129**	**2.03**	**0.111**	0.86
Clone - T123	5.47	0.334	**0.092**	**2.04**	**0.137**	0.72
l.s.d$_{0.05}$			*0.0118*	*0.214*	*0.01209*	
GM	5.40	0.352	0.114	1.93	0.118	0.81
SE	0.4643	0.0581	0.00933	0.169	0.0095	0.1031
CV %	8.6	16.5	8.2	8.7	8.0	12.8

B.2.1.5. *Conclusion*

There was no effect of fertilizer levels on FFB yield and leaf nutrient contents. However there were differences between the clone lines in leaflet N, P, Mg, Ca and S contents, The high nutrient contents observed in progenies T038 and T123 correlated well with high FFB yields in these two progenies. There were no effect on leaflet K contents and this will be monitored with time and increased yields. The trial is recommended to continue.

B.3. Hargy Oil Palms – Bialla

Susan Tomda, Andy Ullian and Peter Mupa

B.3.1. Trial 211: Systematic N Fertiliser Trial on Volcanic soils, NAVO Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.3.1.1. *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 and 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 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. N fertilizers significantly increased yield and yield components, and most leaf tissue nutrient contents. Addition of TSP in 2014 has yet to affect yields either alone or in combination with N fertilizers. 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.

B.3.1.2. *Introduction*

Factorial fertiliser trials with randomised spatial allocation of treatments generally showed poor responses to fertilisers in NBPOL trials since late 1980s. Yields and tissue nutrient concentrations in control plots were generally higher than it would be expected. It was suspected that fertiliser may be moving from plot to plot and or nutrients were poached from the neighbouring 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 neighbouring plantations on similar soil types. Trial background information is presented in Table 16.

Table 16 Trial 211 background information

Trial number	211	**Company**	Hargy Oil Palm Ltd-HOPL
Estate	Navo Plantation - Karla Div. 3	**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	Mar-98	**Topography**	Flat and swampy
Age after planting	18 years	**Altitude**	164 m asl
Treatments 1st applied	Nov-01	**Previous Land-use**	Sago and forest
Progeny	unknown	**Area under trial soil type (ha)**	37.16
Planting material	Dami D x P	**Agronomist in charge**	Susan Tomda

B.3.1.3. *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 17). 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. In 2014, TSP treatment was included in the trial. Rates of 0.0, 0.5, 1.0, 2.0 and 4.0 kg/palm/year was imposed on the trial. Each rate was randomly allocated to the existing 8 replicates. This meant there were duplicates of 4 of the TSP rates imposed on the trial.

Due to unavailability of AN in 2016, AC was used instead with equivalent N content and 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 17 Trial 211 Nitrogen treatments and rates in kg/palm/year

N fertiliser code	N0	N1	N2	N3	N4	N5	N6	N7	N8
Ammonium chloride(AC)	0.00	0.96	1.92	2.88	3.84	4.8	5.76	6.72	7.68
N rate(equivalent)	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00

Data Collection

Yield recording, physiological growth measurements and leaf tissue sampling were done as per the standard trial management SOP (Appendix 1)

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. A general ANOVA was also carried out to check possible main effects of N and P and combined effects of the two fertilizers.

B.3.1.4. ***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 2016 and the combined 2014-2016 period (Table 18). FFB yield increased with N rate from 27.5 at nil N to a maximum of 38.9 t/ha/year in 2016. Yield also increased with N rate in 2014-2016 (Table 18). Effect of N fertilizer was consistent on FFB yield and its components since 2004 (**Error! Reference source not found.**). A separate analysis on the effect of TSP rates and combined effect of N and TSP on FFB yield and yield components indicated no main and combined effects on yields.

Table 18 Trial 211 main effects of N rate treatments on FFB, yield (t/ha), bunch number (BHA) and single (SBW) (kg/bunch) for 2016 and 2014-2016

N rate	Equivalent AC rate	2016			2014-2016		
(kg/palm/year)	(kg/palm/year)	FFB yield (t/ha)	BHA	SBW (kg)	FFB yield (t/ha)	BHA	SBW (kg)
0.00	0.00	27.5	1151	23.8	27.3	1161	23.4
0.25	0.96	31.2	1244	25.0	30.5	1242	24.5
0.50	1.92	31.4	1203	26.1	31.2	1230	25.3
0.75	2.88	34.4	1275	27.0	32.7	1257	26.0
1.00	3.85	35.5	1308	27.1	33.5	1281	26.1
1.25	4.81	35.7	1280	27.9	34.5	1286	26.8
1.50	5.77	37.0	1347	27.5	34.5	1316	26.2
1.75	6.73	38.9	1405	27.8	36.4	1374	26.5
2.00	7.69	37.4	1358	27.6	35.1	1335	26.3
L.S.D $_{0.05}$		*2.34*	*86.638*	*0.866*	*2.171*	*82.974*	*0.74*
Significance		**p<0.001**	**p<0.001**	**p<0.001**	**p<0001**	**p<0.001**	**p<0.001**
GM		34.3	1285	26.6	32.8	1276	25.7
SE		2.33	86.498	0.865	2.167	82.839	0.74
CV%		6.8	6.7	3.2	6.6	6.5	2.9

P values <0.05 are in bold

Yield response over time

There were significant responses to effects of the N treatments over time (2004-2016) with yield performing above 30 t/ha (Figure 3). Yield was maintained above 30 t/ha with increasing N rates over time. 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.

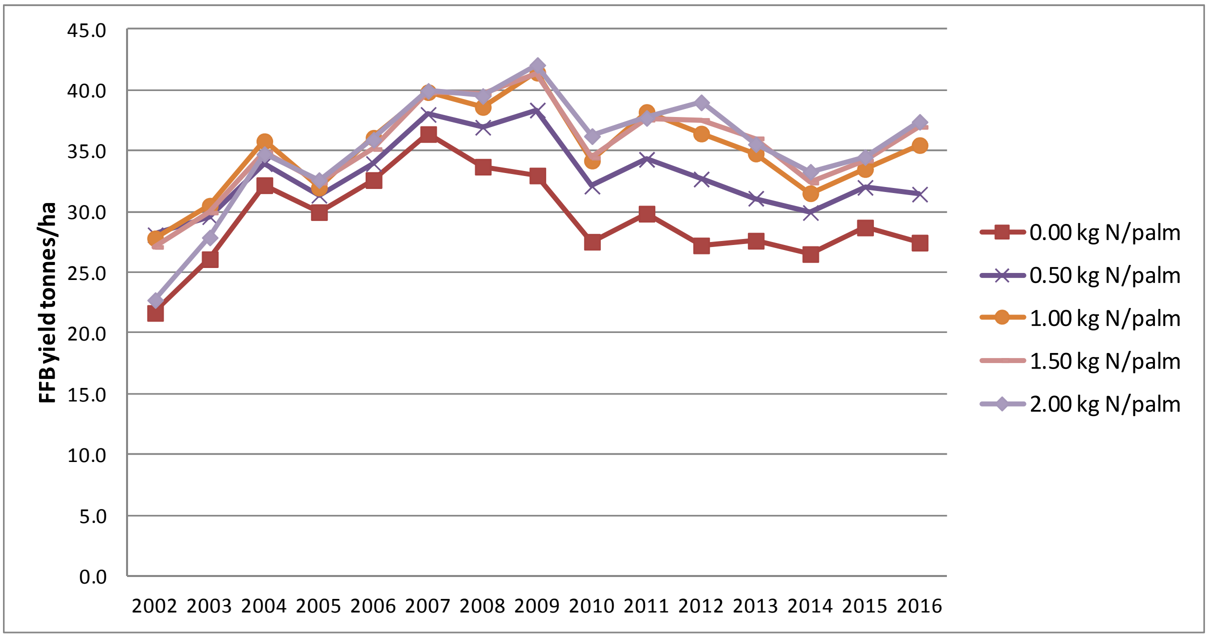


Figure 3 Trial 211 Yield trend from 2002 to 2016 for 5 rates of N (kg/palm). Significant differences were reported since 2005. Note: in 2004 the palms were 6 years old

The relationship between average FFB yield and N rates for the period 2014 to 2016 is presented in **Error! Reference source not found.**. There was a very strong quadratic relationship between N rates and FFB yield (R^2=0.9646) in the nature of the graph. However, yield response decreased with N rates. FFB yield increased with N rates (0.25-1.5 N kg) and curved off thereafter. 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 and actually have negative effect on yield.

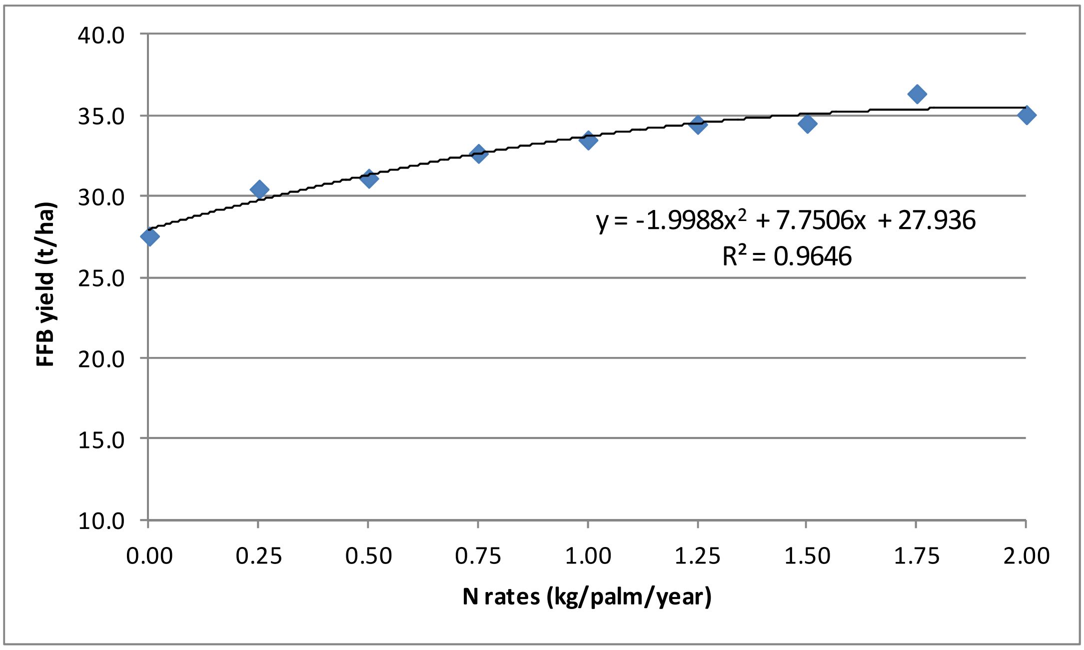


Figure 4 Trial 211 N rates and FFB yield response curve for 2014-2016

Effects of treatments on leaf tissue nutrient concentrations

The effect of N fertilizer on leaf tissue nutrient contents in 2016 is presented in Table 19 and

Table 20. N rates did have an effect on leaflet N (p<0.001) and also on other nutrient levels. Leaflet and rachis cations (except rachis Ca) were significantly reduced with N rates. Leaflet Mg contents decreased with N rates equal to or less than 0.20 % DM, which could referred to as deficient. Lack of Mg in these volcanic soils could limiting responses to high N and P fertilizer rates in these soils.

N rates	Equivalent AC rate	Leaflet nutrient contents (% DM) except B in ppm								
(kg/palm/yr)	(kg/palm/yr)	Ash	N	P	K	Mg	Ca	Cl	B	S
0.00	0.00	14.4	2.15	0.137	0.57	0.25	0.95	0.45	23	0.184
0.25	0.96	14.8	2.16	0.134	0.56	0.24	0.97	0.49	24	0.184
0.50	1.92	14.9	2.20	0.138	0.57	0.22	0.96	0.51	22	0.188
0.75	2.88	15.0	2.23	0.138	0.56	0.22	0.94	0.44	21	0.186
1.00	3.85	15.2	2.33	0.137	0.57	0.20	0.91	0.47	20	0.186
1.25	4.81	15.4	2.36	0.139	0.56	0.20	0.90	0.49	21	0.190
1.50	5.77	15.3	2.38	0.142	0.58	0.20	0.88	0.47	21	0.190
1.75	6.73	15.3	2.38	0.141	0.58	0.18	0.87	0.49	21	0.193
2.00	7.69	15.4	2.40	0.141	0.57	0.19	0.87	0.50	21	0.191
$L.S.D_{0.05}$		0.527	0.0911	0.00309		0.0176	0.0325	0.0450	1.183	0.00518
Significance		p=0.006	p<0.001	p<0.001	p=0.778	p<0.001	p<0.001	p=0.027	p=0.002	p+0.005
GM		15.1	2.29	0.138	0.57	0.21	0.92	0.48	21	0.188
SE		0.527	0.091	0.00309	0.0295	0.0175	0.0324	0.0448	1.183	0.00517
CV %		3.5	4.0	2.2	5.2	8.3	3.5	9.4	8.5	2.8

Table 19 Trial 211 effects of N rate treatments on leaflet nutrients (% DM except B mg/kg) concentrations in 2016
p values less than 0.05 are in bold

Table 20 Trial 211 effects of N rate treatments on rachis nutrients (% DM) concentrations in 2016

N rates	Equivalent AC rate	Rachis nutrient contents (% DM)					
(kg/palm/yr)	(kg/palm/yr)	Ash	N	P	K	Mg	Ca
0.00	0.00	6.55	0.378	0.248	2.54	0.102	0.61
0.25	0.96	6.50	0.353	0.202	2.52	0.093	0.61
0.50	1.92	6.69	0.374	0.196	2.55	0.093	0.67
0.75	2.88	6.43	0.402	0.182	2.61	0.097	0.70
1.00	3.85	6.68	0.406	0.161	2.56	0.090	0.68
1.25	4.81	6.64	0.416	0.151	2.49	0.088	0.70
1.50	5.77	6.30	0.411	0.150	2.46	0.085	0.70
1.75	6.73	6.46	0.414	0.142	2.42	0.086	0.66
2.00	7.69	6.31	0.408	0.134	2.34	0.084	0.67
$L.S.D_{0.05}$			0.0417	0.0264		0.00771	0.0497
Significance		p=0.422	p=0.037	p<0.001	p=0.083	p<0.001	p<0.001
GM		6.50	0.396	0.174	2.50	0.091	0.67
SE		0.4153	0.0416	0.0264	0.168	0.0077	0.0496
CV %		6.4	10.5	15.2	6.7	8.5	7.4

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 in **Error! Reference source not found.**. The N content was averaged for 2014 to 2016 to minimize year to year variations. There was a strong quadratic relationship between N rates (kg/palm/yr) and leaflet N contents (R^2=0.9482). Leaflet N content was low at 2.30 %DM at 0.75 N kg/palm/yr. Leaflet N perform well above 2.35 %DM at 1.00 kg N 0.75 kg N to 1.75kg N but still below the critical level (N=2.45 % DM). The deficient Mg contents at high N rates could be limiting further increase in leaflet N contents with N fertilizer rates.

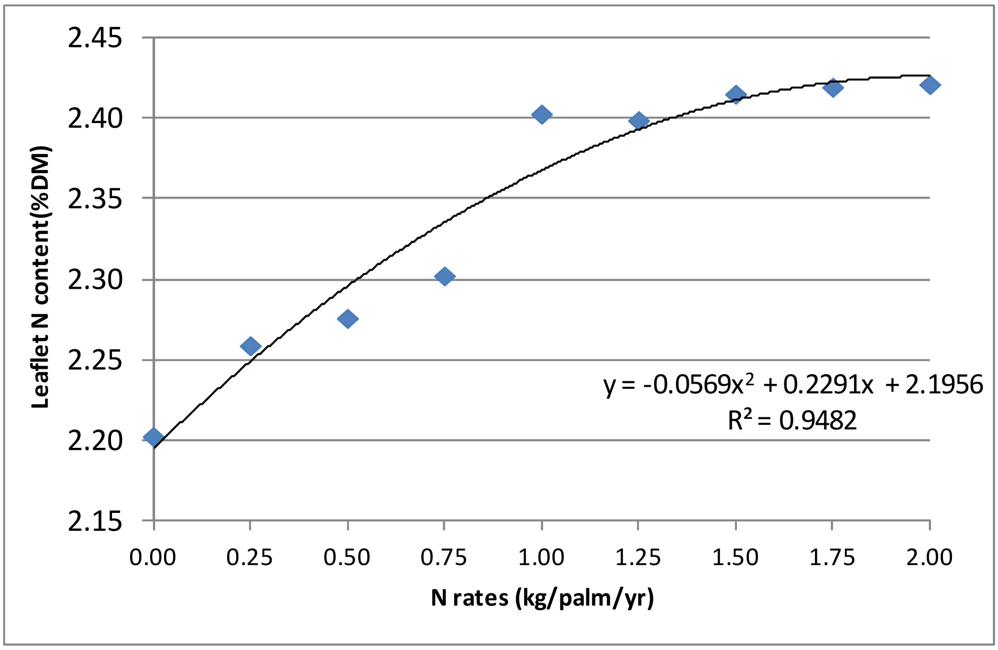


Figure 5 Trial 211 Relationship between N rates and leaflet N content averaged for 2014 to 2016

Effects of TSP fertilizer on leaf tissue P contents

A separate analysis of effects of TSP on leaf P contents showed that only leaflet P contents were increased from 0.132 % DM at 0.0 kg TSP/palm to 0.141 %DM at 0.5 kg TSP /palm/year. There was no further increase at rates 2 and 4 kg TSP/palm/year. There was also no main and combined fertilizer N and P effects on rachis P contents. The lack of responses to TSP levels were probably limited by falling and deficient Mg contents in the leaflets.

B.3.1.5. *Conclusion*

Nitrogen rates had a significant effect on yield (t/ha), its components (BHA and SBW) and leaflet N consecutively since 2004. The optimum N rate for FFB production at Navo is between 0.75 and 1.0 kg N/palm/year which is 3-4 kg AC (1.6-2.2 kg Urea/palm/year). 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. Addition of TSP has yet to affect yield either alone or in combination with N fertilisers. Responses to N and P fertilizers is probably affected by low Mg contents in the leaflets.

B.3.2. Trial 214: Phosphorous (TSP) Fertiliser Placement Trial on Volcanic soils, Hargy Plantation

(RSPO 4.2, 4.3, 4.6, 8.1)

B.3.2.1. *Summary*

The soils at Hargy have very high P retention capacity due to high allophanic clay mineral content. This affects P availability 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. To date 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 with the view to saturate the clay mineral surfaces and make excess P available for uptake. In 2016, there was no significant effect on the yield and its components, however rachis P contents were increased. It was recommended the trial continue.

B.3.2.2. *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 and
(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 to take up. 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 has 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 in Table 21.

Table 21 Trial 214 background information

Trial number	214	**Company**	Hargy Oil Palms Ltd-HOPL
Estate	Hargy - Division 3	**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	22 years	**Altitude**	263m 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
Treatment started	2008		

B.3.2.3. *Materials and Methods*

Experimental design and Treatment

The trial had 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 22). Treatment fertilisers were applied in split application every year. The treatment rates were half the current rates from 2007-2011, 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 22 Trial 214 fertiliser treatments and placement information

	Details of TSP treatment				
Levels	1	2	3	4	5
Rates (kg/palm/year)	0.0	2.0	2.0	4.0	4.0
and placement	Nil	WC	FP	WC	FP

Trial management, data collection and analysis

Yield data recording, vegetative measurements and sampling of frond tissues for analysis were carried out as detailed in Appendix 1.

B.3.2.4. *Results*

Fresh fruid bunch yield running 3 years mean from 2007 to 2016 are presented in Table 23. The data is presented in 3 years running mean to smooth out annual yield fluctuations. There was no significant effect of TSP rates and placement on yield since 2007.

Table 23 Trial 214 running 3 year mean FFB yield trend from 2007 to 2016

TSP rates and placement	FFB yield (t/ha)							
(kg/palm/year)	2007-2009	2008-2010	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016
0 – Control	23.4	22.7	22.8	23.7	24.2	26.8	26.7	25.7
2 – WC	25.0	24.4	24.9	25.2	25.0	27.3	26.8	26.8
2 – FP	23.0	23.2	24.4	24.9	25.0	26.9	26.9	26.0
4 – WC	24.0	23.2	24.6	25.2	25.1	26.1	26.3	26.3
4 – FP	24.5	24.4	25.5	26.4	25.6	27.0	26.6	26.7
Grand mean	24.0	23.6	24.4	25.1	25.0	26.8	26.7	26.3
Significance	ns	ns	ns	ns	ns	ns	ns	ns
CV %	10.9	8.2	9.0	8.8	10.8	12.2	10.6	9.4

ns =not statistically significant

TSP rates and placement did not affect yield and yield components in both 2016 and 2014-2016 (Table 24).The mean ffb yield was 25.2 and 26.3 t/ha/year in 2016 and 2014-2016 respectively.

Table 24 Trial 214 main effects of AN on yield and yield components in 2016 and 2014-2016

	2016			**2014-2016**		
TSP rates and placement	FFB yield	BHA	SBW	FFB yield	BHA	SBW
(kg/palm/year)	(t/ha)		(kg)	(t/ha)		(kg)
0 – Control	24.3	839	29.0	25.7	1006	25.9
2 – WC	25.4	818	31.0	26.8	1001	27.2
2 – FP	24.7	848	29.1	26.0	997	26.3
4 – WC	25.3	876	29.0	26.3	985	26.9
4 – FP	26.5	938	28.2	26.7	1040	25.8
Significance	ns	ns	ns	ns	ns	ns
GM	25.2	864	29.3	26.3	1006	26.4
SE	3.497	118.02	1.682	2.482	74.8	1.375
CV %	13.9	13.7	5.7	9.4	7.4	5.2

ns =not statistically significant

Effects of treatments on leaf (F17) nutrient concentrations

The effects of P placement treatments on leaflet tissue nutrient contents are presented in Table 25 and Table 26. TSP treatments significantly increased rachis P ($p<0.001$) however there was no effect of placement. TSP also had a significant effect on leaflet K ($p=0.049$) and rachis Mg ($p=0.023$). Except for mean leaflet Mg, mean leaflet N, P, Ca, Cl, B and rachis K contents were within the optimum range. Mean leaflet Mg contents was 0.18 %DM which was deficient, and this could be limiting responses to N and P in these soils.

Table 25 Trial 214 effects of treatments on frond 17 leaflet nutrient concentrations in 2016

TSP rates and placement	Leaflet nutrient contents (% DM except B in mg/kg)								
(kg/palm/year)	Ash	N	P	K	Mg	Ca	Cl	B	S
0-Control	15.2	2.37	0.136	0.52	0.18	0.98	0.43	20	0.193
2-WC	15.3	2.37	0.140	0.53	0.17	1.00	0.43	21	0.191
2-FP	15.3	2.34	0.134	0.54	0.18	0.96	0.45	21	0.186
4-WC	15.4	2.34	0.138	0.51	0.18	1.01	0.43	22	0.188
4-FP	15.4	2.36	0.140	0.52	0.18	0.99	0.45	22	0.189
Significance	p=0.653	p=0937	p=0.285	**p=0.049**	p=0.748	p=0.607	p=0.942	p=0.925	p=0.367
GM	15.3	2.35	0.138	0.52	0.18	0.99	0.44	21	0.190
SE	0.318	0.0841	0.0051	0.019	0.017	0.053	0.064	3.527	0.0063 8
CV %	2.1	3.6	3.7	3.6	9.5	5.4	14.7	16.6	3.4

ns =not statistically significant

Table 26 Trial 214 effects of treatments on frond 17 rachis nutrient concentrations in 2016

TSP rates and placement	Rachis nutrient contents (% DM)					
(kg/palm/year)	Ash	N	P	K	Mg	Ca
0-Control	5.88	0.322	0.064	1.72	0.085	0.71
2-WC	5.89	0.316	0.082	1.64	0.088	0.76
2-FP	6.29	0.373	0.099	1.60	0.099	0.76
4-WC	5.93	0.346	0.123	1.62	0.095	0.83
4-FP	6.11	0.348	0.130	1.62	0.102	0.79
Significance	p=0.710	p=0.142	**p<0.001**	p=0.460	**p=0.023**	p=0.152
GM	6.02	0.341	0.100	1.64	0.094	0.77
SE	0.592	0.0403	0.0188	0.119	0.009	0.077
CV %	9.8	11.8	18.9	7.2	9.5	10.0

ns =not statistically significant

Conclusion

TSP rates did not have a significant effect on FFB yield and its components (BHA and SBW) but affected rachis P contents. The responses by leaf tissue P contents did not translate to yield. The responses to TSP fertilizer would be expected 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. The low Mg levels in the leaflets could be affecting the responses to N and P fertilizers including where placed under the palms. In the meantime it is recommended that TSP fertilizers are placed in a meter band outside of the weeded circle for convenience of management and supervision checks. It was recommended the trial continue with the current increased TSP rates.

B.3.3. Trial 217: NPK trial on Volcanic soils at Navo Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.3.3.1. *Introduction*

The soils at Navo are relatively young being derived from volcanic ash and alluvial materials. Past fertiliser trials on these soils have shown significant FFB yield responses to nitrogen fertilisers. This N, P and K fertiliser trial aimed develop fertiliser recommendations for the new replant on similar soils at Navo. Trial information is presented in Table 27. Formal recording commenced in Dec 2014 and treatment application started in 2015 (4 years after planting).

Table 27 Trial 217 background information

Trial number	217	**Company**	Hargy Oil Palms Ltd- HOPL
Estate	Navo	**Block No.**	Field 5 Block K
Planting Density	128 palms/ha	**Soil Type**	Volcanic
Pattern	Triangular	**Drainage**	Well drained
Date planted	Dec-11	**Topography**	Flat slightly sloping
Age after planting	5 years	**Altitude**	159 masl
Treatment started	2015	**Previous Land use**	Oil palm
Recording started	Dec-14	**Area under trial soil type (ha)**	13.34
Progeny	known	**Agronomist in charge**	Susan Tomda
Planting material	Dami D x P		

B.3.3.2. *Materials and method*

Design and Treatment

The trial was planted in December 2014 with four known progenies (Dami materials 09080221, 09070112, 09071493 and 09110165). The four progenies were randomly allocated four times totaling 16 palms in a plot. There were 50 plots planted and 24 plots were selected for the experiment using petiole cross section measurements to eliminate extreme plots. Prior to planting, 100 g TSP was placed into each of the planting holes.

The design was a N P K Central Composite arrangement similar to the design used in Trial 216 at Barema.

B.3.3.3. *Results and discussion*

2016 was the second year of treatment application and data collection and analysis indicated no significant responses to the fertilizer treatments (p=0.615). There was also no significant responses (p=0.406) for the combined data for 2015-2016. The estimated yield parameters for 2016 are presented in Table 28. The estimated yield at nil fertilizers was 19.1 t/ha/year. The FFB yield range was 21.7 – 31.3 t/ha/year and 18.5-26.5 t/ha/year in 2016 and 2015-2016 respectively.

Table 28 Estimated yield parameters from regression analysis for 2016

Parameter	estimate	s.e.	t(14)	t pr.
Constant	19.1	6.28	3.04	0.009
AC	1.51	2.1	0.72	0.484
TSP	8.5	5.05	1.69	0.114
MOP	1.71	2.02	0.85	0.411
AC squared	0.031	0.199	0.16	0.878
TSP squared	-2.41	1.79	-1.35	0.2
MOP squared	-0.123	0.287	-0.43	0.675
AC x MOP	-0.488	0.407	-1.2	0.25
AC x TSP	-1.2	1.02	-1.18	0.259
AC x TSP X MOP	0.293	0.229	1.28	0.222

B.3.3.4. *Conclusion*

The trial to continue.

B.3.4. Trial 220: NPKMg Fertiliser Trial on Volcanic soils, Pandi Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.3.4.1. *Summary*

The soils at Pandi estate are young volcanic soils but different from other soils with basalt gravels at depth. This is the first fertilizer trial on this particular soil type in the WNB volcanic soils types. The trial tests responses to N, P, K and Mg in factorial combinations. Though 2016 was second year of fertilizer treatments applications, already responses to the fertilizers were recorded. This trial is recommended to continue.

B.3.4.2. *Introduction*

The soils at Pandi Estate are young being formed recently from Mt Ulawun volcanic materials and therefore are very friable to loose, structureless and are weakly to moderately developed with high infiltrability properties. The surface soils are sandy loam to loamy sand and have buried soils at depth. Sand/gravel and pure basalt gravels layers at depth are common features throughout the landscape. Soils at Alaba are different from those at Navo. The soil deepen to 200 cm and has basalt gravel layers setting limits to nutrient storage capacity. The trial area and surrounding blocks are on slopes of varying steepness ranging from flat in the floodplains and steeper with altitude. This trial is established with the aim to provide information for fertiliser recommendation in the Alaba- Bakada areas. There was no fertilizer trial on this soil type in the plantations in the past. Trial information is presented in Table 29.

Table 29 Trial 220 background information

Trial number	220	**Company**	Hargy Oil Palms Ltd-HOPL
Estate	Pandi	**Block No.**	Bakada Plantation,Field 5, Blk B-03
Planting Density	128	**Soil Type**	Volcanic
Pattern	Triangular	**Drainage**	Freely draining
Date planted	Jun-11	**Topography**	Rising and hilly
Age after planting	5 years	**Altitude**	90 m asl
Recording Start	Dec-14	**Previous Land-use**	Forest (Primary)
Treatment start	2015		
Progeny	Known*	**Area under trial soil type (ha)**	30.69
Planting material	Dami D x P	**Agronomist in charge**	Susan Tomda

B.3.4.3. *Methods*

Experimental design and Treatments

The trial was established at Alaba in 2011. Sixteen known Dami progenies were selected and randomly planted in 100 plots. The 16 palms were surrounded by 20 palms of unknown progenies to act as guard row palms giving a total of 36 palms per plot. Measurements were taken from the 16 palms. The different progenies were planted in each of the plots to remove progeny effects. Sixty four plots were selected from the 100 plots for the trial.

The trial design was a RCBD of a factorial confounded single replication of 4 levels of N (Urea), 4 levels of K (MOP), 2 levels of P (TSP) and 2 levels of Mg (Kieserite). The treatment rates are presented in Table 30.

Table 30 Trial 220 Fertiliser levels and treatments in kg/palm/year

Treatments	Levels			
	1	2	3	4
Urea	1.0	2.0	3.0	4.0
MOP	0.0	1.0	2.0	3.0
TSP	0.0	2.0		
Kieserite	2.0	2.0		

Data collection

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

Statistical Analysis

Yield and its components and tissue nutrient concentration were analysed using ANOVA (General Analysis of Variance

B.3.4.4. *Results and discussion*

Effects of treatment on FFB yield and its components

Urea, TSP and kieserite did not affect yield and yield components while MOP only affected single bunch weight in 2016 and 2015-2016 at p=0.004 and p=0.027 respectively (Table). Though not statistically significant, MOP also appeared to increase FFB yield from 28 t/ha/year at MOP-1 to 30.7 t/ha/year at MOP-4 in 2016.

Table 31 Trial 220 main effects of fertilizer treatments on FFB yield (t/ha) and its components in 2016 and 2015-2016

Treatments	2016			2015-2016		
	FFB yield (t/ha)	BNO/ha	SBW(kg)	FFB yield (t/ha)	BNO/ha	SBW(kg)
Urea-1	28.9	2999	9.6	22.1	2652	8.1
Urea-2	29.7	2995	9.9	22.6	2654	8.3
Urea-3	27.9	2932	9.5	20.9	2488	8.1
Urea-4	29.7	3083	9.6	23.5	2774	8.3
MOP-1	28.0	2987	**9.4**	21.7	2655	**8.0**
MOP-2	27.9	2966	**9.4**	21.1	2570	**8.0**
MOP-3	29.6	2969	**9.9**	22.5	2617	**8.3**
MOP-4	30.7	3088	**9.9**	23.7	2727	**8.5**
l.s.d $_{0.05}$			*0.538*			*0.537*
TSP-1	29.2	3020	9.6	22.7	2681	8.3
TSP-2	28.9	2984	9.7	21.8	2603	8.1
Kieserite-1	29.0	2973	9.8	22.2	2619	8.2
Kieserite-2	29.1	3032	9.6	22.4	2665	8.2
GM	29.0	3002	9.7	22.3	2642	8.2
SE	4.094	381.8	0.529	3.824	414	0.547
CV%	14.1	12.7	5.5	17.2	15.7	6.6

p values <0.05 shown in bold

Effects of treatments on leaf nutrient concentrations

The effects of the fertilizers on leaf nutrient contents in 2016 are presented in Table 32 and Table 33. Urea only affected rachis K (p=0.008) while MOP affected leaflet K, Mg and Cl and rachis N, P, and K nutrient contents. TSP affected leaflet Cl and rachis P, K and Mg and kieserite affected rachis K only. 2016 was the second year of fertilizer treatments applications and effects of fertilizer treatments on the leaf nutrient contents are already observed.

The 2016 leaflets and rachis tissue nutrient contents results are presented in (Table 34) and

Treatment	Leaflet nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	12.6	2.61	0.157	0.62	0.28	1.15	0.24	24	0.219
Urea-2	12.6	2.65	0.161	0.65	0.28	1.15	0.20	26	0.224
Urea-3	12.4	2.65	0.160	0.65	0.28	1.15	0.24	24	0.224
Urea-4	12.8	2.65	0.158	0.63	0.28	1.15	0.24	25	0.220
l.s.d $_{0.05}$									
MOP-1	12.6	2.60	0.159	**0.66**	**0.29**	1.13	**0.20**	25	**0.219**
MOP-2	12.8	2.64	0.159	**0.65**	**0.28**	1.15	**0.18**	26	**0.223**
MOP-3	12.6	2.65	0.160	**0.64**	**0.27**	1.14	**0.27**	25	**0.224**
MOP-4	12.5	2.67	0.157	**0.61**	**0.26**	1.18	**0.28**	24	**0.221**
l.s.d $_{0.05}$				*0.0220*	*0.0100*		*0.0383*		*0.00449*
TSP-1	12.8	2.64	0.158	0.64	0.28	1.15	**0.21**	25	0.223
TSP-2	12.4	2.64	0.160	0.64	0.28	1.14	**0.26**	25	0.221
l.s.d $_{0.05}$							*0.0271*		
Kieserite-1	12.7	2.62	0.159	0.65	0.27	1.15	0.23	25	0.222
Kieserite-2	12.6	2.66	0.159	0.63	0.28	1.15	0.23	25	0.222
GM	12.6	2.64	0.159	0.64	0.28	1.15	0.23	25	0.222
SE	0.929	0.0926	0.005	0.0306	0.0198	0.0614	0.0524	2.32	0.0062
CV%	7.4	3.5	3.2	4.8	7.1	5.3	22.7	9.4	2.8

Table 35. Urea increased the rachis N contents. MOP increased leaflets Cl and S and rachis N, P and K contents while at the same time lowered leaflet K and Mg contents. TSP increased leaflet Cl and rachis P, K and Mg contents. Kieserite lowered rachis K contents.

Except for MOP affecting SBW, the effects of the other 3 fertilisers seen on the leaflets nutrient contents did not translate to yield responses. Early indications are that palms grown on this particular soil type will be responsive to fertilizers in the future.

Table 32 Trial 220 effects (*p values*) of treatments on leaflet nutrient contents in 2016

Source	Leaflet nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.612	0.516	0.068	0.016	0.723	0.997	0.166	0.115	**0.049**
MOP	0.712	0.172	0.369	**<.001**	**<.001**	0.149	**<.001**	0.211	0.143
TSP	0.093	0.880	0.108	0.306	0.256	0.519	**<.001**	0.766	0.362
Kieserite	0.629	0.160	0.636	**0.040**	**0.042**	0.799	0.938	0.557	0.926
Urea x MOP	0.331	0.383	0.810	0.026	0.638	0.66	0.059	0.115	0.857
Urea x TSP	0.131	0.410	0.235	0.021	0.778	0.129	0.108	0.879	0.580
Urea x Kieserite	0.723	0.382	0.817	0.310	0.745	0.921	0.273	**0.037**	0.873
MOP x TSP	0.779	0.871	0.560	0.140	0.314	0.327	0.622	0.280	0.946
MOP x Kieserite	0.063	0.896	0.560	0.349	0.55	0.553	**0.006**	0.971	0.891
TSP x Kieserite	0.524	0.569	0.223	0.418	0.714	0.921	0.231	0.627	0.366
CV %	7.4	3.5	3.2	4.8	7.1	5.3	22.7	9.4	2.8

Table 33 Trial 220 effects (*p values*) of treatments on rachis nutrient contents in 2016

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Urea	0.761	**0.008**	0.343	0.335	0.093	0.199
MOP	0.086	**0.010**	**0.002**	**<.001**	0.067	0.065
TSP	0.450	0.272	**0.002**	**0.031**	**0.021**	0.307
Kieserite	0.163	0.930	0.110	**0.043**	0.216	0.357
Urea x MOP	0.295	**0.042**	0.541	0.769	0.725	0.247
Urea x TSP	0.579	**0.005**	0.967	0.469	0.706	0.435
Urea x Kieserite	0.950	**0.027**	0.280	0.812	**0.050**	0.868
MOP x TSP	0.696	0.061	0.800	0.493	0.745	0.623
MOP x Kieserite	0.319	0.318	0.793	0.069	**0.040**	0.166
TSP x Kieserite	0.746	0.275	0.236	0.771	0.065	0.831
CV %	8.2	11.9	15.9	8.4	8.1	10.5

Table 34 Trial 220 effects of treatments on leaflet tissue nutrient concentrations in 2016 p values <0.05 shown in bold

Treatment	Leaflet nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	12.6	2.61	0.157	0.62	0.28	1.15	0.24	24	0.219
Urea-2	12.6	2.65	0.161	0.65	0.28	1.15	0.20	26	0.224
Urea-3	12.4	2.65	0.160	0.65	0.28	1.15	0.24	24	0.224
Urea-4	12.8	2.65	0.158	0.63	0.28	1.15	0.24	25	0.220
l.s.d$_{0.05}$									
MOP-1	12.6	2.60	0.159	**0.66**	**0.29**	1.13	**0.20**	25	**0.219**
MOP-2	12.8	2.64	0.159	**0.65**	**0.28**	1.15	**0.18**	26	**0.223**
MOP-3	12.6	2.65	0.160	**0.64**	**0.27**	1.14	**0.27**	25	**0.224**
MOP-4	12.5	2.67	0.157	**0.61**	**0.26**	1.18	**0.28**	24	**0.221**
l.s.d$_{0.05}$				*0.0220*	*0.0100*		*0.0383*		*0.00449*
TSP-1	12.8	2.64	0.158	0.64	0.28	1.15	**0.21**	25	0.223
TSP-2	12.4	2.64	0.160	0.64	0.28	1.14	**0.26**	25	0.221
l.s.d$_{0.05}$							*0.0271*		
Kieserite-1	12.7	2.62	0.159	0.65	0.27	1.15	0.23	25	0.222
Kieserite-2	12.6	2.66	0.159	0.63	0.28	1.15	0.23	25	0.222
GM	12.6	2.64	0.159	0.64	0.28	1.15	0.23	25	0.222
SE	0.929	0.0926	0.005	0.0306	0.0198	0.0614	0.0524	2.32	0.0062
CV%	7.4	3.5	3.2	4.8	7.1	5.3	22.7	9.4	2.8

Table 35 Trial 220 effects of treatments on rachis tissue nutrient concentrations in 2016 p values <0.05 shown in bold

Rachis nutrient contents (%DM)						
	Ash	N	P	K	Mg	Ca
Urea-1	5.24	**0.317**	0.097	1.98	0.115	0.85
Urea-2	5.30	**0.329**	0.103	1.99	0.107	0.79
Urea-3	5.25	**0.365**	0.094	2.00	0.109	0.83
Urea-4	5.39	**0.323**	0.102	2.08	0.112	0.80
l.s.d$_{0.05}$		*0.0286*				
MOP-1	5.16	**0.321**	**0.089**	**1.86**	0.110	0.83
MOP-2	5.17	**0.313**	**0.094**	**1.97**	0.106	0.77
MOP-3	5.34	**0.360**	**0.101**	**2.05**	0.110	0.83
MOP-4	5.52	**0.341**	**0.111**	**2.16**	0.115	0.85
l.s.d$_{0.05}$		*0.0286*	*0.0113*	*0.1214*		
TSP-1	5.34	0.328	**0.092**	**2.06**	**0.108**	0.81
TSP-2	5.26	0.339	**0.105**	**1.96**	**0.113**	0.83
l.s.d$_{0.05}$			*0.0080*	0.09	0.0045	
Kieserite-1	5.37	0.333	0.102	**2.06**	0.109	0.83
Kieserite-2	5.22	0.334	0.095	**1.97**	0.112	0.81
GM	5.30	0.334	0.099	2.01	0.111	0.82
SE	0.4319	0.0398	0.0157	0.1688	0.00893	0.0862
CV%	8.2	11.9	15.9	8.4	8.1	10.5

Conclusion

Responses to fertilizer treatments have commenced in the second year of fertilizer applications suggesting fertilizer management is important in the environment for high yields in the future. The trial is to continue to build up knowledge for fertilizer recommendations.

B.4. New Britain Palm Oil, Kula Group: Popondetta

Jim A. Nathan and Merolyn Koia

B.4.1. Trial 334: Nitrogen x Phosphorus Trial (Mature Phase) on Volcanic Ash Soils, Sangara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.4.1.1. *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 2013-2015, Urea significantly increased yield. In 2015, urea increased leaflet and rachis N 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.

B.4.1.2. *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 36.

Table 36 Trial 334 background information

Trial number	334	**Company**	NBPOL
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	18	**Altitude (m)**	104.79
Recording started	2006	**Previous landuse**	Oil palm replant
Planting material	Dami DxP	**Area under trial soil type**	Area
Progeny	Not known	**Supervisor in charge**	Nathan JA and Merolyn Koia

B.4.1.3. *Methods*

Urea treatment was applied three times per year while TSP was applied twice a year (Table 37). Fertiliser applications started in 2007. Every palm within the trial field received a basal applications of 1 kg Kieserite and 2 kg MOP per palm per year. Yield recording, leaf tissue sampling and vegetative measurements are described in Appendix 1.

Table 37 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

B.4.1.4. *Results and discussion*

Effects of treatment on FFB yield and its components

Urea affected FFB yield and SBW in 2016 and 2014-2016 (Table 38). At Urea level 1 (460 gN/palm/year), FFB yield was greater than 35 t/ha in both 2016 and 2014-2016 periods and were increased to 39.8 t/ha/year and 38.4 t/ha/year in 2016 and 2014-2016 respectively (
Table 39). There was no effect of TSP on yield and yield components in both 2016 and 2014-2016. The mean FFB yield was 38.3 t/ha in 2016.

Table 38 Trial 334 effects (*p values*) of treatments on FFB yield and its components in 2016 and 2014-2016

Source	2016			2014-2016		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	**0.034**	0.480	**0.010**	**0.045**	0.520	**0.050**
TSP	0.657	0.270	0.319	0.619	0.174	0.442
Urea.x TSP	**0.030**	0.088	0.466	0.097	0.138	0.860
CV %	10.3	10.6	4.9	7.5	7.8	4.7

Table 39 Trial 334 main effects of treatments on FFB yield (t/ha) in 2016 and combined harvest for 2014-2016

Treatments	2016			2014-2016		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea-1	**36.1**	1403	**25.7**	**35.7**	1408	**25.4**
Urea-2	**39.0**	1463	**26.7**	**37.4**	1450	**25.8**
Urea-3	**39.8**	1461	**27.3**	**38.4**	1448	**26.6**
l.s.d$_{0.05}$	*2.95*		*0.980*	*2.1*		*0.914*
TSP-1	38.3	1431	26.8	36.8	1394	26.5
TSP-2	38.4	1480	26.0	37.5	1476	25.5
TSP-3	38.6	1434	26.9	36.3	1388	26.1
TSP-4	39.5	1511	26.2	38.3	1497	25.6
TSP-5	36.7	1355	27.1	36.9	1422	26.0
l.s.d$_{0.05}$						
GM	38.3	1442	26.6	37.1	1435	25.9
SE	3.94	152.2	1.31	2.797	111.8	1.222
CV %	10.3	10.6	4.9	7.5	7.8	4.7

p values <0.05 are shown in bold.

Effects of interaction between treatments on FFB yield

There was a significant interaction between Urea x TSP on FFB yield in 2016 (p=0.030) (Table 35). However two way table for the running average for 2014-2016 is presented in Table 40. The highest yield of 40.4 t/ha was obtained at Urea-3 and TSP-3.

Table 40 Trial 334 effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2014-2016. The interaction was not significant (p=0.097)

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	36.5	36.3	33.2	38.0	34.7
Urea-2	34.2	38.8	35.4	39.5	39.1
Urea-3	39.7	37.6	40.4	37.3	36.8
Grand mean	37.1				

Effects of Urea and TSP treatments on leaf nutrient concentrations

Urea had significant effects on leaflet N, Ca and S and rachis P and Ca contents (Table 41 and Table 42). Urea at level 1 increased leaflet N from 2.43 % DM to 2.54 % DM (Table 43). TSP did not affect any of the nutrient contents except rachis P contents (Table 44). All leaflet and rachis nutrient concentrations were above their respective critical levels.

Table 41 Trial 334 effects (*p values*) of treatments on frond 17 leaflets nutrient concentrations 2016. *p values* <0.05 are indicated in bold

Source	Leaflets nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.947	**<0.001**	0.671	0.167	0.916	**<0.001**	0.557	0.062	**0.025**
TSP	0.375	0.594	0.233	0.289	0.206	0.422	0.359	0.760	0.615
Urea.TSP	0.746	0.297	0.111	0.972	0.889	0.135	0.496	0.564	0.157
CV%	4.1	2.6	2.6	6.3	9.9	6.2	6.0	19.5	2.7

Table 42 Trial 334 effects (*p values*) of treatments on frond 17 rachis nutrient concentrations 2016. *p values* <0.05 are indicated in bold

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Urea	0.303	0.325	**<0.001**	0.961	0.310	**0.046**
TSP	0.543	0.658	**0.044**	0.523	0.131	0.565
Urea.TSP	0.247	0.102	0.364	0.193	0.293	0.325
CV%	5.5	10.3	12.4	8.8	10.7	10.2

Table 43 Trial 334 main effects of treatments on leaflet tissue nutrient concentrations in 2016

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	15.0	**2.43**	0.141	0.56	0.22	**0.79**	0.54	28	**0.186**
Urea-2	15.0	**2.43**	0.141	0.56	0.22	**0.75**	0.55	24	**0.187**
Urea-3	15.1	**2.54**	0.142	0.58	0.22	**0.69**	0.55	23	**0.191**
l.s.d$_{0.05}$		*0.0479*				*0.0348*			*0.0038*
TSP-1	15.0	2.45	0.140	0.57	0.21	0.76	0.53	25	0.187
TSP-2	15.4	2.48	0.142	0.58	0.23	0.72	0.54	24	0.190
TSP-3	14.8	2.45	0.142	0.57	0.22	0.74	0.55	26	0.187
TSP-4	15.0	2.48	0.141	0.55	0.23	0.75	0.56	26	0.187
TSP-5	15.0	2.47	0.144	0.58	0.22	0.75	0.56	24	0.189
l.s.d$_{0.05}$									
GM	15.0	2.47	0.142	0.57	0.22	0.74	0.55	25	0.19
SE	0.618	0.640	0.004	0.0345	0.022	0.046	0.033	4.888	0.005
CV %	4.1	2.6	2.6	6.3	9.9	6.2	6.0	19.5	2.7

Effects with p<0.05 are shown in bold.

Table 44 Trial 334 main effects of treatments on rachis tissue nutrient concentrations in 2016

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	5.42	0.296	**0.246**	1.82	0.093	**0.49**
Urea-2	5.36	0.306	**0.210**	1.82	0.088	**0.47**
Urea-3	5.54	0.314	**0.160**	1.81	0.089	**0.44**
***l.s.d*$_{0.05}$**			*0.0190*			*0.017*
TSP-1	5.33	0.294	**0.190**	1.84	0.082	0.49
TSP-2	5.50	0.315	**0.195**	1.80	0.092	0.46
TSP-3	5.36	0.311	**0.206**	1.81	0.092	0.47
TSP-4	5.52	0.302	**0.211**	1.76	0.094	0.45
TSP-5	5.50	0.305	**0.226**	1.89	0.090	0.47
***l.s.d*$_{0.05}$**			*0.0246*			
GM	5.44	0.305	0.206	1.82	0.090	0.47
SE	0.301	0.0314	0.0254	0.160	0.0096	0.0478
CV %	5.5	10.3	12.4	8.8	10.7	10.2

Effects with p<0.05 are shown in bold

B.4.1.5. *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 35 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.

B.4.2. Trial 335. Nitrogen x TSP Trial on Outwash Plains Soils, Ambogo Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.4.2.1. *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, and continue to mature phase in the outwash sandy soils. In 2016, nitrogen fertilizer (minimum 460 g N/palm/year) was recommended for the Ambogo soils to produce FFB yields greater than 30 t/ha/year. P fertilizers had to be adjusted to replace exported P in yield. It was recommended this trial continue.

B.4.2.2. *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 45.

Table 45 Trial 335 background information

Trial number	335	**Company**	NBPOL
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	8	**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	**.Supervisor in charge**	JA Nathan and Merolyn Koia

Methods

The Urea.TSP trial was set up as a 3 x 5 factorial arrangement, resulting in 15 treatments (Table 46). 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.

Table 46 Trial 335 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

Yield and yield components

The effects of fertiliser on yield and its components are presented in Table 47 and
Table 48. Urea had significant effect on FFB yield and SBW in 2016 and 2014-2016. In 2016, FFB yield increased by 1.0 t/ha for every kg increase in Urea (Table 48). The average FFB yield was 38.2 t/ha in 2016.

Table 47 Trial 335 effects (*p values*) of treatments on FFB yield and its components in 2016 and 2014-2016

Source	2016			2014-2016		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	<0.001	0.248	<0.001	<0.001	0.119	<0.001
TSP	0.216	0.587	0.904	0.058	0.218	0.913
Urea.x TSP	0.213	0.305	0.968	0.382	0.338	0.907
CV %	7.4	8.2	5.1	4.2	5.5	4.2

Table 48 Trial 335 main effects of treatments on FFB yield (t/ha) in 2016 and 2014-2016

Treatments	2016			2014 - 2016		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea-1	**35.1**	1998	**17.6**	**35.8**	2291	**15.8**
Urea-2	**36.8**	2006	**18.4**	**38.2**	2323	**16.6**
Urea-3	**40.4**	2079	**19.5**	**40.6**	2376	**17.3**
l.s.d$_{0.05}$	*1.779*		*0.607*	*1.028*		*0.447*
TSP-1	36.0	1972	18.3	37.1	2270	16.5
TSP-2	37.2	2014	18.5	37.9	2313	16.6
TSP-3	37.3	2017	18.5	38.3	2327	16.6
TSP-4	38.6	2064	18.7	38.8	2349	16.7
TSP-5	38.1	2071	18.4	38.9	2392	16.4
GM	37.4	2028	18.5	38.2	2330	16.6
SE	2.788	165.4	0.951	1.611	127.2	0.700
CV %	7.4	8.2	5.1	4.2	5.5	4.2

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of Urea x TSP however the highest yield of 41.5 t/ha was obtained at Urea-3 and at TSP-5 (Table 49).

Table 49 Trial 335 effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2014-16

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	35.5	36.5	35.4	35.6	35.9
Urea-2	36.8	37.1	38.0	39.8	39.3
Urea-3	39.1	40.0	41.3	41.1	41.5
Grand mean	38.2	p=0.382			

Effects of Urea and TSP treatments on leaf nutrient concentrations

Urea had significant effect on leaflet N, Ca, Cl and S, and rachis N, P, K Mg and Ca contents (Table 50). Urea increased leaflet N, Cl, S and rachis N while lowering leaflet Ca and rachis P, K, Mg and Ca contents . Urea appeared to increase the anions while reducing the cations contents in the tissues. TSP increased both the leaflet and rachis P contents. Urea x TSP had no effect on all nutrient concentrations. Mean nutrient contents were above the critical nutrient contents.

Table 50 Trial 335 effects (*p values*) of treatments on frond 17 leaflet nutrient concentrations in 2016. *p values* <0.05 are indicated in bold

Source	Leaflet nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	**0.006**	**<0.001**	0.203	0.136	0.327	**<0.001**	**0.004**	0.711	**<0.001**
TSP	0.082	0.725	**0.017**	0.937	0.617	0.422	0.215	0.985	0.142
Urea.TSP	0.280	0.664	0.404	0.738	0.731	0.135	0.757	0.570	0.818
CV%	4.4	2.5	2.4	5.5	8.1	6.2	7.1	16.5	2.6

Table 51 Trial 335 effects (*p values*) of treatments on frond 17 rachis nutrient concentrations in 2016. *p* values <0.05 are indicated in bold

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Urea	0.501	**<0.001**	**<0.001**	**0.039**	**<0.001**	**0.005**
TSP	0.441	0.805	**0.003**	0.489	0.192	0.528
Urea.TSP	0.495	0.190	0.694	0.800	0.201	0.320
CV%	7.5	14.5	19.5	7.4	8.2	6.3

Table 52 Trial 335 main effects of treatments on F17 leaflet nutrient concentrations in 2016

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	**13.9**	**2.43**	0.144	0.66	0.22	**0.79**	**0.44**	48	**0.183**
Urea-2	**14.0**	**2.53**	0.146	0.66	0.23	**0.75**	**0.44**	47	**0.189**
Urea-3	**14.6**	**2.60**	0.145	0.64	0.23	**0.69**	**0.47**	46	**0.194**
l.s.d$_{0.05}$	*0.400*	*0.044*				*0.0348*	*0.0204*		*0.00318*
TSP-1	13.8	2.50	**0.142**	0.66	0.23	0.76	0.45	46	0.186
TSP-2	14.1	2.51	**0.144**	0.66	0.22	0.72	0.45	47	0.188
TSP-3	14.2	2.51	**0.145**	0.65	0.22	0.74	0.44	48	0.188
TSP-4	14.4	2.54	**0.146**	0.66	0.23	0.75	0.47	47	0.190
TSP-5	14.4	2.53	**0.147**	0.65	0.22	0.75	0.45	47	0.191
l.s.d$_{0.05}$			*0.0028*						
GM	14.2	2.52	0.145	0.66	0.22	0.74	0.45	47	0.189
SE	0.627	0.0694	0.0034	0.036	0.0182	0.0465	0.0320	7.73	0.0050
CV %	4.4	2.8	2.4	5.5	8.1	6.2	7.1	16.5	2.6

Table 53 Trial 335 main effects of treatments on F17 rachis nutrient concentrations in 2016

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	4.77	**0.230**	**0.259**	**1.84**	**0.102**	**0.42**
Urea-2	4.77	**0.231**	**0.186**	**1.73**	**0.098**	**0.41**
Urea-3	4.89	**0.299**	**0.131**	**1.79**	**0.090**	**0.39**
l.s.d$_{0.05}$		*0.0234*	*0.0239*	*0.084*	*0.00501*	*0.0165*
TSP-1	4.81	0.254	**0.162**	1.76	0.092	0.40
TSP-2	4.74	0.256	**0.183**	1.74	0.097	0.40
TSP-3	4.69	0.243	**0.187**	1.78	0.095	0.40
TSP-4	4.86	0.262	**0.204**	1.82	0.099	0.41
TSP-5	4.95	0.252	**0.226**	1.82	0.098	0.42
l.s.d$_{0.05}$			*0.0308*			
GM	4.81	0.253	0.192	1.78	0.096	0.41
SE	0.361	0.0367	0.0374	0.132	0.00785	0.0258
CV %	7.5	14.5	19.5	7.4	8.2	6.3

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 of more than 35 t/ha/year. Because of no clear responses to TSP treatments, P fertilizers should be adjusted to meet exported P only. It was recommended the trial continue.

B.1. New Britain Palm Oil, Kula Group: Milne Bay Estates

Wawada Kanama

B.1.1. Trial 516: New NxK trial at Maiwara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.1.1. *Summary*

Our studies have shown that N 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. Urea was responsible to explain yield responses to fertilizers in the alluvial soils of Milne Bay. It was recommended the trial continue.

B.1.1.2. *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. 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 54.

Table 54 Trial 516 back ground information

Trial number	516	**Company**	NBPOL-Milne Bay
Estate	Hagita, Maiwara	**Block No.**	AJ 1290
Planting density	143 palm/ha	**Soil type**	Alluvial plain
Pattern	Triangular	**Drainage**	Often water logged
Date planted	2001	**Topography**	Flat
Age after planting	16	**Altitude**	Not known
Recording started	2005	**Previous landuse**	Forest
Planting material	DxP	**Area under soil type (ha)**	Not known
Progeny	Mix	**Supervisor in charge**	Wawada Kanama

Basal fertiliser applied in 2016: 0.5 kg TSP

B.1.1.3. *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). Multiple linear regressions were 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.

B.1.1.4. *Results*

Yield data (2016 and 2014-2016) and leaf tissue nutrient contents for 2015 were analysed using multiple linear regression function in Genstat. The results are presented in Table 55. In 2016, 88.4% of the variance ($p<0.001$) in FFB yield, 59.1% for BNO and 49.1% for SBW were explained by the regression. In 2014-2016 period, 86.1 % ($p=0.001$) of the variance in FFB yield, 58 % for bunch numbers and 76.4 for SBW were explained by the regression. The regression did not statistically explain differences in leaflet and rachis N and K nutrient contents.

Table 55 Trial 516 Regression parameters for yield and its components and leaf tissue N and K contents

Parameter	d.f	F probability	% variance accounted for	SE
FFB yield 2016	5	<0.001	88.4	1.57
BNO/ha 2016	5	0.038	59.1	99
SBW 2016	5	0.075	49.1	1.46
FFB yield 2014-2016	5	0.001	86.1	1.66
BNO/ha 2014-2016	5	0.041	58	82.4
SBW 2014-2016	5	0.006	76.4	1.05
Leaflet N contents	5	0.504	Residual variance > response variate	0.104
Leaflet K contents	5	0.168	33.1	0.0152
Rachis N contents	5	0.114	41.5	0.0315
Rachis K contents	5	0.196	29.4	0.305

FFB yield for the period 2014-2016 was chosen to develop a response surface. In 2014-2016, Urea appeared to explain significantly (p=0.003) the increase in FFB yield (Table 56).Yield was at 13.4 t/ha/year at nil fertilizer rates. There was no clear optimum fertilizer rate between Urea and MOP (Figure 6). High FFB yields were obtained at high Urea rates with little effect from MOP. The general trend was that yields reached its maximum between 3.7 kg Urea and 4.6 kg Urea per palm at all levels of MOP.

Table 56 Trial 516 estimated coefficients for FFB yield in 2014-2016

Parameter	estimate	s.e.	t(7)	t pr.
Constant	13.35	2.08	6.42	**<.001**
Urea	5.84	1.28	4.57	**0.003**
MOP	0.068	0.851	0.08	0.939
Urea squared	-0.353	0.204	-1.73	0.128
MOP squared	0.063	0.113	0.55	0.597
Urea x MOP	-0.284	0.21	-1.35	0.219

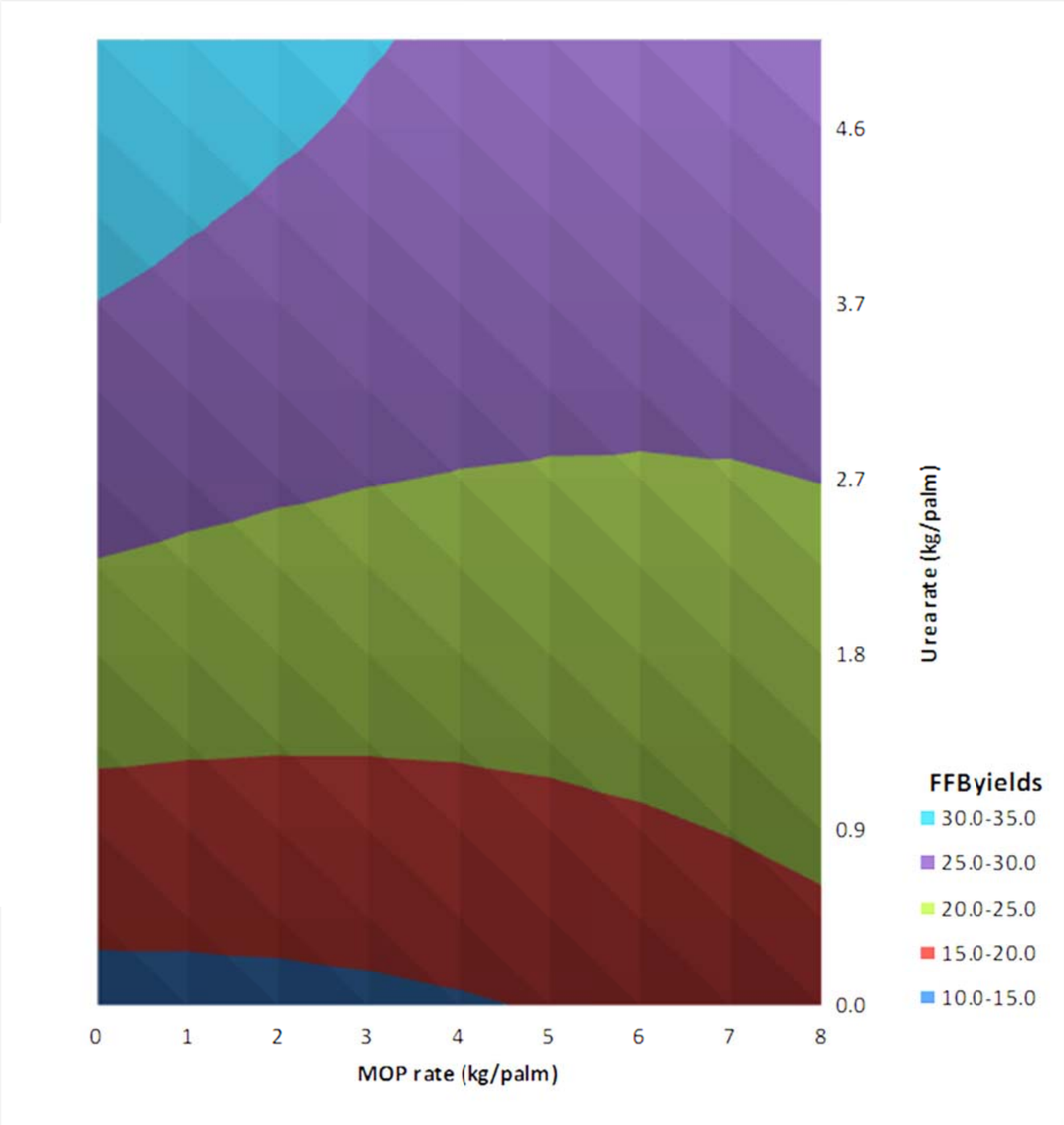


Figure 6 Trial 516 2014-2016 FFB yield surface for Urea and MOP combination

Neither Urea nor MOP individually affected any leaflet and or rachis nutrient N contents in 2016.

B.1.1.5. *Conclusion*

In 2016, Urea was more influential in determining yield response in the trial and a maximum combination was not possible to be determined. It was recommended the trial continued.

B.2. Appendix

Appendix 1 Field trials operations

B.2.1.1. *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.

B.2.1.2. *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.

B.2.1.3. *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 in selected trials. The data is entered into the data base system and summarised for each plot which is then analysed.

B.2.1.4. *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.

B.2.1.5. *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.

C. ENTOMOLOGY

HEAD OF SECTION II: DR MARK ERO

C.1. Executive summary

The Entomology Section undertakes applied research and provides technical advice on best pest management practices. It also conducts pest surveys and provides management recommendations to the oil palm industry.

The key pests reported frequently during the year that required routine management intervention remained to be the 3 species of sexavae (*S. decoratus*, *S. defoliaria*, *S. gracilis*) and 1 species of stick insect (*E. calcarata*). Most reports were from WNB followed by NI.

Oryctes rhinoceros infestation was encountered in most of the replant plantations at Poliamba Estate. Ongoing control was through pheromone trapping, and *Metarhizium* infection and release of male beetles.

Weed control targeted *Mimosa pigra* eradication in WNB (Numundo and Wandoro), and the rearing and release of the seed feeding biological control agent (*Acanthoscelides* spp.) in Northern Province. Generally, the number of weeds treated/uprooted in WNB during the year dropped considerably (particularly for Wandoro). A total of 265 weeds were treated at Wandoro and 858 at Numondo. Around 27,699 beetles (*Acanthoscelides* spp.) were released in Northern Province. Post release monitoring for establishment started for 4 sites during the year. The program will continue until the weed is eradicated from WNBP and the biological control agent is well established in Northern Province.

Less insecticide was applied (through TTI) in 2016 (12,733L) than in 2015 (15,403L). More areas were treated in WNB than NI, with more treatments done in smallholder blocks (more than 90%) than the plantations. PNGOPRA Entomology will continue to work closely with the plantations and smallholders (OPIC, SHA and their Associations) to effectively monitor and control recurrence of regular pests.

Less *D. leefmansi* and *A. eurycanthae* were released in 2016 than 2015. No *L. bicolor* and *S. dallatoreanum* were released in 2016. The biological agents rearing and release program was severely affected by the delayed effect of the prolong drought experienced during 2015. The rearing and release program will continue with the aim of re-establishing the lost insect cultures.

Evaluation of ant baits against LFA and monitoring of their impact against the pollinating weevil (*E. kamerunicus* Faust) started during the year. Three baits (Engage P™, Engage Plus™, Campaign P™) were found to be more attractive to the ants, and preliminary indications are that there is no impact by the ant on pollinating weevils. The studies will continue into 2017 before the final recommendations are made.

Biological control agents release improvement study continued throughout the year. Sugar concentration measurements for beneficial plants were done using Glucometer™. Significantly higher concentrations of sugar (glucose) were measured in Brazilian Snapdragon (*O. caeruleus*) and Coral Vine (*A. leptopus*). Preference among the weeds by the biological control agents will be studied in 2017.

Combination of the Guam and the Pacific/Samoan biotypes of the Coconut Rhinoceros Beetle (CRB) are present in NCD. ENB, NI and WNB had only the Pacific biotype. Oryctes NudiVirus was only found on Pacific/Samoan biotype. Severe damage was widespread in NCD and parts of the Central Province than the other sites surveyed. Localized damage hotspots were noted for NI. Monitoring pheromone traps were set up at Mariawatte and Gadaisu for Milne Bay, and at Oro Bay, Girua Airport and Kokoda Station for Northern. Monitoring of these traps will continue. Ongoing monitoring and application of control measures for Poliamba Estate replants to be maintained. Investigations into the pheromone for the Guam biotype *O. rhinoceros* has been considered in 2017 work program.

Sharon Agovaua completed her BARD course at Unitech and graduated in April 2016. Richard Dikrey continued the course during the year and will continue into 2017.

C.2. Routine pest reports and their management

C.2.1. Oil palm pest reports- (RSPO 4.5, 4.6, 8.1)

Most of the pest reports in PNG were from WNBP for both smallholders (OPIC) and the plantations (HOPL and NBPOL) followed by NI (smallholder- OPIC and Plantation- NBPOL) (Figure 7, Figure 8, Figure 9). The only report from the mainland was of grasshopper and *Scapanes australis* damage at Milne Bay Estates (MBE) (Figure 9). GPPOL reported Tussock moth and *Oryctes rhinoceros* (Guam biotype) infestations. The species with high proportion of reports were *Segestes decoratus* (Tettigoniidae), *Segestidea defoliaria defoliaria* (Tettigoniidae), *Eurycantha calcarata* (Phasmatidae) and *Segestidea defoliaria gracilis* (Tettigoniidae). Apart from these regularly reported pest species, *Oryctes rhinoceros* (Coleoptera: Scarabaeidae) 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 (NBPOL and HOPL). There was one (1) new taxa (grasshopper: Tettigoniidae) that was not reported in 2015 which was reported during 2016. There are other sporadic pest species known to cause damage to oil palm but none of these were reported during the year. The insect species include *Segestidea novaeguineae* (Tettigoniidae), *Eurycantha insularis* (Phasmatidae), *Acria emarginella* (Peleopodidae), *Eumeta variegatus* (Psychidae), *Mahasena corbetti* (Psychidae), *Manatha conglacia* (Psychidae), *Dermolepida* sp. (Scarabaeidae), *Lepidiota reauleauxi* (Scarabaeidae), *Oryctes centaurus* (Scarabaeidae) and *Papuana* spp. (Scarabaeidae).

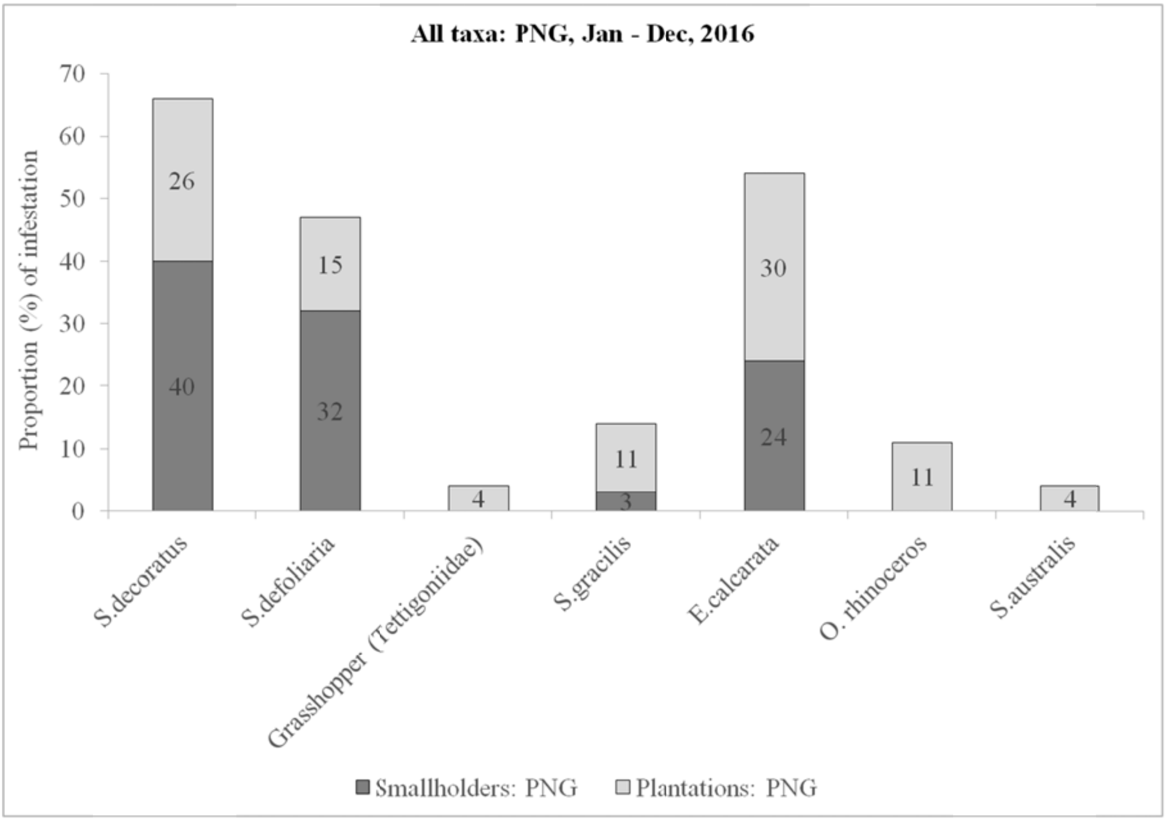


Figure 7 The proportion (%) of major pests reported in 2016 from PNG by smallholders and plantations.

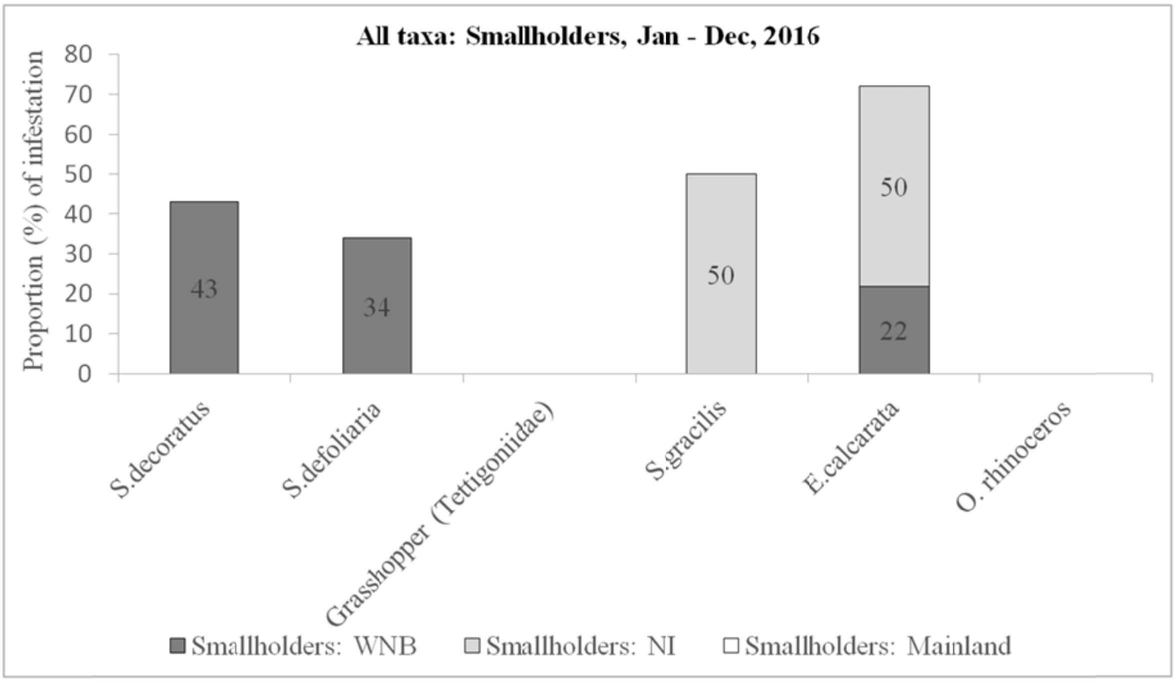


Figure 8 The proportion (%) of major pests reported by smallholders from WNB and NI in 2016. None was reported from the mainland.

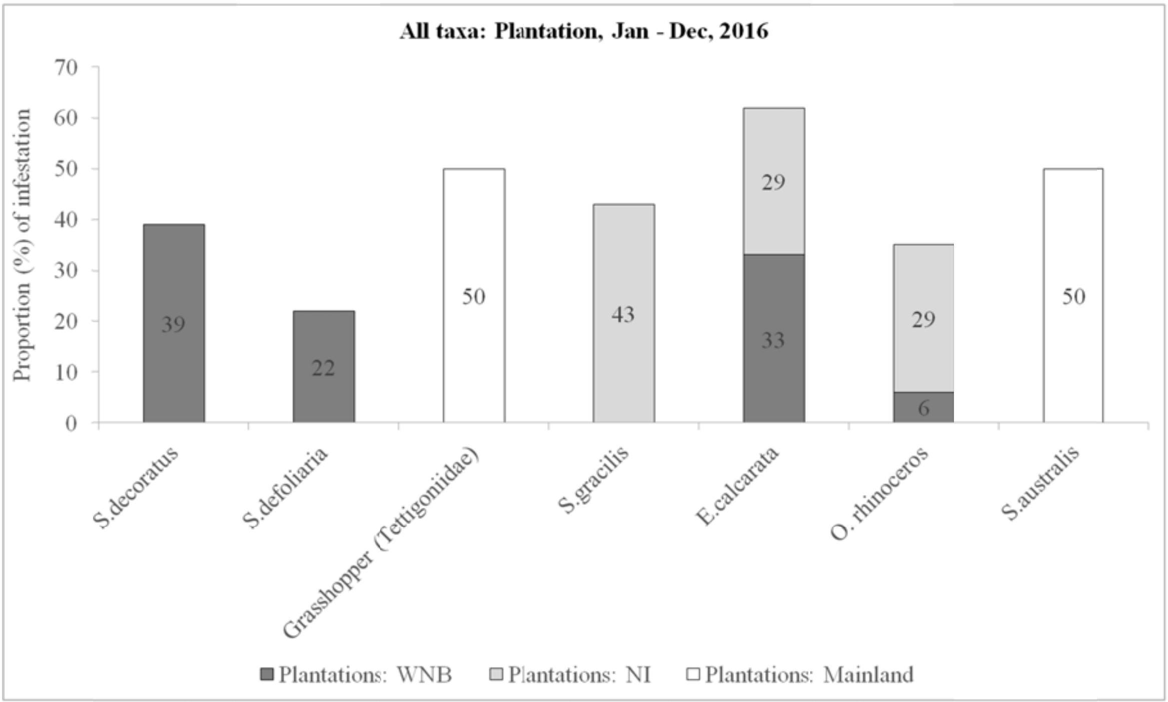


Figure 9 The proportion (%) of pests reported by plantations from WNB, NI and mainland in 2016.

C.2.2. Monthly pest infestation reports in 2016 (RSPO 4.5, 8.1)

Sixty nine (69) infestation reports were received in 2016 from PNG (21 from plantations and 48 from smallholders) [Figure 10]. This is an increase of 1% from the reports received in 2015. Most reports were received during February for Smallholders and April for Plantations. Most of these reports were from WNB and NI (Figure 11 and Figure 12). Only two reports were received from the Mainland for *S. australis* and grasshopper infestation at Milne Bay Estates (MBE).

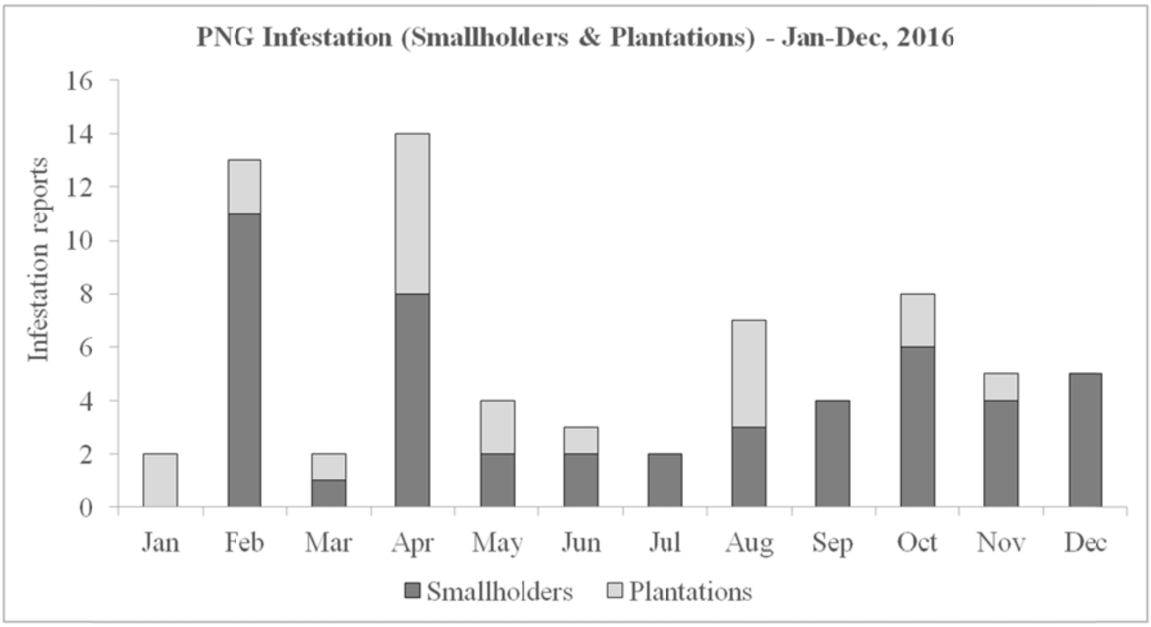


Figure 10 Pest infestation reports received from smallholders and plantations (PNG) in 2016.

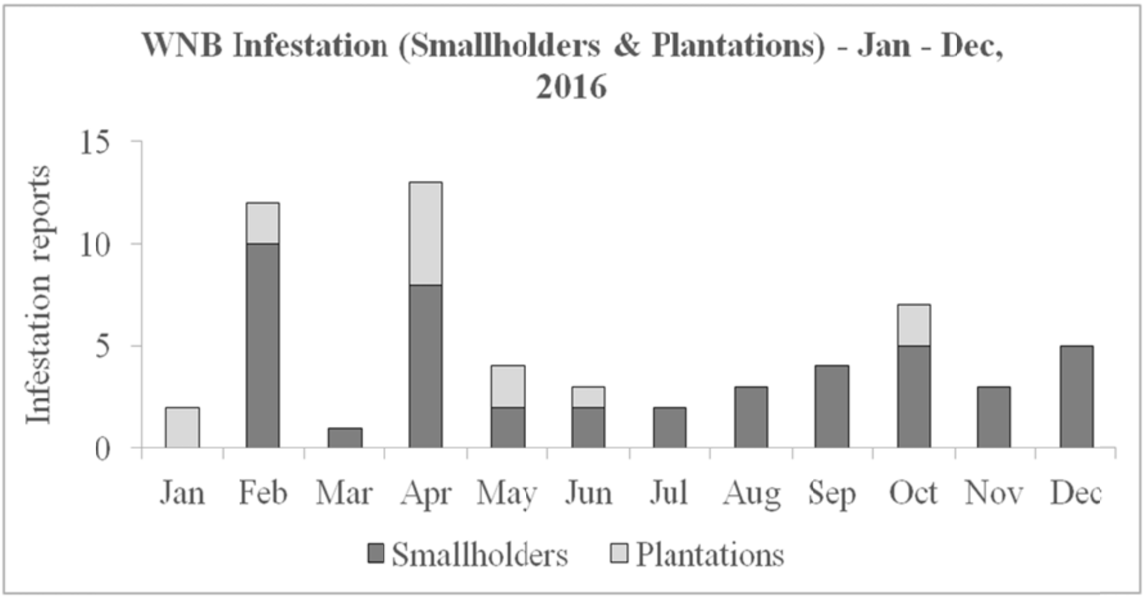


Figure 11 Pest infestation reports received from smallholders and plantations for WNB in 2016.

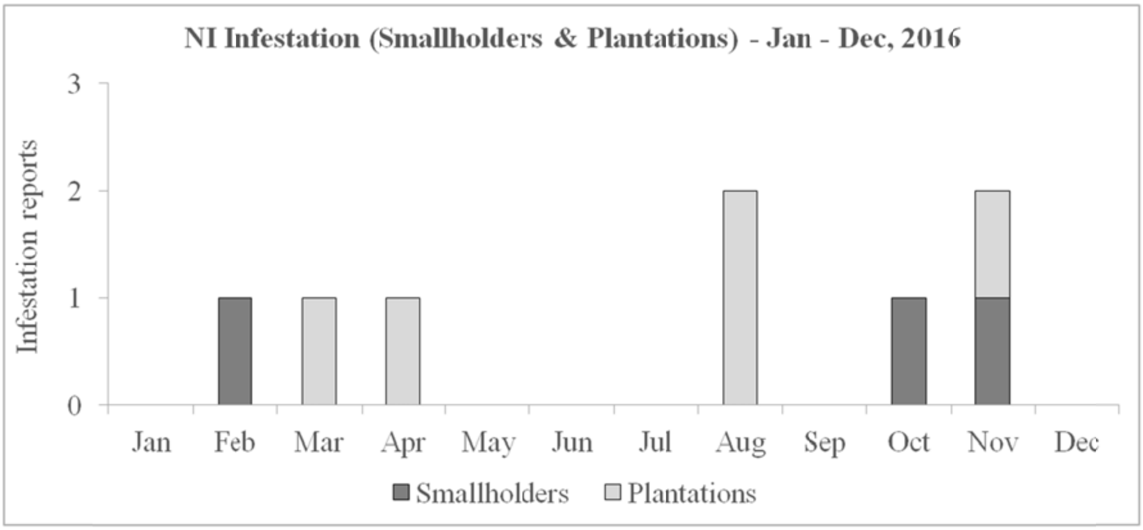


Figure 12 Pest infestation reports received from smallholders and plantations in NI for 2016.

C.2.3. Management of *Oryctes rhinoceros* L. (Coleoptera: Scarabaeidae) at Poliamba Estates (NBPOL)

The management of *O. rhinoceros* beetles at Poliamba Estates continued during the year. Infestations were at Baia, Lakurumau, Maramakas, Fileba, Madina and Kafkaf replants. Trapping at Maramakas started in August and the trapping in Kafkaf started in December. Trapping in the rest of the plantations went on for the rest of the year. Severe infestation was encountered at the beach blocks for Baia, Lakurumau, Maramakas, Fileba and Madina as delayed replanting was done in those blocks. The infestation levels in the main blocks were subsiding towards the back end of the year. The main focus of management was pheromone trapping to reduce the population and disrupt breeding cycles, and the infection and release of *Metarhizium* infected males for field population re-infection. Pheromone traps in all replants were monitored by PNGOPRA. The trapping data for Kafkaf replant is not provided here as the traps were set up late in December. The data will be reported in 2017.

A total of 32,434 beetles were caught from all four replant plantations during the year. Highest number of beetles was caught between February and May with 24,534 beetles trapped and dropped off considerably towards the back end of the year. There was no direct relationship between the number of beetles caught and rainfall within the area (Figure 13).

For all sites, highest numbers of beetles were caught between January and June. The highest numbers of beetles were caught from Madina Plantation followed by Baia Plantation (Figure 14). The beetles caught were largely dependent on the density of pheromone traps and the period of infestation. Madina with 17 traps (a trap per 2 hectares as a standard) and incursion detection in August 2015 caught 15,894 beetles. With this trapping density, it took up to six months for the population to decline considerably. The incursion at Fileba was detected about the same time but caught 4,436 with only four traps (2 barrel and 2 PVC traps) set up. Baia and Maramakas Plantations had 8 traps each but caught 7,656 and 1,190 beetles respectively. The difference in the catch between these plantations is due to the difference in the time of trap set up. The traps at Baia Plantation were set up two years earlier whilst the traps at Maramakas were set up in August 2016. The traps at Lakurumau were set up in 2013 and the beetle incidence was slowly declining as most of the fallen palm trunks which are the main breeding substrates had fully decayed. Most of the incidence was from the beach block which was planted in 2014.

Releases of *Metarhizium* infected *O. rhinoceros* male beetles continued throughout the year for all replants. More infected male beetles were released at Madina replant (4005 beetles) due to the large number of beetles caught there, followed by Baia replant (2,103 beetles). The least number of beetles was released at Lakurumau replant (988 beetles). The number of beetles infected and released fluctuated over the months depending on the number of beetles collected in the pheromone traps (Figure 16).

High density pheromone trapping, and *Metarhizium* infection and release need to continue for any new replants with beetle infestation. NudiVirus infection and release at sites with low incidence of infection should be considered in the New Year.

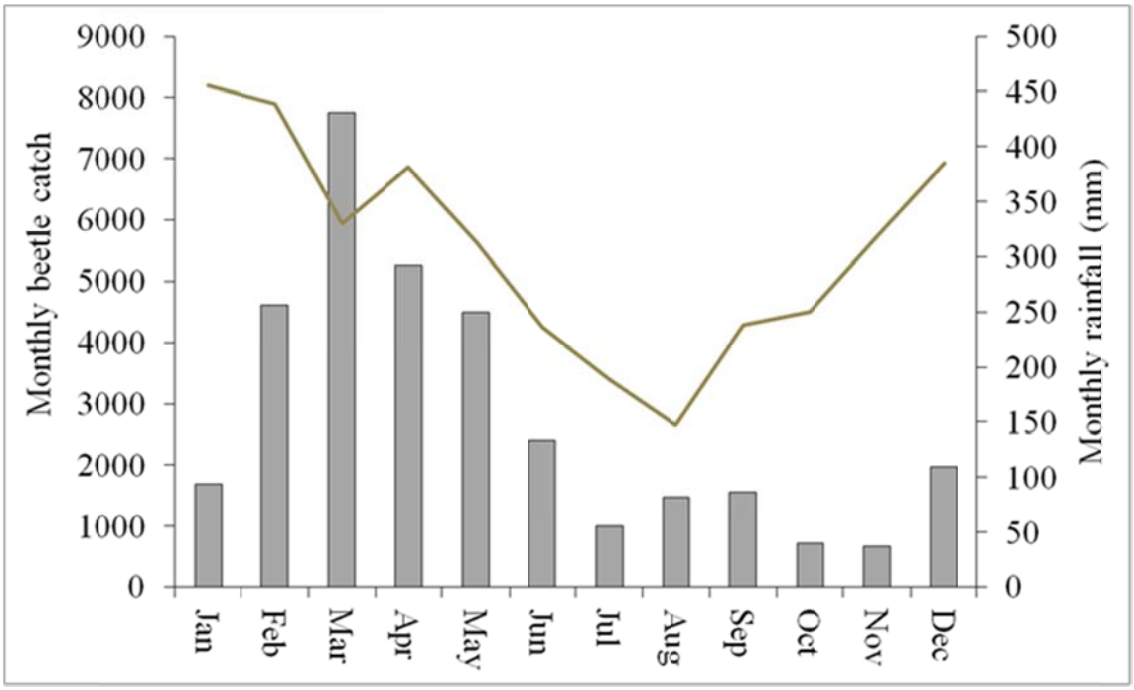


Figure 13 Number of *O. rhinoceros* trapped (combined across different plantations) at Poliamba Estate and the average monthly rainfall (mm) for the site in 2016.

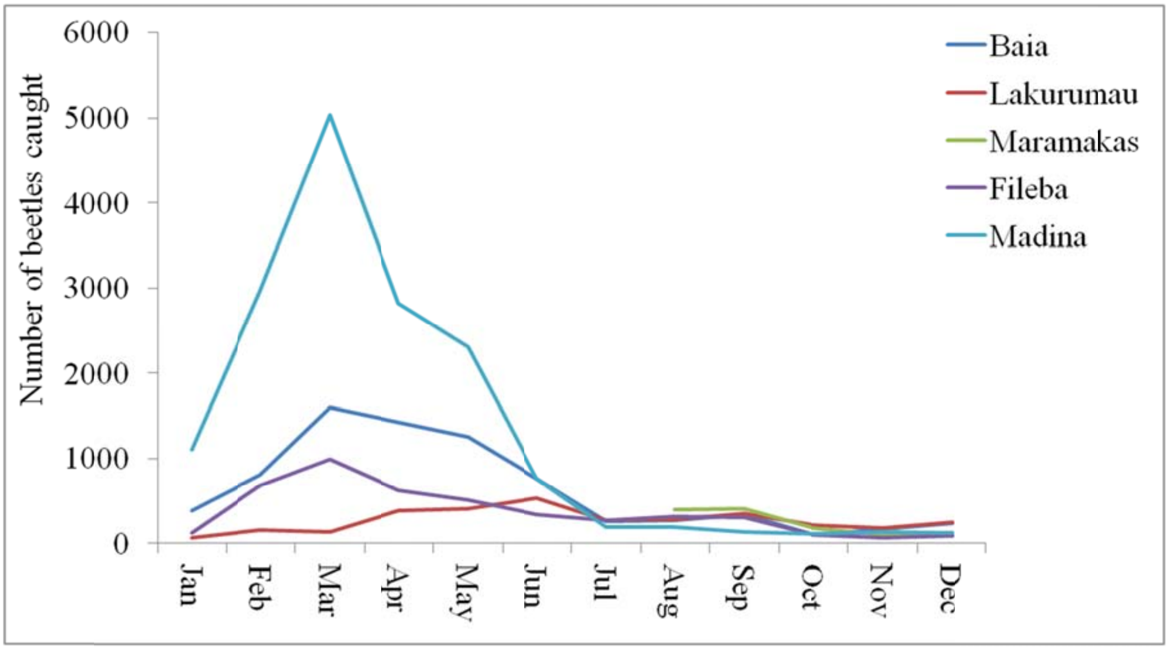


Figure 14 Monthly *O. rhinoceros* catch from the different plantations (replant plantations) at Poliamba Estate.

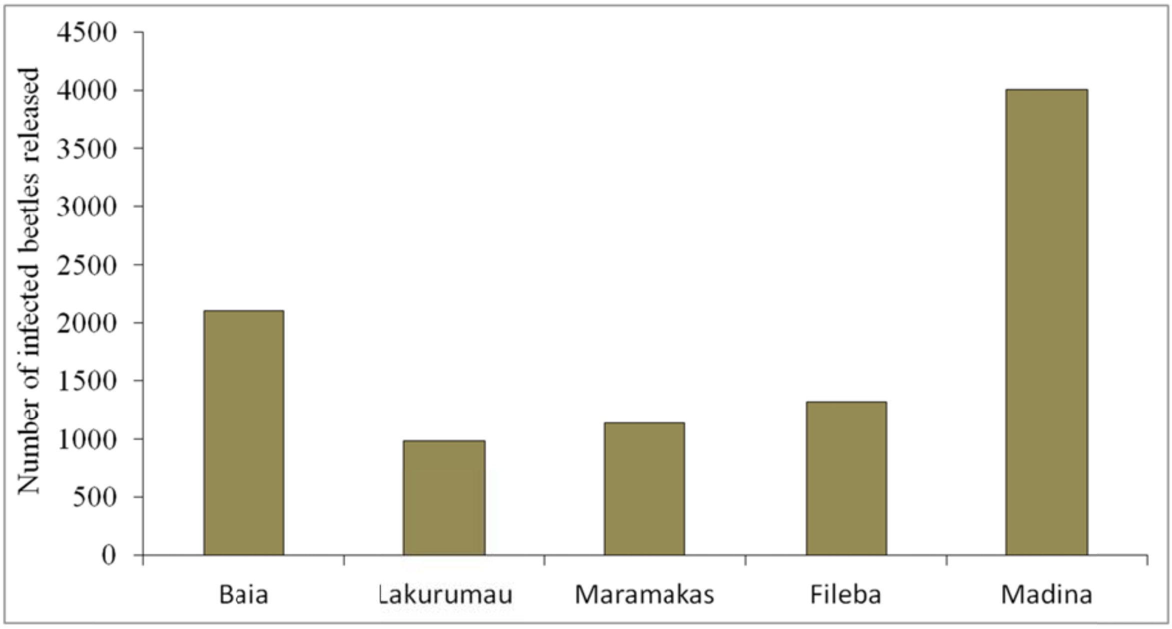


Figure 15 Number of *Metarhizium* infected male *O. rhinoceros* released at different beetle infested replants plantations.

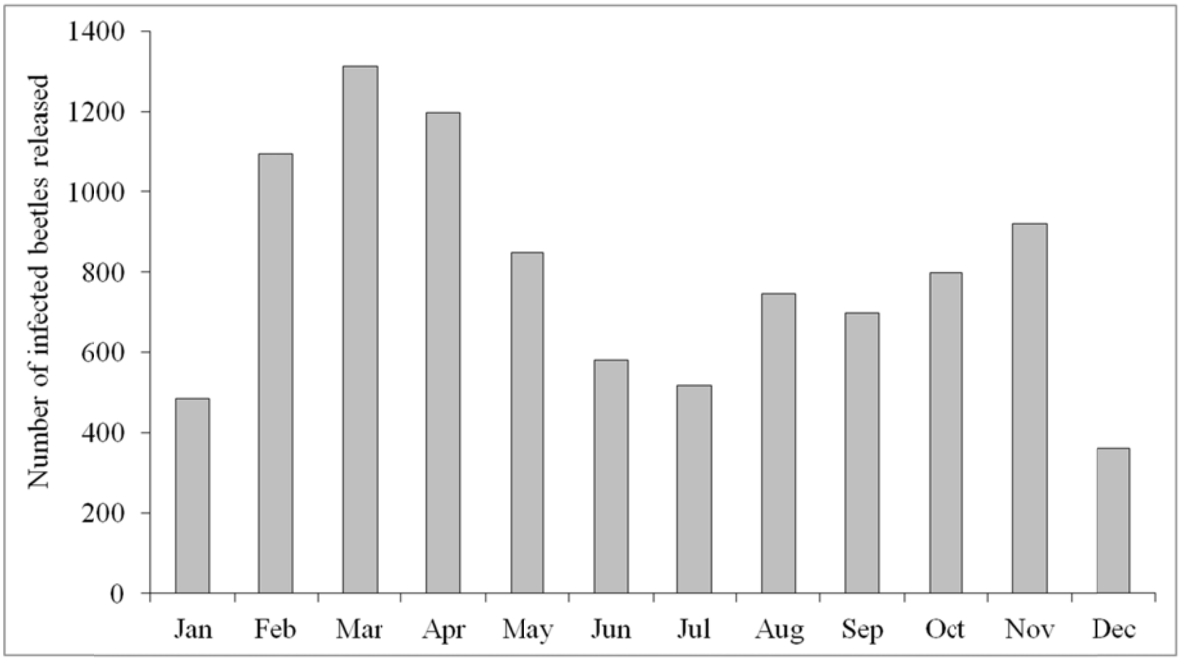


Figure 16 Number of *Metarhizium* infected male *O. rhinoceros* released per month (combine for all plantations).

C.2.4. Management of targeted weeds in Papua New Guinea

The Entomology Section continued with the management of some of the invasive weeds. As was the case in 2015, the main focus in 2016 was the eradication of *Mimosa pigra* in WNB (Numundo and Wandoro- Pusuki Estate) using Ally 20 (Metsulfuron methyl as an active ingredient) and the rearing and release of its seed feeding biological control agent (*Acanthoscelides* spp.) in Northern.

The treatment at Wandoro (Pusuki Estate) started in August 2014 with fortnightly treatments done. Since then 50 rounds of treatment have been done with 6,927 plants (66 mature stands and 6,861 new germinations) have been treated. A total of 743 new germinations were treated in 2016. For Numondo, the treatment programme started some months later in February 2015, with 40 rounds of treatment done. Since then, a total of 2,826 plants (170 mature stands and 2,656 new germinations) have been treated. A total of 832 new germinations were treated in 2016.

For most part of 2016, the number of weeds that were either treated or uprooted from Wandoro (Pusuki Estate) remained below the average (orange line) compared to 2014 and 2015 which generally remained above the average (Figure 17). This is an indication of the seed bank being gradually depleted through the control programme. However, the number of seedlings controlled (treatment/uprooting) from Numondo during the year (2016) fluctuated along the average (Figure 18). This result does not necessarily reflect the persistence of the weed but a result of the late start of the control programme compared to Wandoro. As is the case for Wandoro, large seed banks may have been deposited prior to the start of the eradication programme started, hence will take time before the really drop in the number of new seed germination is noted for the site. For both sites, the delayed control of the weed is expected due to the very long seed dormancy period (up to around 25 years). The exercise will continue until no more new germinations are detected for up to about 12 months.

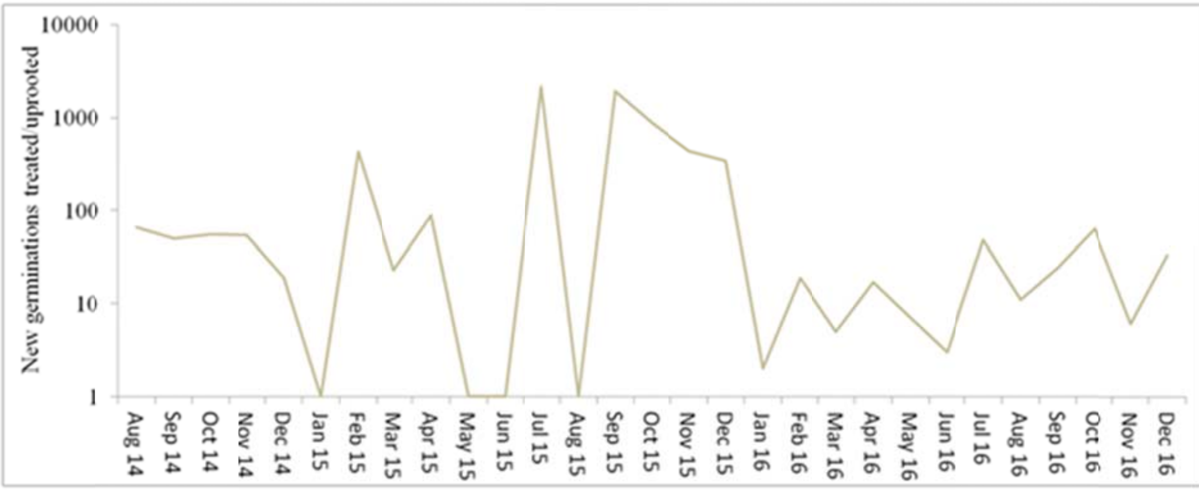


Figure 17 The number of new germination of M. pigra treated at Wandoro (Pusuki Estate) since August 2014 to December 2016 (Log10 transformed data).

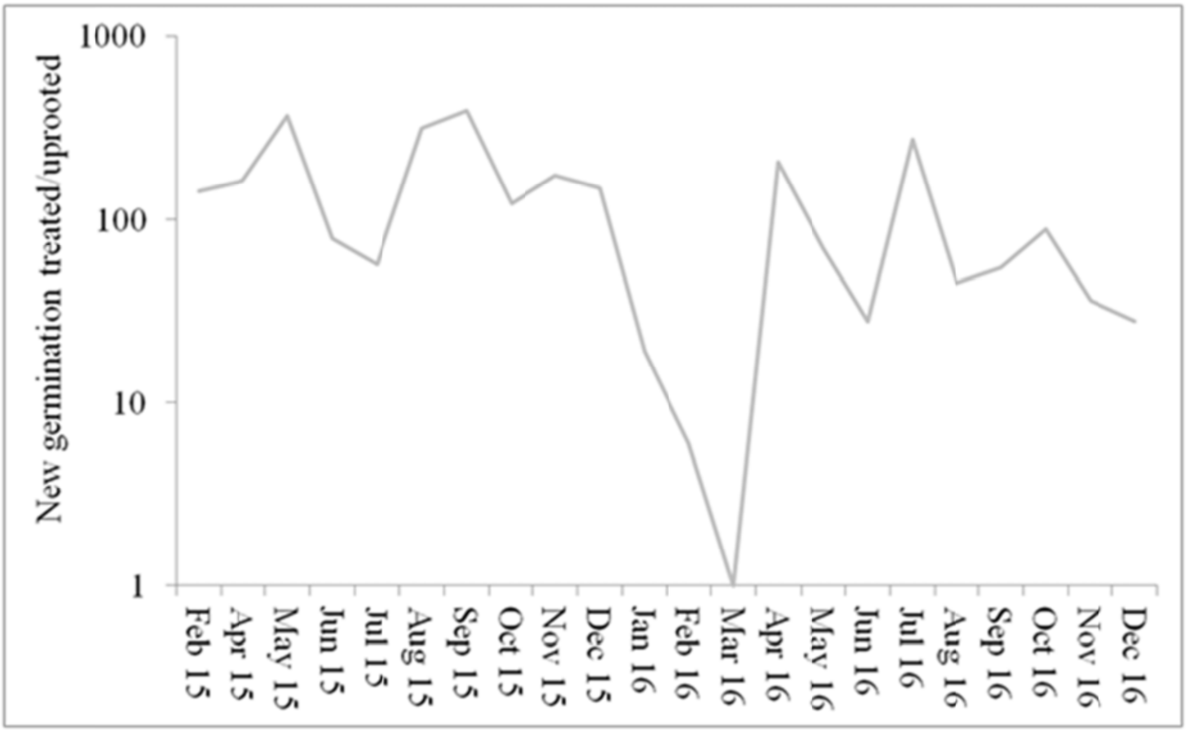


Figure 18 The number of new germination of *M. pigra* treated at Numondo since August 2014 to December 2016 (Log_{10} transformed data).

Rearing of the seed feeding biological control agent (*Acanthoscelides* spp.) started at Higaturu in February 2015 and continued in 2016. Releases have been done at 66 sites (56 sites in 2016) with 33, 338 beetles (27, 699 beetles in 2016) released. Post release monitoring surveys were done for 4 release sites with beetles being reared from all 4 sites and data collected. The programme will continue until releases at all sites where the weed is present are done.

Eradication was targeted for WNB because the distribution of the weed is concentrated at the two mentioned sites, but biological agent release has been instigated for Northern as the weed is widely distributed throughout the province.

The releases of the biological control agents of the other weeds are continuing on *ad hoc* basis whenever new infestations are detected.

C.2.5. Pest damage levels, management recommendations and targeted trunk injection (TTI) in 2016

The most common pest species against which insecticide treatments are usually applied include *Segestes decoratus*, *Segestidea defoliaria*, *Segestidea gracilis* and *Eurycantha. calcarata*. Treatment is only done in areas defined as with 'moderate' to 'severe' infestation. Areas with 'light' infestation levels were recommended for monitoring. The insecticide applied was methamidophos (Monitor™). Application was done through Targeted Trunk Injection (TTI) where 10ml of the insecticide was injected (using a 10ml calibrated drench gun) into a 15cm deep hole drilled at 45° angle. The hole was drilled at about breast height of the palm using a motorized drill. Only PNGOPRA is authorised by CEPA (PNG Conservation and Environment Protection Authority) to permit the use of methamidophos by treatment teams. Hence, monitoring of the insecticide used was done through the completion of Targeted Trunk Injection Daily Report (TTIDR) forms received from treatment team supervisors during treatment operations.

Insecticide application using TTI was only done in WNB and NI. Figure 19 presents the amount of methamidophos used in 2015 (*top*) and 2016 (*bottom*). The figures provided are only for those treatments where the TTIDR reports were received. Approximately 12,733L of methamidophos was applied through TTI in 2016 for PNG (Figure 19 *bottom*). This was 2,670L less than the volume applied in 2015 (15,403 L) (Figure 19 *top*).

In 2016, approximately 99% of the insecticide (12,584L) was applied in WNB; of this, smallholders (Hoskins and Bialla Projects combined) applied 11,339L (ca 90%) and plantations (NBPOL and HOPL combined) applied 1,245L (ca 10%). There was a decrease in the volume applied for plantations (by 3,600L from 4,845L in 2015) and increase for the smallholders (by 1,464L from 9,875L in 2015). The increase in the volumes applied was mainly due to some of the treatment recommendations from 2015 carried on into 2016.

Approximately 149L was applied on both the smallholder blocks and plantations in NI. This was a decrease of 531L (78% drop) from 2015 (Figure 19). This difference is reflective of the pest species present, the area of cultivation, and effective monitoring and control as well as the delayed effect of the prolong drought experienced in 2015. Three of the most destructive pest species (*S. defoliaria, S. decoratus, E. calcarata*) for which TTI is applied are present in WNB and larger area is cultivated there than NI; hence the difference in the volume of methamidophos applied reflected this situation. Treatment in NI was done mainly for *S. gracilis* (actually a sub-species of *S. defoliaria*) and *E. calcarata*.

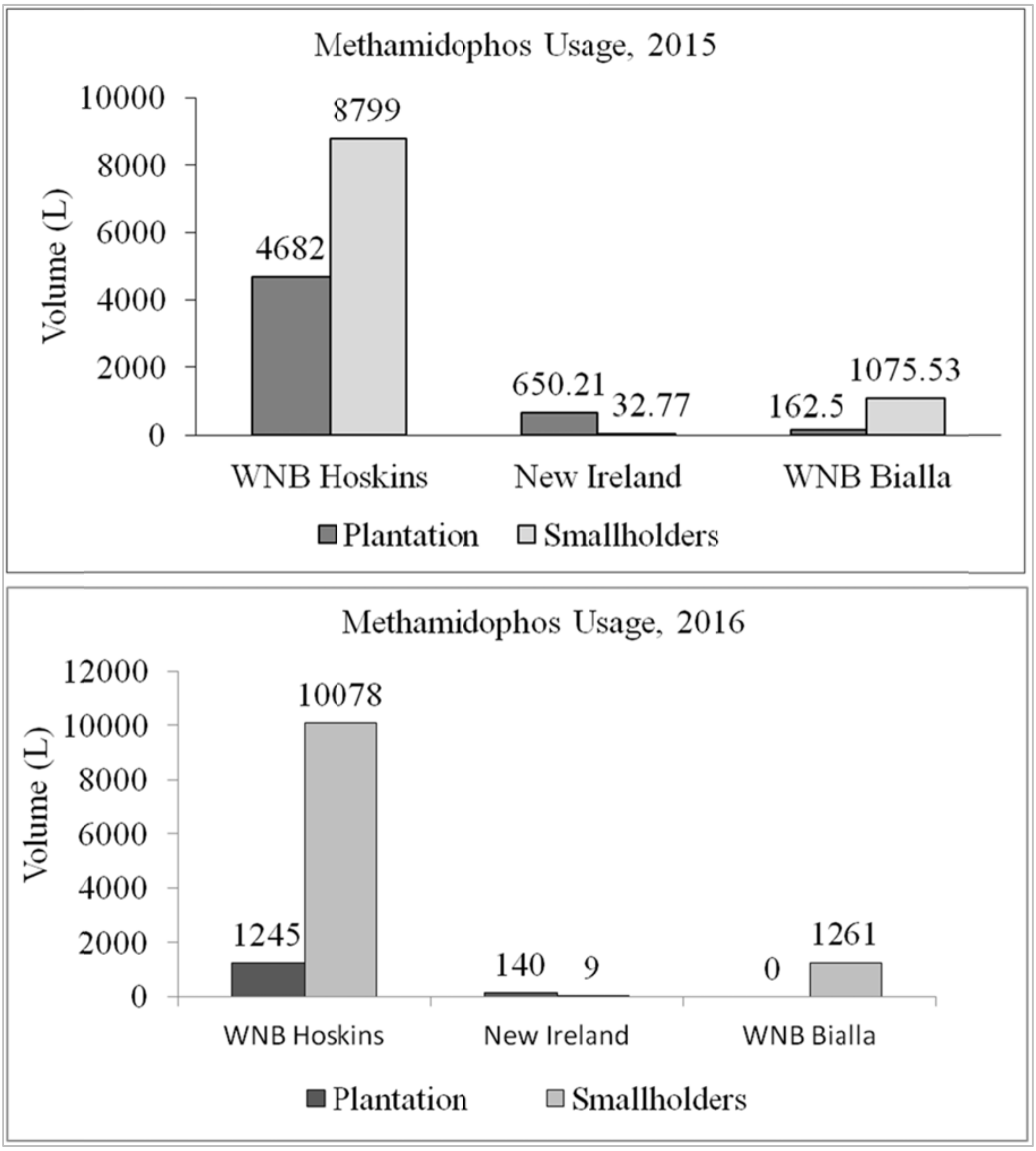


Figure 19 Volume (L) of Monitor™ (methamidophos) applied in smallholder blocks and plantations during 2015 (*top*) and 2016 (*bottom*).

C.2.6. Biological Control Agent Releases

There are 4 biological control agents (*Stichotrema dallatorreanum* for adult and nymph *S. defoliaria, Anastatus eurycanthae* for the eggs of *E. calcarata* [stick insect], *Doirania leefmansi* and *Leefmansia bicolor* for sexavae eggs) maintained in the laboratory at Dami Entomology Laboratory.

The number of biological control agents released in 2016 declined considerably from those released in 2015 for all agents (Figure 21, Figure 22 and Figure 23), where no releases of *L. bicolor* and *S. dallatoreanum* with both cultures lost during the year. The cultures were considerably affected in 2016 by the delayed effect of severe drought experienced in 2015, as most of the host insects for the culture were normally collected from the field. Approximately two thousand (2,000) *A. eurycanthae* and less than two million *D. leefmansi* were released whilst no *S. dallatoreanum* and *L. bicolor* were released. The key objective in 2017 will be to build up sufficient laboratory cultures of all biocontrol agents.

Field releases of these biological control agents are necessary to augment the wild natural enemy populations to suppress the target pest populations in an integrated approach. The number of *D. leefmansi* and *Leefmansia bicolor* released in the field were estimated (Figure 22, Figure 23) because they are too small to be counted without being damaged. The estimation is based on the number of host eggs used to rear them. Based on laboratory observations, an average of 192 adult *D. leefmansi* and 32 adult *L. bicolor* emerge from individual parasitised eggs.

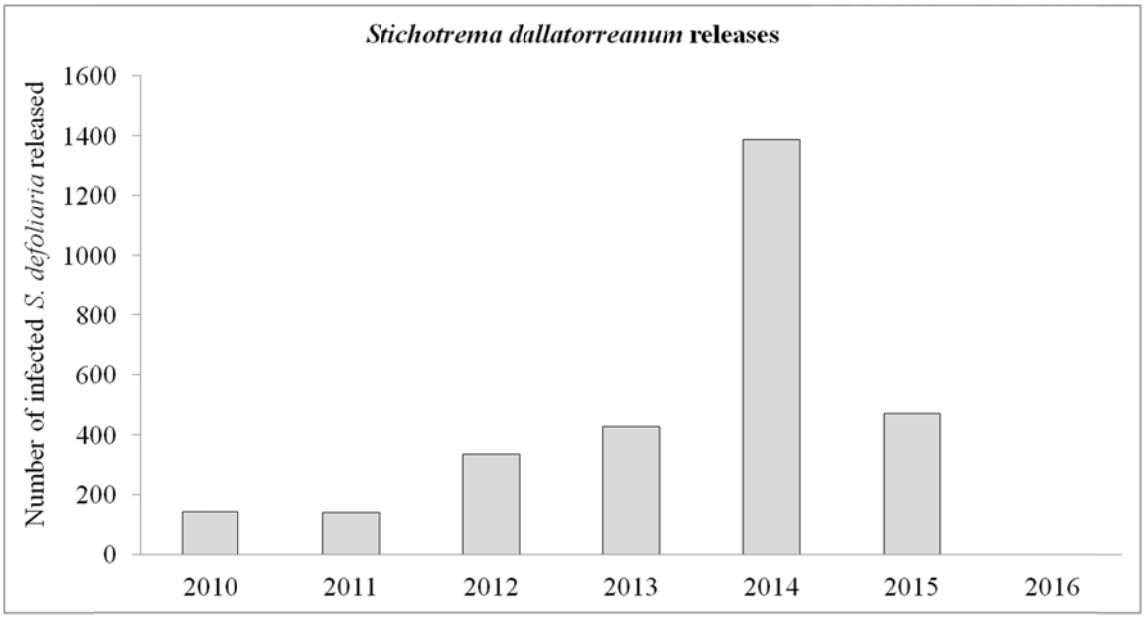


Figure 20 Number of rearing cage *S. dallatoreanum* infected adult males of *S. defoliaria* released between 2011 and 2016 for the control of field population of *S. defoliaria*.

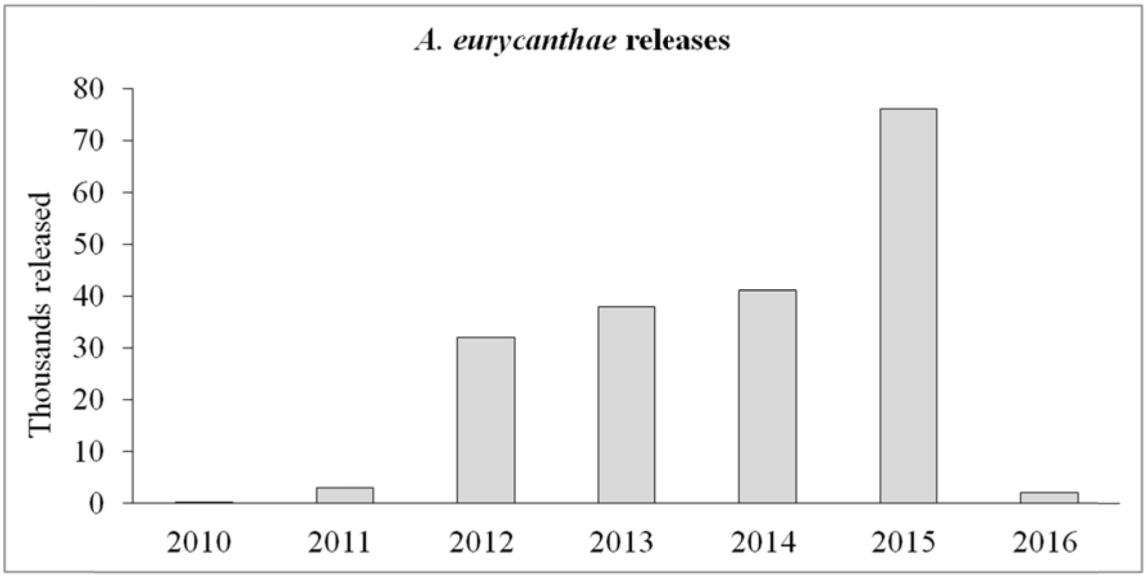


Figure 21 Number of *A. eurycanthae* laboratory reared and field released between 2011 and 2016 for the control of *E. calcarata*.

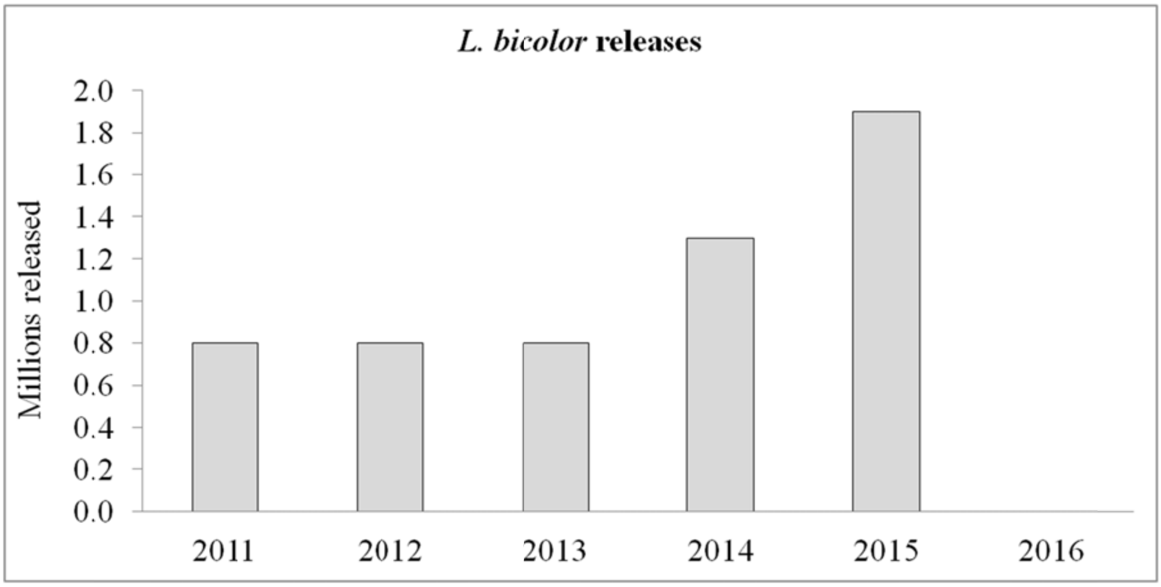


Figure 22 Estimated number of *L. bicolor* laboratory reared and field released between 2011 and 2016 for the control of sexavae pests through egg parasitism.

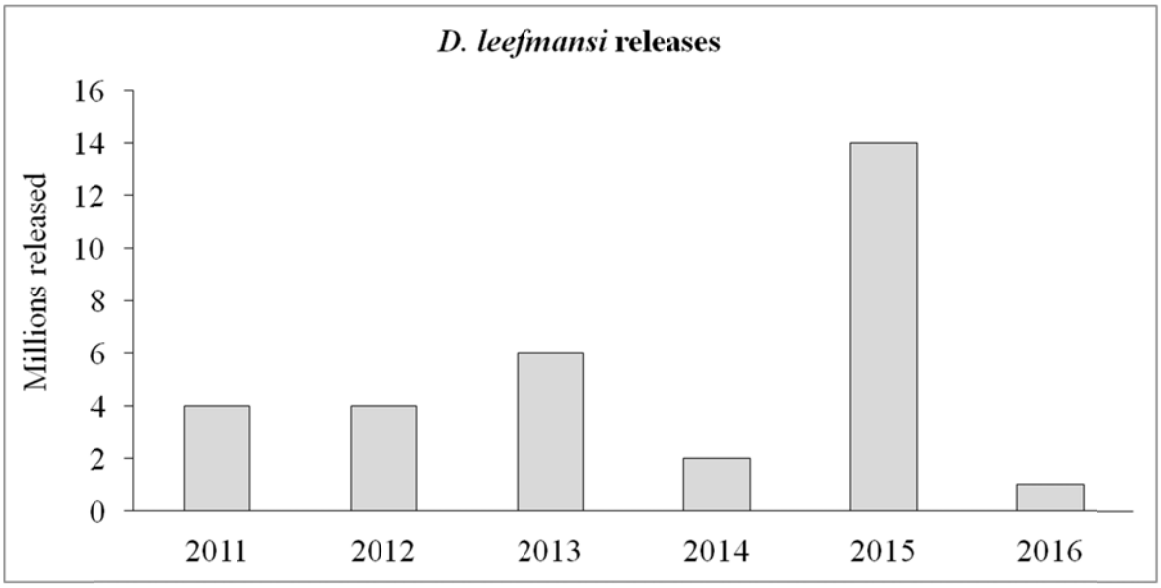


Figure 23 Estimated number (in millions) of *D. leefmansi* laboratory reared and released between 2011 and 2016 for the control of sexavae through egg parasitism.

C.3. Applied research reports

C.3.1. Study into the improvement of the biological control agents release program

Tabitha Manjobie

a. Introduction

Integrated Pest Management (IPM) is important for sustained management of pests in any agricultural systems. It involves a synergetic use of a range of control measures for effective control of target pests. The use of natural enemies as biological control agents has long been an integral component of all IPM programs.

IPM has been strongly promoted for the management of oil palm pests in PNG. Egg parasitoids (*D. leefmansi* and *L. bicolor*) of sexavae have been used as part of sexavae IPM since the 1980s, while the abdominal parasite *S. dallatoreanum* has been identified and promoted since the 1990s. The egg parasitoid (*A. eurycathae*) of stick insects was discovered in 2007 at Malilimi Plantation (WNB), and has since been mass reared and field released as part of stick insect IPM.

One of the key factors for sustenance of biological control agent populations in any agricultural systems where natural enemies are used as bio-control agents is the use of beneficial plants as food source (nectar) to sustain the adult populations of the agents. Without such field bio-control agent populations are prone to collapse. Although the releases of biological control agents in oil palm cropping systems have been done routinely, the promotion and use of beneficial plants has not been methodically investigated. This study was instigated to evaluate the preferred beneficial plants for the key biological control agents of oil palm pests, and to promote their cultivation in the oil palm cropping systems.

The study continued in 2016 and concentrated on investigating the sugar (glucose) concentrations of some of the commonly used beneficial plants. The result from this component of the study is provided in this report. The study will still continue into 2017 and full report provided once all components of the study are completed.

b. Materials and Methods

Beneficial plant species used for sugar concentration measurement

Five species of beneficial plants were used in the study, and they were established on site and sampled for the sugar concentration measurement. They were *Octacanthus caeruleus* (Brazillian Snapdragon), *Turnera subulata* (White Alder), *Turnera ulmifolia* (Yellow Alder), *Antigonan lepitopus* (Coral Vine) and *Crotalaria pallida* (Rattlebox Plant) **[Plate 1]**. The plants were planted in 3m x 2m rectangular plots under a green net shade house on site (Dami).

Plate 1 Five (5) species of commonly used beneficial plants; (A) *Crotalaria pallida*, (B) *Turnera subulata*, (C) *Turnera ulmifolia*, (D) *Antigonan lepitopus* and (E) *Octacanthus caeruleus*.

Flower sampling

Sampling of flowers for nectar extraction and sugar concentration measurement was done between 7.00am and 8.00am of every working day. The number of flowers sampled daily varied depending on the availability of opened flowers. The type and number of insects present on the flowers were also recorded.

Extraction of nectar

The nectar were drawn from flowers using a 1-10µL pipette (Pipetman/GILSON™-z53641k) fitted with plastic micro capillary tube to the estimated volume. For flowers with very low nectar volume, five (5) or more of fully opened flowers (opened but showing no sign of senescence) were selected from a single plant and measured. Nectar was drawn from each flower and placed cumulatively in the cavity block tray until the required volume (1-2uL) was made up. The required nectar volume was then drawn up from the cavity block and placed on the Gluco Strip for sugar (glucose) concentration measurement.

Plate 2 Extraction of nectar from the flower (left) and drawing of required volume of nectar from the cavity block tray (right) for measurement.

Sugar concentration measurement

The measurement of sugar concentration was done using a digital blood Glucometer™ (a home test kit used for measuring human blood sugar level particularly in diabetic patients). Measurement of different sugar concentration using a Refractometer™ was not practical because it needed at least 0.3mls of nectar for detectable measurement which was still too high compared to the volumes that the flowers were producing. Hence, only glucose which is the main sugar was measured as a representative of all sugars (fructose and sucrose) in the flowers. Approximately 1µL of nectar from the micro-pipette was transferred onto the blood glucose test strip and inserted into the Glucometer™ for the measurement. The reading on the Glucometer™ screen was taken as the glucose concentration reading (refer Plate 3). The reading ranged from 30mg/dL to 600mg/dL. Any reading below the lower range was indicated as "**Low**" and reading above the upper range was indicated as "**High**". For those flowers that had high reading, they were diluted with distilled water using the dilution factor of 1:10 (which comprised of 1uL nectar to 9µL distilled water). The actual sugar concentration was then calculated using the formulae **C1 = (C2 x V2)/V1** where **C1** = actual concentration, **C2** = measured glucose concentration, **V2** = diluted nectar volume and **V1** = volume of nectar. The number of readings taken was replicated 50 times for each flower.

Plate 3 The Glucometer™ showing the sugar concentration (glucose) reading of one of the flowers with the Glucometer™ Strip inserted (blue strip on the top). The pointer shows where the nectar was placed.

c. Results and Discussion

The number of flowers used varied for each replicate (n = 50). An average of one flower each were used to draw nectar for the measurement of sugar concentration (glucose) for *T. ulmifolia* (Yellow Alder), *O. caeruleus* (Brazilian Snapdragon) and *C. pallida* (Rattlebox Plant), whilst 5 and 7 flowers respectively were used for *T. subulata* (White Alder) and *A. leptopus* (Coral Vine) [Figure 24].

Sugar concentration (glucose) in *O. caeruleus* and *A. leptopus* were significantly higher [$F_{(4,245)}$ = 483.1, $P < 0.001$) than the other three beneficial weeds (*T. ulmifolia*, *T. subulata*, *C. pallida*) [Figure 25]. *Antigonan leptopus* had small volumes of nectar (which needed more flowers to draw the required volume for measurement), but the concentration of sugar measured from the standard volume used for measurement was significantly high compared to *T. subulata* which also required more flowers to draw the required volume of nectar. The sugar concentration in *T. subulata* was not significantly different from *T. ulmifolia* and *C. pallida* where only single flowers were used to draw the required volume of nectar. The high concentration of sugar in *A. leptopus* can be attributed to the reason why it is used as a common beneficial weed in many agricultural systems. Its preference by biological control agents will be determined in the preference study to be done in the following year (2017).

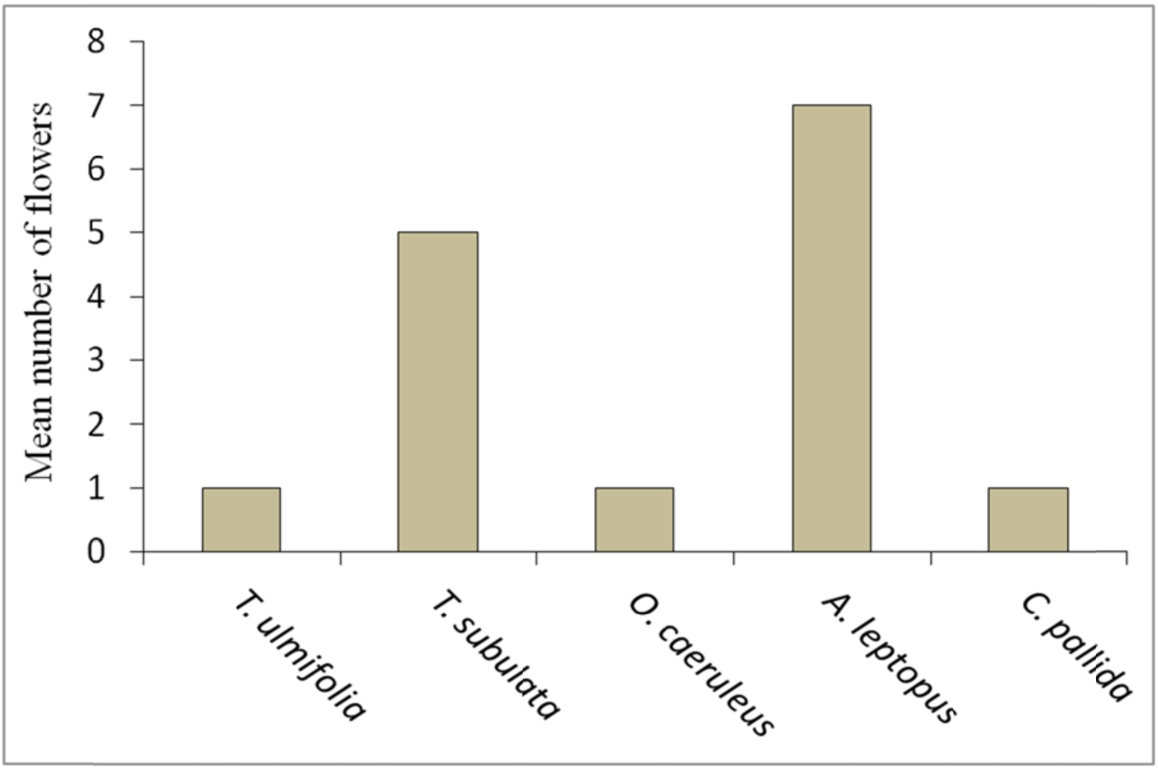


Figure 24 The mean number of flowers used for each beneficial weed to draw the required volume of nectar for sugar concentration measurement.

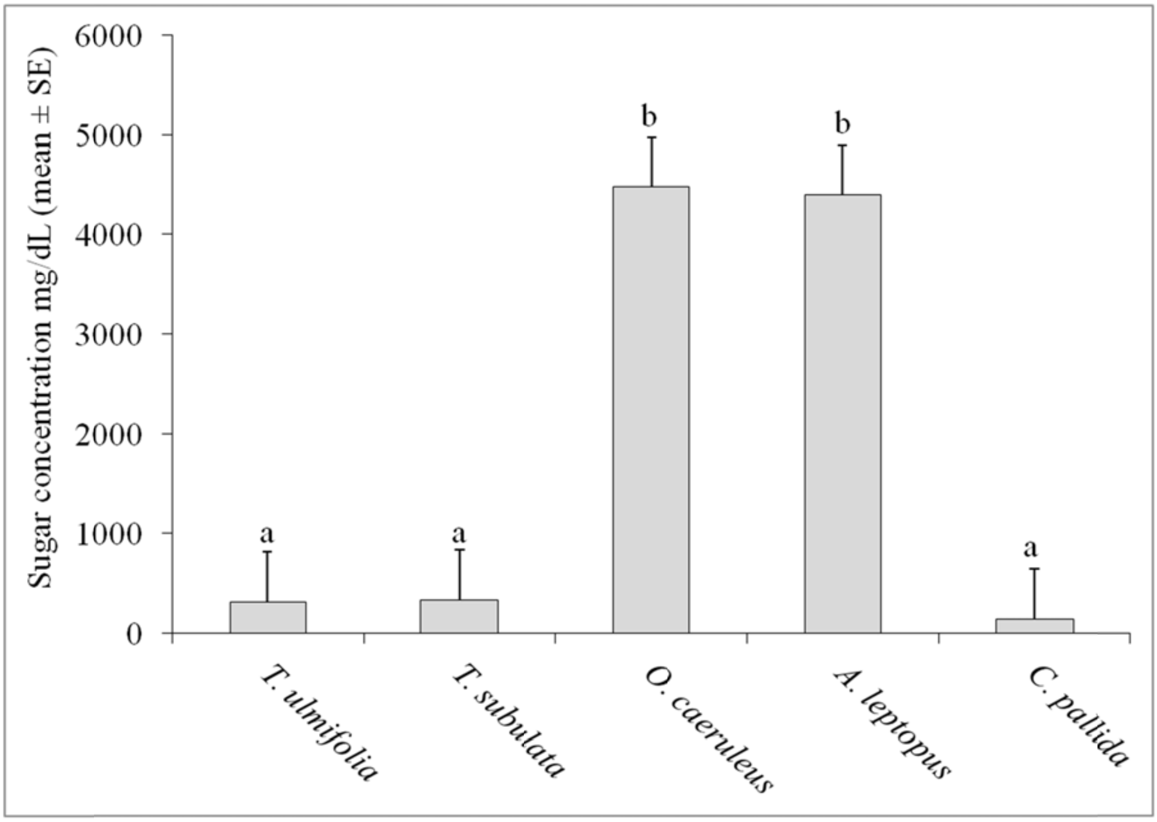


Figure 25 Sugar (glucose) concentration (mean ± SE) measured from the flowers of the five beneficial weeds studied.

d. Conclusion and recommendations

The significant differences in the sugar concentrations among the beneficial plants demonstrate that the preference levels by natural enemies may also vary among the different plants used to sustain biological control agent populations. The following recommendations are made in line with the results:

- Biological control agent preference among the beneficial plants using one of the biological control agents is evaluated in 2017.
- Preferred beneficial plants are planted in the smallholder trial blocks where baseline data were collected and monitored for the establishment of the biological control agents and the level of parasitism on the eggs of pests as well as the pest infestation levels over time. Other aspects of BMP should also be applied.

C.3.2. Evaluation of baits against the little fire ant (*Wasmania auropunctata* Roger) and monitoring of its impact on the oil palm pollinating weevil (*Elaedobius kamerunicus* Faust)

Mark Ero and Richard Dikrey

a. Background

Wasmania auropunctata (Roger) [Hymenoptera: Formicidae] commonly known as "Little Fire Ant (LFA)" is an invasive ant (Wetterer & Porter, 2003; Wetterer & Porter, 2003). LFA poses threat to both biodiversity and human activities (Holway, et al., 2002). It interferes with production in agricultural systems such as coffee and citrus where the ant promotes scale insects and interferes with biological control agents (Fabres & Brown Jnr, 1978). The ants also disturb farm workers, when they are disturbed and get onto people's skin and sting. They nest in houses and rest places, and spoil foods in kitchens. There is also anecdotal evidence that LFA sting domestic and wild animals, especially in the eyes causing permanent blindness, and death particularly of juveniles in some cases.

The incursion of this ant in West New Britain Province was first detected in 2012 but the species confirmation was not done until early 2015. The ant is gradually spreading to different parts of the province, particularly through the movement of planting materials and domestic goods.

The disturbance to field workers in oil palm plantations and smallholder blocks, as well as incursion in residential areas and offices is a course of concern and control options needed to be considered. Six different granular baits (Engage P™, Engage Plus™, Campaign Plus™, Synergy C™, Distance P™ and Synergy P™) were obtained from Sumitomo Chemicals, Australia and tested in 2016.

Apart from the disturbance they cause to field workers, the investigation of its impact on the pollinating weevil (*E. kamerunicus* Faust) is critical as it is aggressive and arboreal in habit. Feeding by the ant on pollinating weevil larvae can have severe impact on pollination and subsequently fruit production. This has also been investigated through monthly palm fruit and pollinating weevil census.

b. Materials and Methods

Evaluation of ant baits against LFA

The test samples of baits were supplied by Sumitomo Chemicals, Australia. The baits included Engage P™, Engage Plus™, Campaign Plus™, Synergy C™, Distance P™ and Synergy P™).

The trial was replicated across three sites (Siki [Block 009-1055], Sarakolok [Block 003-884], Kumbango Plantation [Division 2, MU 5A, Field D15]) with confirmed LFA infestation. The treatments including a Control bottle without any bait placed were replicated 5 times per treatment at each site, and monitored for a month.

Yellow cap urine bottles were used for feeding and response observations. The bottles were weighed individually (ca 12g each) and 10g of the respective baits were weighed and placed in individual containers. The bottles were labelled according to treatment and replicate. They were placed around the frond bases of oil palm where LFA trails were observed and data collected over a month. Every day after the set up of the trials, the urine bottles were checked, and ant movement into the containers and feeding were recorded.

Monitoring of impact on the pollinating weevil (E. kamerunicus)

The study to monitor the impact of LFA on oil palm pollinating weevil has been conducted across 4 smallholder block sites. These include 2 blocks in Siki Division (one infested [Block 009-1055] and the other free of LFA [Block 009-599]) and 2 blocks at Sarakolok in Nahavio Division (one infested [Block 003-884] and the other free of LFA [Block 003-831]). The study started in June 2016 with monitoring done on monthly bases. The study will continue for a year before it is terminated. The standard PNGOPRA pollinating weevil monitoring protocol was used for this study where census of all floral stages (both male and female) and the fruit bunches (both ripe and black) were done, and 10 spikelets each from 5 post anthesising male inflorescences were taken to the lab after the total number of spikelets were counted, and set for weevil emergence. Once all weevils had emerged and died, the number of emergent weevils were counted and recorded. This data was then used to project the total pollinating weevil population per male inflorescence.

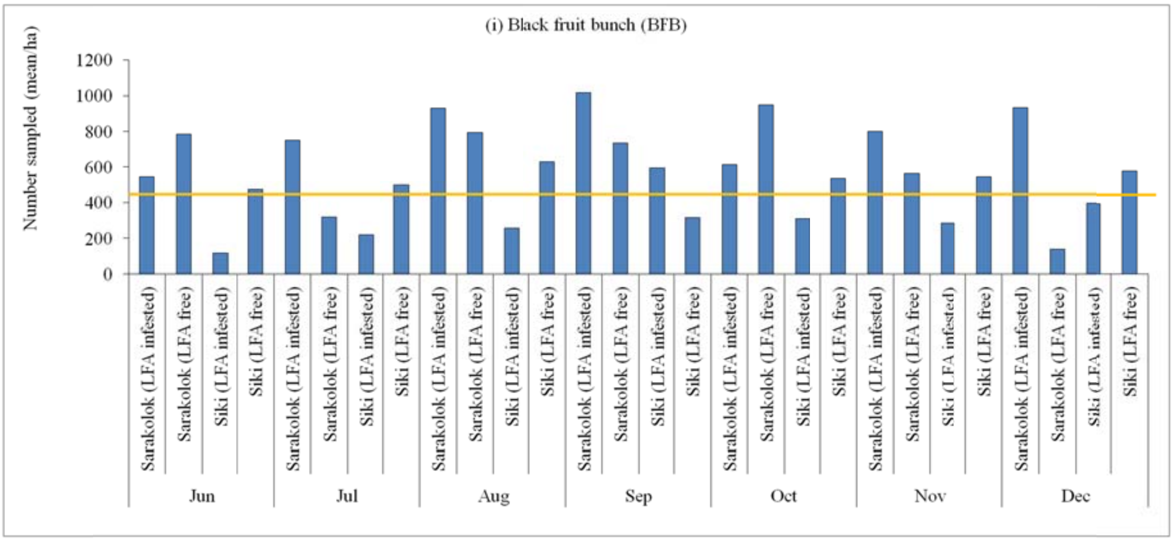
c. Results and Discussion

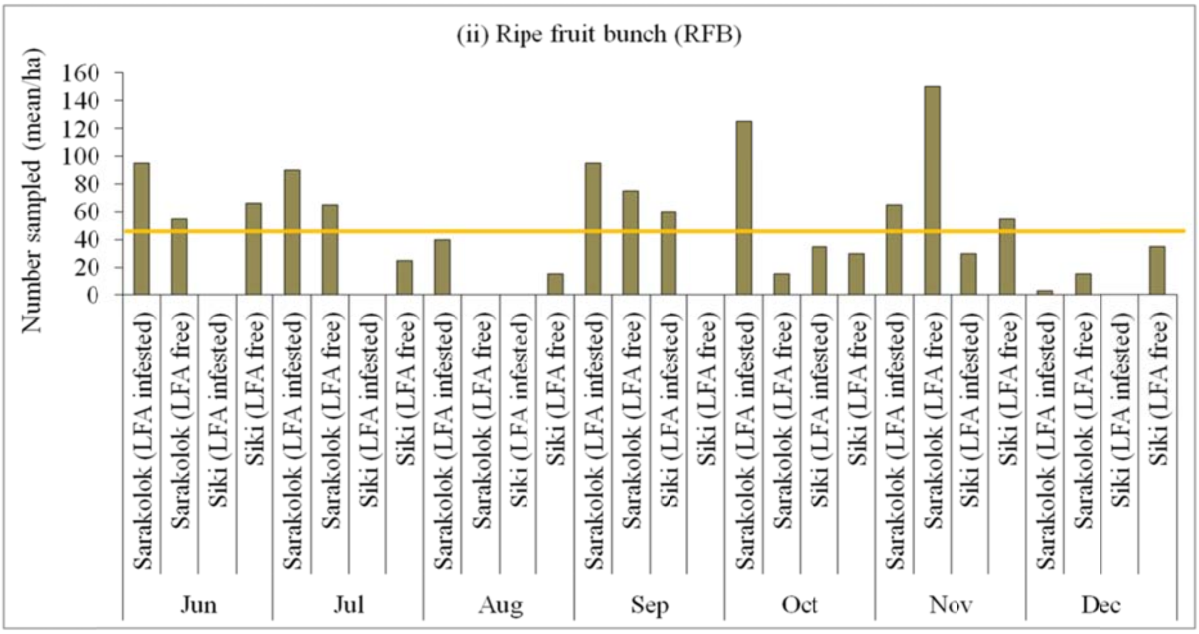
The worker Little Fire Ants (LFA) responded more to Engage P™, Engage Plus™ and Campaign Plus™ in terms of entry into the pots containing the baits and feeding on them than the other three (3) baits (Synergy C™, Distance P™, Synergy P™) that were evaluated (Table 57). The baits with higher preference will need to be tested on a larger scale for effectiveness in terms of the destruction of the colony through the killing of the reproductive queens before any recommendation is made for the effective bait. The cost will also be captured when making the recommendation.

Table 57 Responses of *W. auropuntata* (LFA) to the baits in terms of entry into the bottles and feeding.

Baits	% response
Engage P	39
Engage Plus	24
Campaign Plus	19
Synergy C	7
Distance P	6
Synergy P	4
Control	1

High numbers of black fruit bunches (BFB) were recorded from all blocks (more than 400 per hectare) except for the LFA infested block at Siki (Block 009-1055) which had less than 400 bunches (BFB) during most of the months surveyed (**Error! Reference source not found.**(i)). However, this result is less likely related to the impact of LFA infestation on the pollinating weevil population as the population in the block was high (Figure 28). The low number of ripe fruit bunches (RFB) counted during the survey on all survey blocks was due to the fruits (RFB) being harvested before the census was conducted. There were very few mixed bunches (around 2 per ha) and aborted fruit bunches (less than 1 per ha) (Figure 26 (iii & iv)) implying that pollination process was not affected.


(i) Black fruit bunch (BFB)
Number sampled (mean/ha)
1200
1000
800
600
400
200
0
Sarakolok (LFA infested)
Sarakolok (LFA free)
Siki (LFA infested)
Siki (LFA free)
Jun
Jul
Aug
Sep
Oct
Nov
Dec


(ii) Ripe fruit bunch (RFB)
Number sampled (mean/ha)
160
140
120
100
80
60
40
20
0
Sarakolok (LFA infested)
Sarakolok (LFA free)
Siki (LFA infested)
Siki (LFA free)
Jun
Jul
Aug
Sep
Oct
Nov
Dec

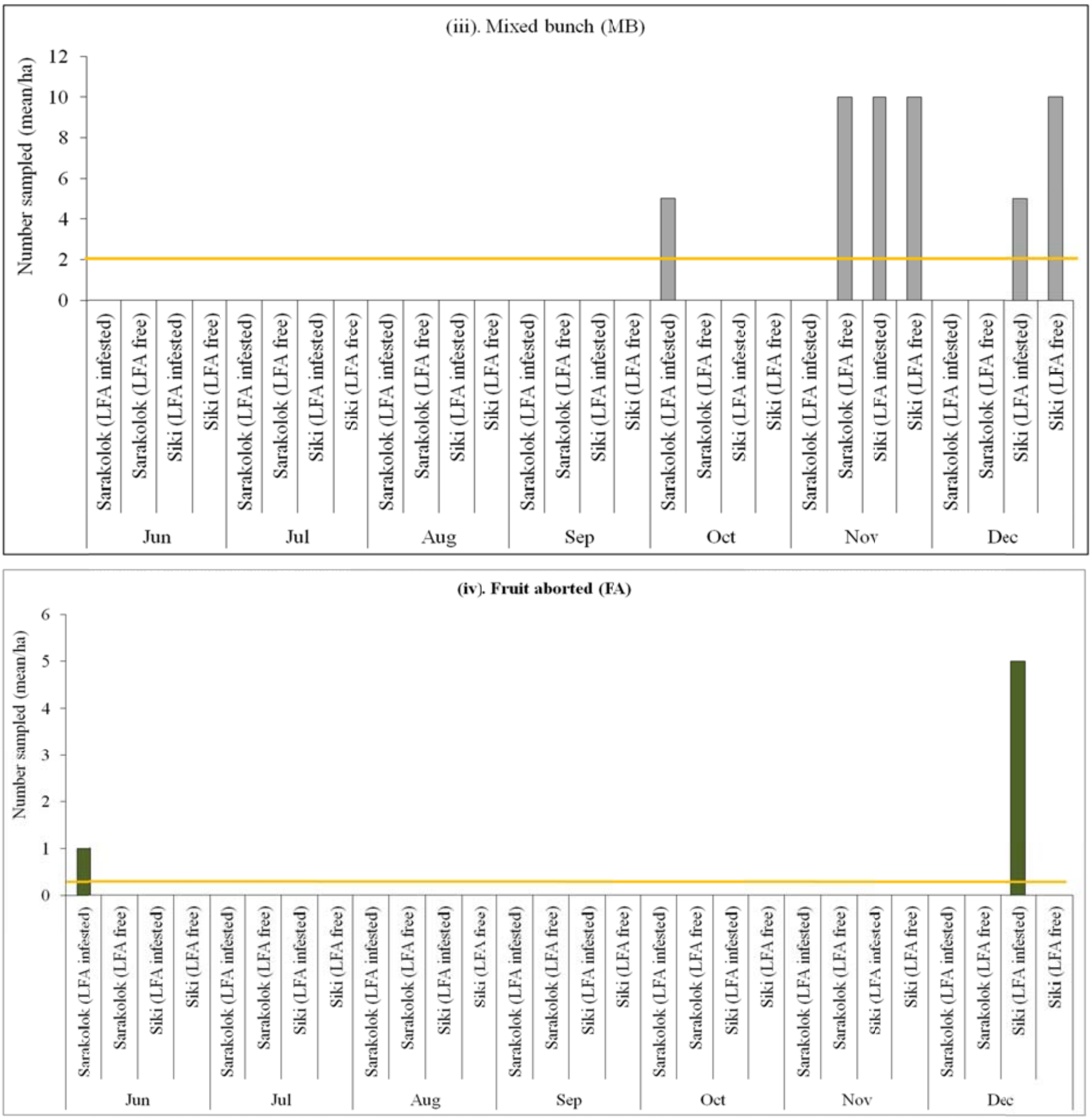


Figure 26 Mean number of black fruit bunches (i), ripe fruit bunches (ii), mixed bunches (iii) and aborted fruit bunches (iv) sampled per hectare (yellow bar = mean of the monthly means).

The mean number of male inflorescences was high at around 33 inflorescences/ha which was adequate to support the pollinating weevil population and to effectively pollinate the palms (Figure 27).

The estimated number of pollinating weevils per hectare calculated from the number of male inflorescences sampled per hectare were high in all sampling blocks (for almost all blocks it was greater than 100,000 weevils per hectare) except for the LFA free block at Sarakolok (Block 003-931) which had less than 100,000 weevils during August (Figure 28). However, since the block is free of LFA infestation, the reason for the lower population cannot be attributed to the impact of LFA preying on the weevil larvae within the male inflorescences.

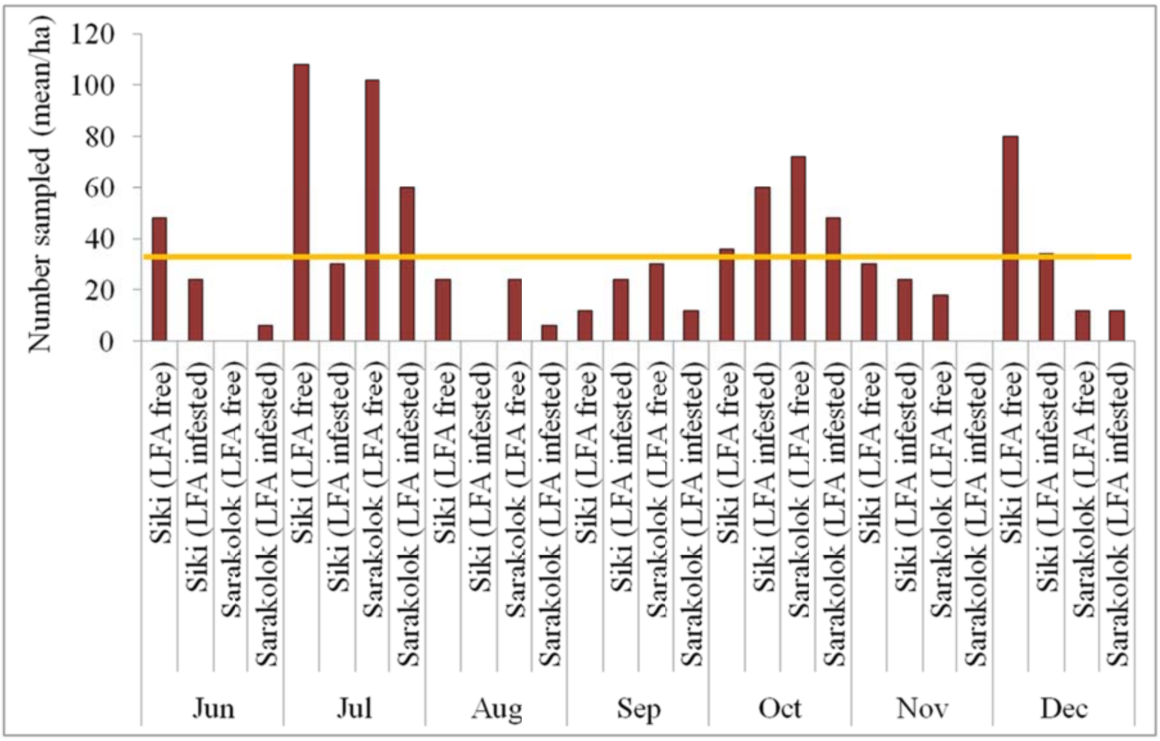


Figure 27 Mean number of male inflorescences sampled per hectare (yellow bar = mean of the monthly means).

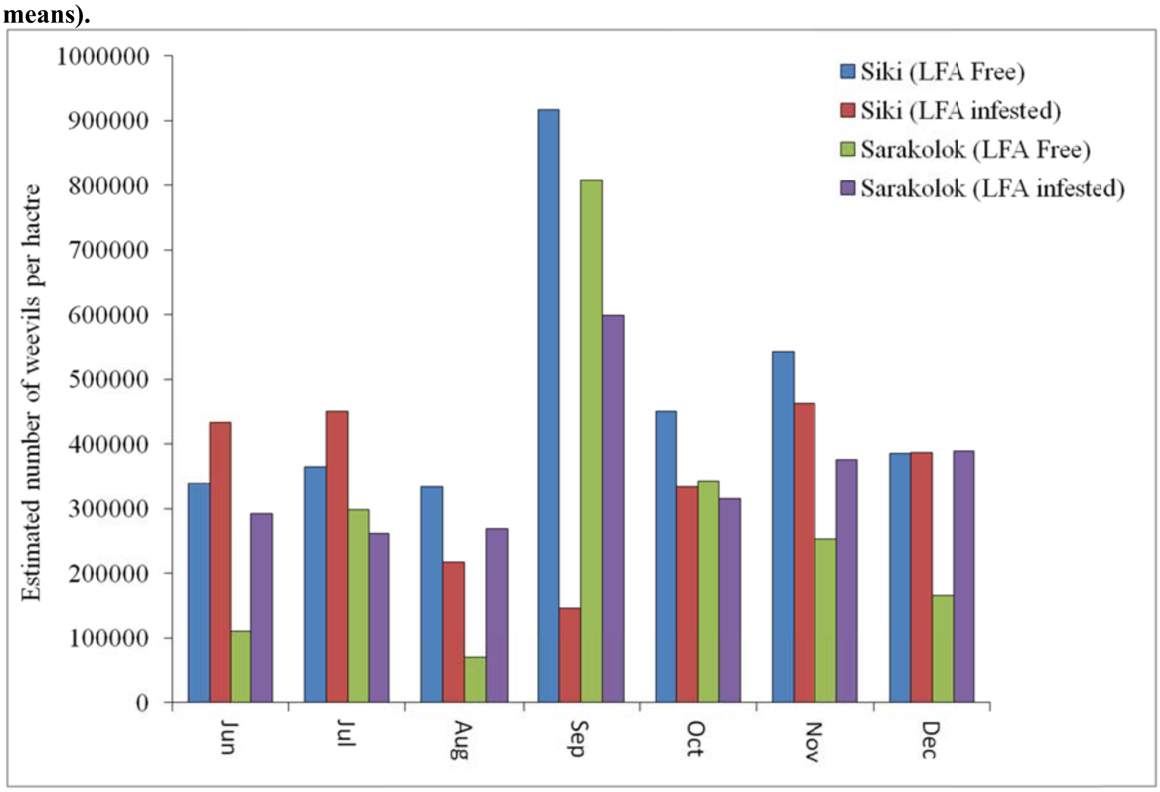


Figure 28 Estimated number of pollinating weevil (Elaedobius kamerunicus Faust) per hectare.

The preliminary indications from the survey results of the first 6 months are that LFA infestation is not having any impact on the pollinating weevil population in terms of the worker ants predating on the weevil larvae within the male inflorescences. However, the study needs to be continued for another 6 months before a final conclusion is drawn.

d. Conclusion and recommendations

The study needs to continue before a final recommendation is made on the effective bait for the control of the ant, and a conclusion is drawn on the impact of the ant on pollinating weevil population in infested areas. It is recommended from the results that the following activities continue:

- Large scale trial concentrating around residential areas is conducted to evaluate the effectiveness of the three ant baits that were found to be more attractive to LFA before the final recommendation is made for the effective bait.
- Other cheaper baits apart from the ones tested are considered.
- The census for the impact on the pollinating weevil is continued for another 6 months before a conclusion is drawn on the potential impact of LFA on the weevil population.
- Consider the possibility of using protective clothing for oil palm field workers (particularly the harvesters).

C.3.3. Pheromone investigation for Coconut Flat Moth, *Agonoxena* sp. (Lepidoptera: Agonoxenidae)

Progress report

David Hall (Natural Resources Institute [NRI], UK) and Sharon Agovaua

a. Introduction

Coconut Flat Moth (CFM), *Agonoxena* spp. is an important pest of coconut palms in many parts of the Pacific. In 2011 an unknown species of CFM was observed causing damage to young oil palms at Milne Bay Estates (MBE), particularly in Naura and Bunebune Divisions of Waigani Estate.

Because of the infestation, there was a need to evaluate possible control measures to manage the pest. Several control options had been considered including the use of pheromone as part of the integrated pest management (IPM) programme for the CFM.

Since there is no commercial synthetic pheromone available for the pest, a need arose to look around for companies that may be interested to investigate this for the pest (CFM). The Natural Resources Institute (NRI) in the United Kingdom (UK) agreed to conduct studies into the pheromone of the pest. Thus, samples of CFM pupae were collected from the field in June 2016 and sent to the institute for the investigation.

This part of the report presents the results of the pheromone study done at NRI, UK.

b. Materials and Methods

Field collection of CFM pupae and shipment

Initial batch of around 200 pupae were collected from the field and sent to NRI in August 2015, however most failed to emerge. This failure was most probably due to the prolong exposure to the cool cabin temperature during the long flight hours (PNG to UK).

A second batch of around 2000 final instar larvae were collected from the field and kept in BugDorm cages to pupate. Once the larvae pupated, 500 pupae were collected and packed into micro-oven lunch box containers (placed over layers of paper towel). The samples were hand carried to the UK by Mr Charles Dewhurst when he visited PNGOPRA in June 2016. Upon arrival at Heathrow International Airport, he courier mailed the samples to NRI for lab studies.

Because of the short life cycle, the insects had already started emerging upon arrival at NRI, so they were separated into individual containers and maintained in a humidified incubator at 20°C with a reversed 12:12h (L: D) cycle for the pheromone study.

Pheromone Extraction

Virgin female moths were anaesthetised with carbon dioxide and the ovipositor extruded by gently squeezing the abdomen. The ovipositor was excised with dissecting scissors directly into hexane (30 μl) in a small conical vial. Batches of 10 ovipositors were collected in the hexane and after 10-15 min the solvent was transferred to another vial with a micro-syringe. Extracts were made 2 hr, 3 hr, 4 hr, and 6 hr into the dark period and stored at 4°C before analysis. An extract of male abdominal tips was also made after 3 hr into the dark period.

Analysis by Gas Chromatography-Mass Spectrometry (GC-MS)

Extracts were analysed by GC-MS using a Varian 3500 GC coupled to a Saturn 2200 MS (Agilent Technologies, Stockport, Cheshire, UK) operated in electron impact mode. A polar GC column was used (30 m x 0.25 mm i.d. x 0.25 μ) coated with DBWax (Supelco, Gillingham, Dorset, UK) and the oven temperature was programmed from 40°C for 2 min then at 10°C/min to 240°C.

Analysis by Gas Chromatography-Electroantennography (GC-EAG)

For GC-EAG analyses an Agilent 6890N GC (Agilent) was used with a fused silica capillary columns (30 mm x 0.32 mm i.d.) coated with polar DB Wax (Agilent). Injections were splitless (220˚C), the carrier gas was helium (2.4 ml/min) and the oven temperature was held at 50˚C for 2 min before increasing at 20˚C/min to 250˚C. The ends of the GC columns went into a push-fit Y- connecter that led through a second Y- connector fitted with two equal lengths of deactivated fused silica capillary going to the flame ionisation detector (FID) and to the EAG preparation through a heated transfer line (250°C). The column effluent was passed over the EAG preparation in a stream of humidified air (500 ml/min) through a glass tube (4mm i.d).

Various approaches to preparation of the antenna for EAG recording were tried. Either the head with antennae or just an excised antenna were used. These were either suspended between two metal electrodes with electro-conducting gel or between two glass microelectrodes filled with Ringer solution and attached to silver wire electrodes. Antennal responses were recorded using a Syntech INR-2 micromanipulator assembly (Syntech, Hilversum, The Netherlands). The antennal responses were amplified x 10 and converted to digital format through the second detector channel of the GC. Data from FID and EAG were captured and processed with EZChrom Elite v 3.3.1 software (Agilent). Antennae of males were used in most runs (N = 6) but some runs with antennae of females (N = 3) were carried out for comparison.

c. Results and discussion

GC-MS Analyses

GC-MS analyses showed only small amounts of material and no obvious differences between the extracts of female ovipositors made at different times into the dark period and the extract of male abdominal tips (Figure 29). Peaks were mainly saturated *n*-alkanes, (e.g. eicosane and tricosane). Single ion scanning at m/z 61 for acetates and examination of the mass spectra of each peak failed to show any peaks characteristic of insect pheromones, e.g. acetates, aldehydes or alcohols.

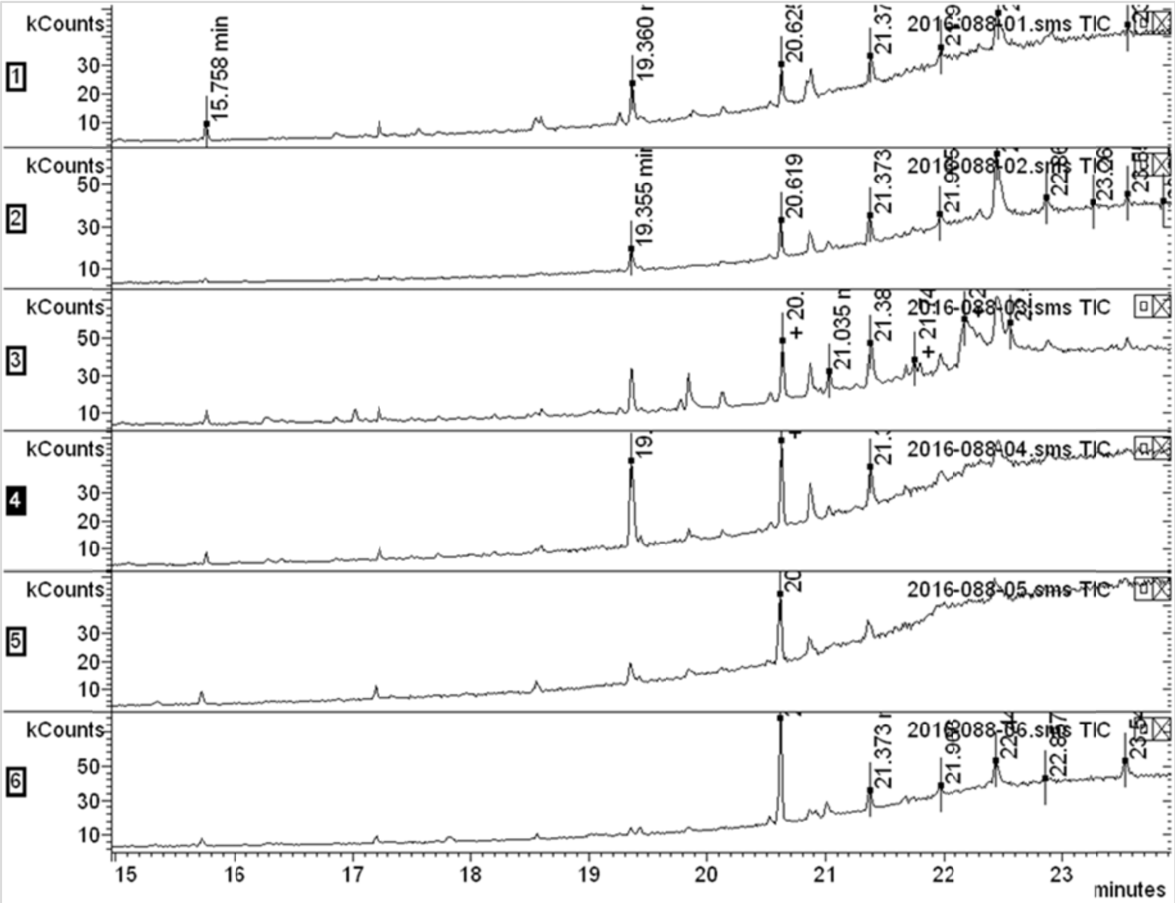


Figure 29 GC-MS Analyses of (from top) extracts of female ovipositors made at 2 hr, 4 hr, 6 hr, 6 hr and 3 hr into the dark period and extract of male abdominal tips (eicosane at 19.36 min; tricosane at 20.62 min).

GC-EAG Analyses

Representative GC-EAG runs with male antennae are shown in Figure 30. No consistent responses were observed, and similar results were obtained with female antennae.

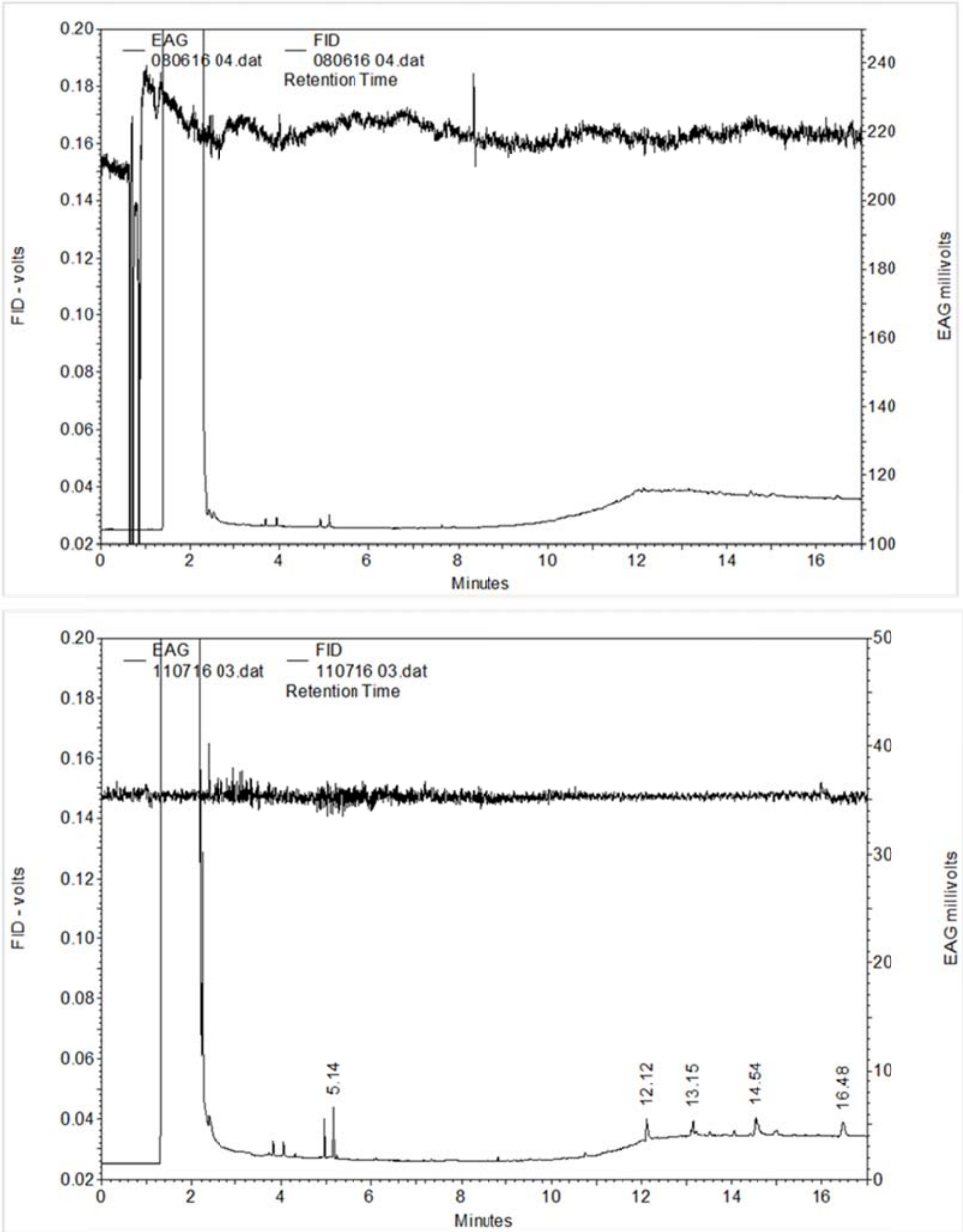


Figure 30 GC-EAG analyses of female ovipositor extract with male EAG preparation.

No EAG response was observed to synthetic (*Z*)-11-hexadecenal (Z11-16: Ald), (*Z*)-11-hexadecenyl acetate (Z11-16:Ac) or (*Z*)-11-hexadecenol (Z11-16:OH) which are common components of sex pheromones in Lepidoptera (Figure 3).

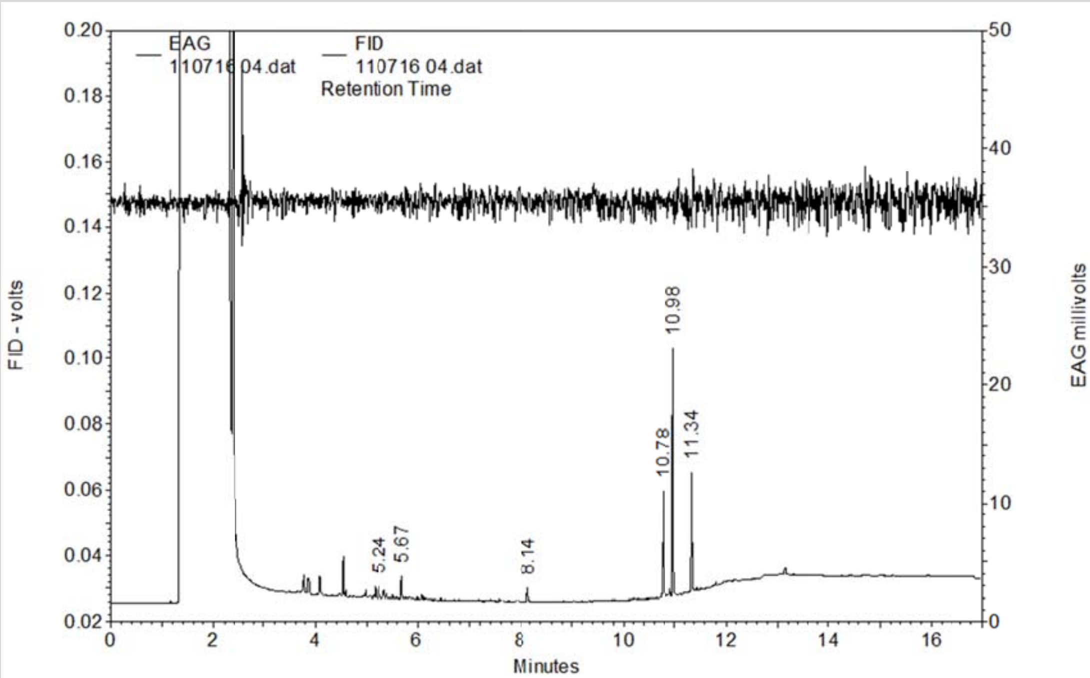


Figure 31 GC-EAG Analysis of Z11-16:Ald, Z11-16:Ac and Z11-16:OH (approx. 10 ng) with male EAG preparation.

Analysis of ovipositor extracts from female coconut flat moths, *Agonoxena* spp., by GC-MS and GC-EAG failed to show any candidate components of a female sex pheromone. It was assumed that any sex pheromone glands would be on the ovipositor as in other Lepidoptera. Extracts were made from moths at 2 hr, 4 hr, 6 hr and 8 hr into the dark period, assuming that the moths are sexually active at night.

Sex pheromones have been identified in other species of moth from the Elachistidae family and these are female-produced and have chemical structures typical of other Lepidoptera. *Elachista apicipunctella* Stainton uses (Z,E)-8,10-tetradecadienol (Peltotalo & Tuovinen, 1986). Males of *Elachista consortella* Stainton are attracted to blends of (*Z*)- and (*E*)-11-tetradecenal (Ostrauskas, et al., 2010). The major component of the female sex pheromone of *Stenoma catenifer* Walsingham is (9*Z*)-9,13-tetradecadien-11-ynal (Millar, et al., 2008); (Hoddle, et al., 2009), and that of *Stenomia cecropia* Meyrick is (*Z,E*)-9,11,13-tetradecatrienal (Zagatti, et al., 1996); Hall et al., unpublished).

However, the antennal morphology of *Agonoxena* spp does not immediately indicate evolutionary selection for male detection of female-produced, long-distance pheromones. Antenna of males and females are similar, with relatively few chemical-detecting sensilla hairs.

Conclusion and recommendation

Since no pheromone candidates were detected during the early hours of night where the extractions were done, they could be more sexually active during the late hours of the night and this is when the pheromones could be released. It is therefore recommended that further mating study is conducted back in PNG throughout the night (from around 5.00pm to 6.30am) to determine the age and time of the night when pheromone is released.

C.3.4. Pheromone trapping of the Coconut Rhinoceros Beetle (CRB), *Oryctes rhinoceros* L. (Coleoptera: Scarabaeidae) for molecular analysis to identify

the biotype and to confirm infection by Oryctes NudiVirus [*Completed study report*]

Solomon Sar and Akia Aira

d. Introduction

The Coconut Rhinoceros Beetle (*Oryctes rhinoceros* L.) has the potential to cause economic damage to oil palm if infestations are not detected early enough and controlled effectively. The species has been observed causing considerable damage to young replant palms (2-3 years old) at Poliamba Estate (NBPOL). Ongoing control strategy has been in place for the management of the pest.

In 2007, a more destructive population of *O. rhinoceros* L. which was found to be tolerant to the Oryctes NudiVirus (bioagent used for the control of the pest), less responsive to the standard pheromone and with the ability to breed actively in the palm canopy was detected in Guam. This population has been referred to as the Guam biotype to differentiate from the commonly distributed population which is referred to either as the Pacific or the Samoan biotype. It has also been confirmed in Hawaii and Palau. Similar damage to those experienced on coconuts in Guam was observed on coconuts in Port Moresby since 2010.

Because of this observation, a collaborative research project among AgResearch New Zealand, the Secretariat of the Pacific Community (SPC) and PNGOPRA has been conducted since 2012 to determine the "biotype" of *O. rhinoceros* in parts of PNG and their infection by Oryctes Nudivirus. Apart from these, rapid damage assessments on coconuts were done in some parts of the country to determine the rhinoceros beetle hotspot areas. This study continued and concluded at the end of the year. A manuscript of the study has been prepared and is in press with "*The Planter*".

e. Materials and Methods

PVC pheromone traps using Oryctes pheromones (OryctaLure™) were set up in New Ireland Province, West New Britain Province, East New Britain Province and the National Capital District (NCD) at sites where visible rhinoceros beetle damage had been observed on coconuts to sample the beetles.

Gut tissue of the trapped *O. rhinoceros* were extracted, preserved in 70% ethanol and sent off to AgResearch NZ for DNA analysis to determine the beetle biotype and to confirm the presence of the Oryctes NudiVirus.

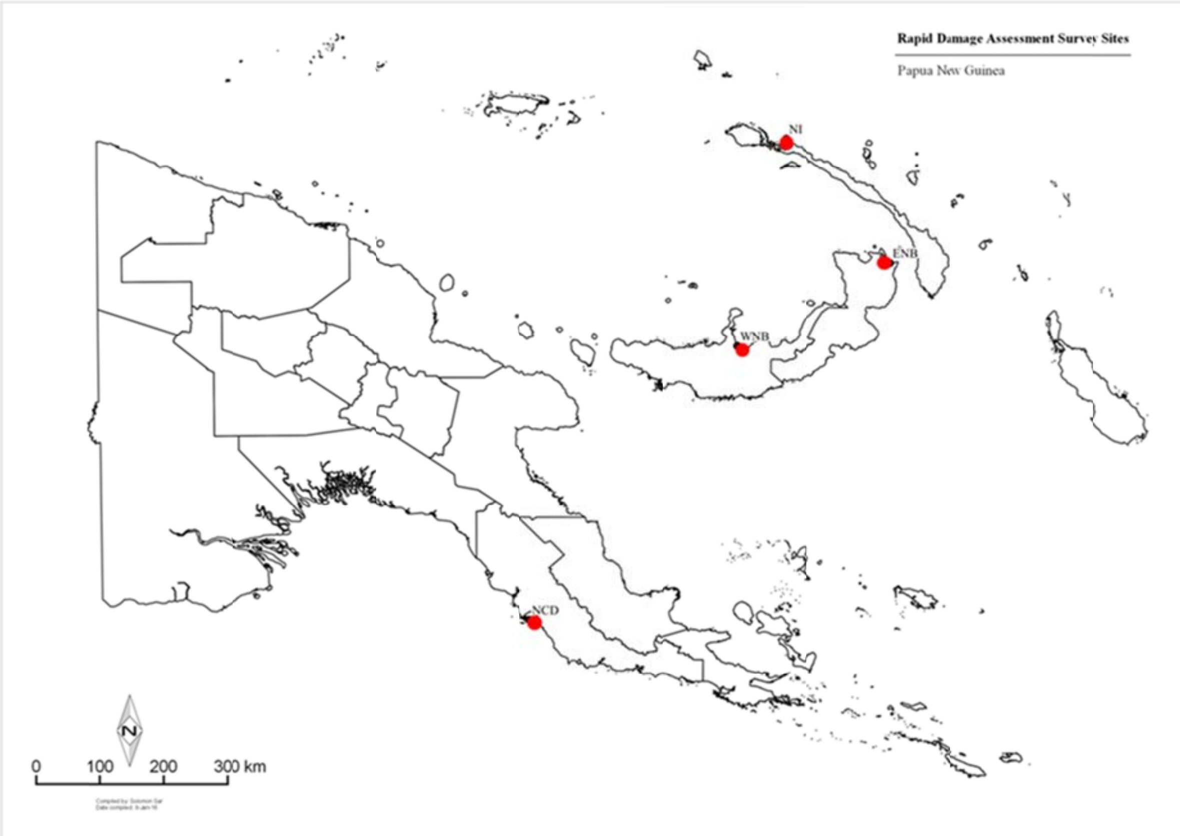


Figure 32 Map of PNG indicating the provinces where the pheromone trapping, gut sampling and the rapid damage assessment surveys (RDAS) were done. RDAS was also done in Central, Milne Bay and Northern Provinces.

For the rapid damage assessment, a camera with inbuilt GPS (Global Position System) was used to photograph the coconut palms and the damage levels determined. The overall damage levels were categorized as follows [no damage (0% defoliation), light damage (1-10% defoliation), moderate damage (11-30% defoliation), severe defoliation (31-100% defoliation) or dead palm]. The survey has been done in Central, East New Britain, Milne Bay, National Capital District, New Ireland, Northern and West New Britain.

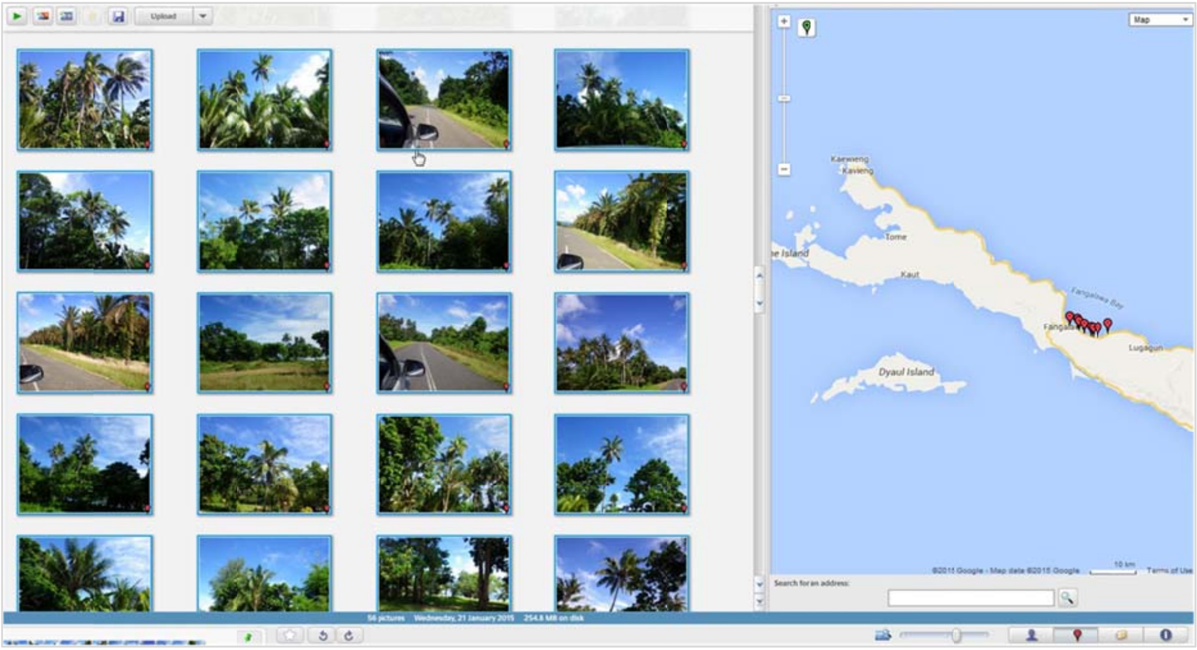


Figure 33 Photographs and map showing how the photographing and geo-tagging was done.

f. Results and Discussion

The molecular analysis results from AgResearch, NZ laboratory showed that only the Pacific/Samoan biotype (CRB-S) was present in East New Britain (ENB), New Ireland (NI) and West New Britain (WNB) with some specimens infected with Oryctes NudiVirus (OrNV) whilst the National Capital District (NCD) population was a mixture of both the Guam (CRB-G) and the Pacific/Samoan (CRB-P) biotypes with the Oryctes NudiVirus only infecting the Pacific/Samoan biotype (Table 58). No pheromone trapping was done in Central, Northern and Milne Bay Provinces.

Table 58. Coconut rhinoceros beetle analysis results showing the beetle biotype and the presence of Oryctes NudiVirus.

Sampling site (Province)	Beetle biotype	OrNV Presence
East New Britain	CRB-P/S	Yes
National Capital District (Port Moresby)	CRB-G, CRB-P/S	Yes- only CRB-P/S
New Ireland	CRB-P/S	yes
West New Britain	CRB-P/S	Yes

OrNV = Oryctes NudiVirus, CRB-G = Coconut rhinoceros beetle- Guam, CRB-P/S = Coconut rhinoceros beetle- Pacific/Samoan

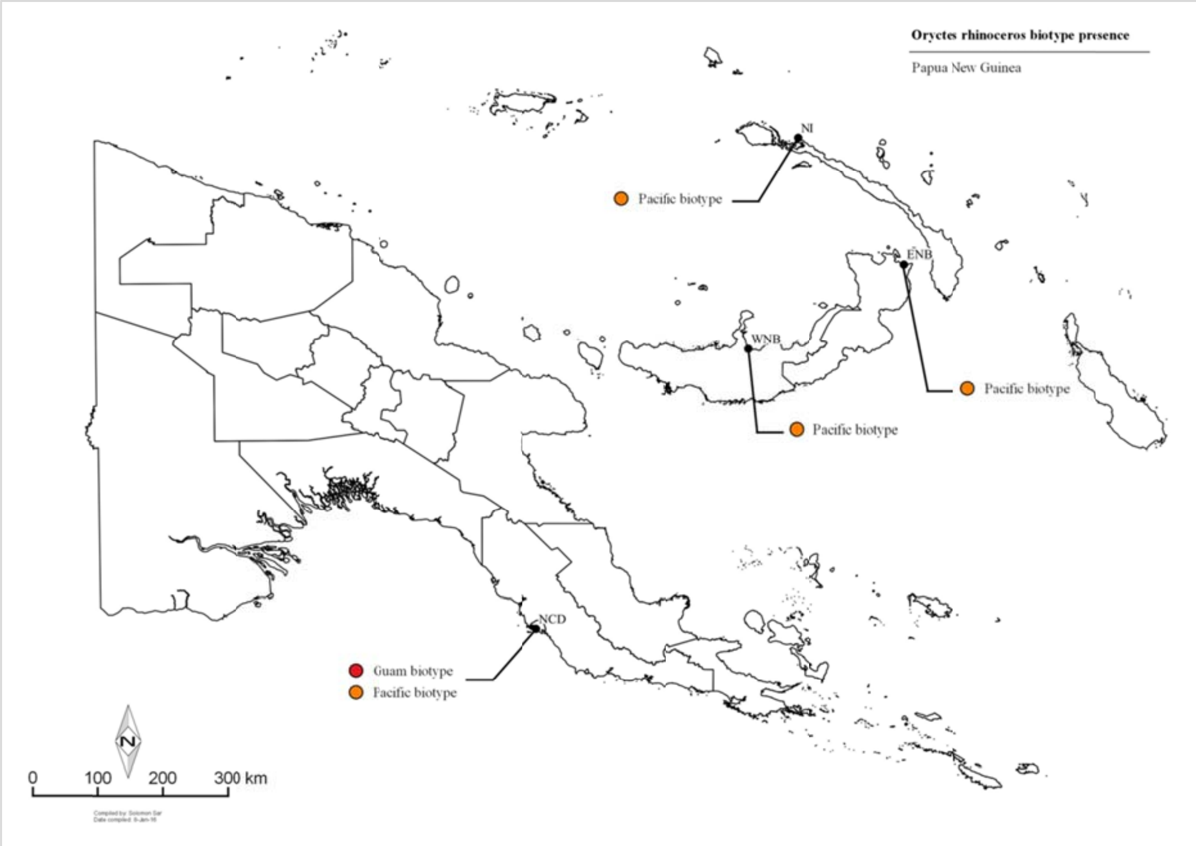


Figure 34 Map of PNG showing the presence of the two *O. rhinoceros* biotypes (Pacific/Samoan and Guam biotypes).

NCD, Central and parts of New Ireland had widespread moderate to severe damage. In ENB severe damage was concentrated around Rabaul, whilst for WNB a single hotspot area (moderate to severe damage) was noted around Numondo-Walindi area. Large areas in Central, Northern, ENB and New Ireland provinces also had widespread light damage. Most of WNB and Milne Bay were free of beetle damage (Figure 36).

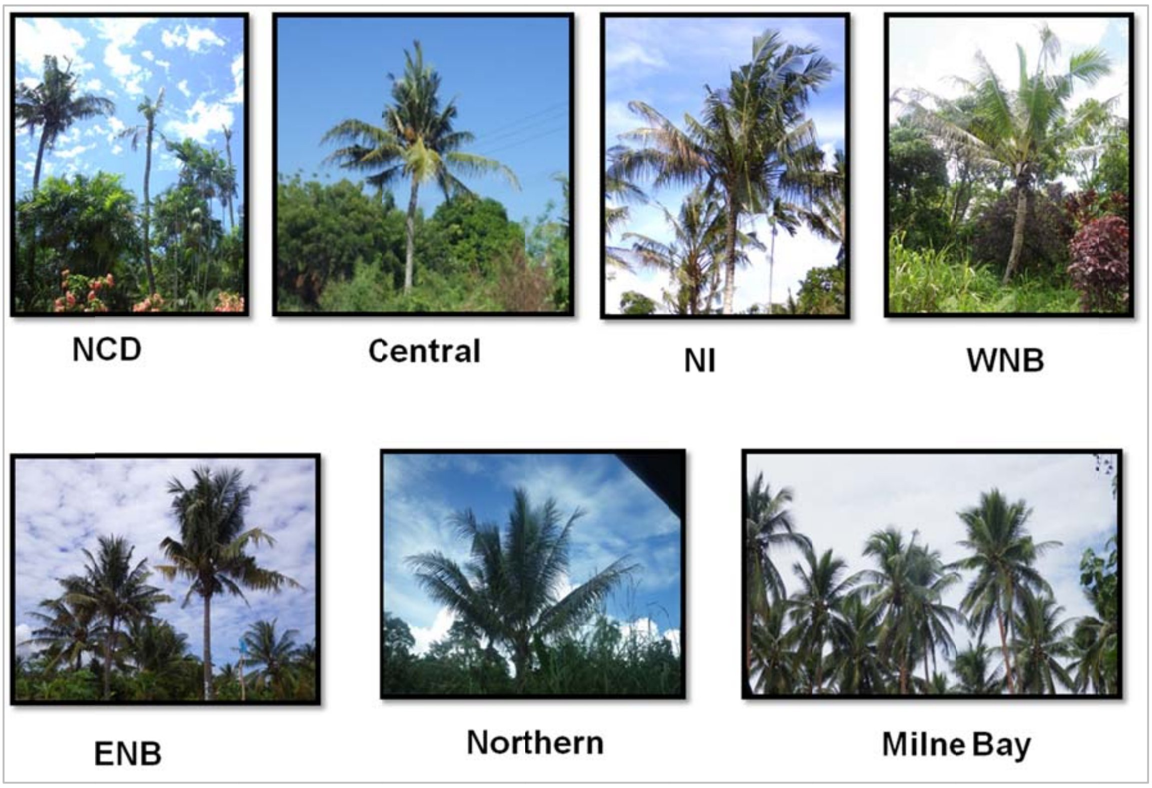


Figure 35 Photographs of coconuts showing the levels of damage among the different provinces.

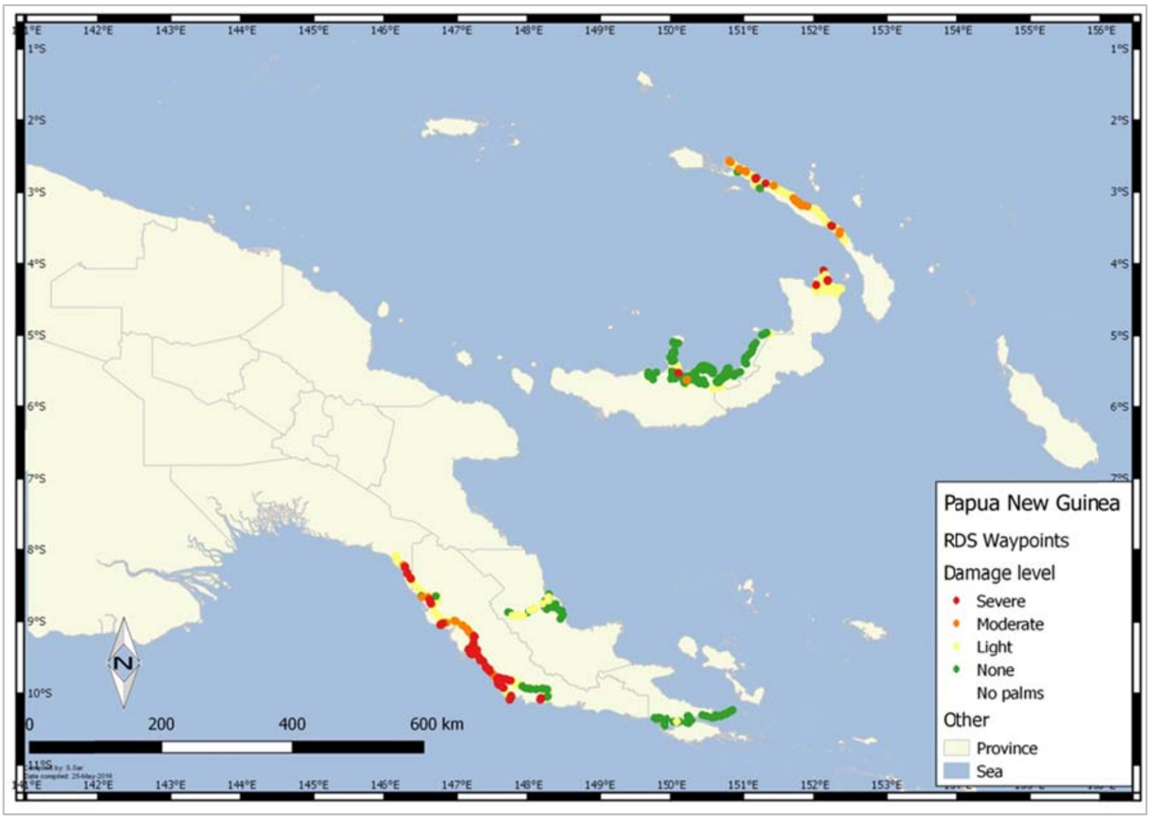


Figure 36 Map of PNG showing the different levels of damage among the provinces where the rapid damage assessments were done (damage levels are colour coded- see insert).

The level of damage directly related to the biotype and the thriving populations of beetles. The widespread severe damage on coconuts in NCD related to the confirmation of the Guam biotype from there. The recurrent infestation of young replant oil palms by the Pacific/Samoan biotype in NI compared to WNB is most likely due to the large thriving population of the beetle in old abandoned coconut plantations that is spread throughout the province. The concentration of severe damage to Rabaul area in ENB was influenced the old dead coconuts from the volcanic activities within the area that created conducive breeding conditions for the beetles.

The widespread occurrence of the NudiVirus in all three provinces is likely to keep the Pacific/Samoan biotype of the wild population of coconut rhinoceros beetle (*O. rhinoceros*) under control.

Rapid damage assessment technique can be used as a contingency planning tool for the management of the pest when either new planting or replanting of oil palm is done in hot spot areas.

Because of the detection of the Guam biotype in NCD, pheromone traps (using the standard pheromone) have been set up in Milne Bay (Mariawatte and Gadaisu) and Northern (Oro Bay, Girua Airport and Kokoda station) which are potential entry points. The use of standard pheromones in these traps will continue until a specific pheromone is developed.

g. Conclusion and Recommendation

Confirmation of the Guam biotype in NCD is a concern for the industry, particularly for Milne Bay Estates (MBE) and Higaturu Oil Palm Ltd (HOP) because of the common land bother they share with NCD and Central Province.

It is likely that Poliamba Estates (including the smallholder growers) will continue to encounter *O. rhinoceros* beetle damage on replant palms because of the thriving population of the beetle on large abandoned coconut plantations in NI.

It is recommended from the results that:

- Routine monitoring and control programme (high density pheromone trapping, and *Metarhizium* and NudiVirus infection and release) for Poliamba Estates continues.
- New more virulent strain of Oryctes NudiVirus is investigated for the effective control of both Guam and Pacific/Samoan biotypes of the beetle.
- If new planting is to be done in old coconut plantations, it is necessary that rapid damage assessments are done prior to clearing and planting to predict any likelihood of infestation by the beetle.
- Since the Guam biotype is less responsive to the standard pheromone, chemical studies into the pheromone for this biotype is investigated.

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C.5. Donor Funded Projects

There were two donor funded projects that the section was involved in during the year. They included the *Oryctes rhinoceros* management project in collaboration with AgResearch New Zealand (NZ) and the Secretariat of the Pacific Community (SPC), and the Bogia Coconut Syndrome Biology Study in collaboration with RAIL, NARI, KIK, PNG CCI and Charles Sturt University. The *O. rhinoceros* L. management project concluded at the end of the year and the results were presented at the end of the project meeting held at the SPC headquarters in Suva, Fiji. The Director, CPO-Islands and HoE attended the meeting. The involvement by the section in the later project was minimal limited only to insect collection and head dissection for DNA extraction (which was done by the Plant Pathology Section).

C.6. Formal publications and technical Notes

Gurr, G. M.; Johnson, A.C.; Ash, G.J.; Wilson, B.A.L.; **Ero, M.M**.; Pilotti, C.A.; Dewhurst, C.F. and You, M.S. (2016). Coconut lethal yellowing diseases: A *phytoplasma* threat to palms of global economic and social significance. A review paper published in *Frontiers in Plant Science*. Volume 7, Article 1521.

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C.7. Other activities

C.7.1. 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 trainings whenever opportunities arise. Sharon Agovaua completed her BARD course at PNG University of Technology (Unitech) and graduated in April 2016. Richard Dikrey continued the same course throughout the year. He is expected to complete the study in 2017.

Most of the trainings provided throughout the year were on pest monitoring and reporting as well as TTI. The trainings that Entomology section provided in 2016 are provided in the table below (Table 59).

All smallholder field days run on weekly basis for Hoskins Project from April to October and for the other projects as per whenever organised was attended by the Entomology Section.

Table 59 Number of trainings provided by Entomology Section in 2016.

Date	Division/Department	Training name	Conducted by	Received by	Area/Location
16-Feb-16	PNGOPRA, Entomology	Pest Monitoring & Reporting	SS, SM	Management & Supervisory trainees	Dami Conference Room
22-Mar-16	PNGOPRA, Entomology	Pest Monitoring training	ME	Mosa Group-Managers & Supervisors	Dami Conference Room
4-May-16	PNGOPRA, Entomology	Cadets training-NBPOL	ME, SM	Cadets	Dami Conference Room
18-Aug-16	PNGOPRA, Entomology	Cadets training-Hargy Oil Palms	ME, SM	Cadets	Hargy, Bialla
7-Sep-16	PNGOPRA, Entomology	OP Pest & their management	ME, SA	Managements & Supervisory Attendees	RAIL Conference Room
19th – 23rd Sep -16	PNGOPRA, Entomology	In house training on Research Planning, Implementation & Data Analysis	ME	Senior Entomology Research Staff	Dami Conference Room
27-Oct-16	PNGOPRA, Entomology	TTI Training	ME, SS, SM	Management & Supervisory Attendees	Dami Conference Room
14-Nov-16	PNGOPRA, Entomology	TTI training	AA	Field Workers	Poliamba Conference Room
10-Dec-16	PNGOPRA, Entomology	TTI Training for new team	ME, SS, SM	TTI Team	Navo Estate Hargy

ME= Mark Ero, SA= Sharon Agovaua, SM= Simon Makai, SS= Solomon Sar, AA= Akia Aira

C.7.2. OPIC Pest and Disease Meeting- (RSPO 8.1)

The OPIC pest and disease meeting at Nahavio in WNB continued throughout the year. Both OPIC DMs and Smallholder Affairs Department (SHA NBPOL) representatives attended the meetings. 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 and diseases for timely damage assessment and treatment application where required.

C.7.3. Visitors to Entomology Section (Dami Head Office) in 2016

A total of 48 visitors passed through the Entomology Laboratory at Dami during 2016 (61 less than 2015). The visitors were from various organizations within the country as well as abroad, and the organizations from which they came from are listed below.
Kimbe International School (KIS)
AgResearch, New Zealand
New Britain Palm Oil Limited (NBPOL)
IEA- Kimbe International School
East New Britain- NBNI SDA Mission
California St. University
Gilford Ltd, Pomio, ENB
Papua New Guinea Trukai Industry
Hoskins Secondary School Students
Dami Oil Palm Research, NBPOL
DOA, Sri Lanka
CRI, Sri Lanka

West New Britain Provincial Administration
NBPOL Network Based Information System (NBIS)
Moramora Technical School Students
Poinini Vocational Technical School Students
Sime Darby (Chairman)
West New Britain Technical College

C.7.4. Entomology Staff Strength in 2016

The Entomology team comprised of 14 staff in 2016. These included 3 executives (including the Head of Section), 3 Technical Supervisors and 7 Recorders.

D. PLANT PATHOLOGY

HEAD OF SECTION III: DR CARMEL PILOTTI

D.1. Executive Summary

- Progress of basal stem rot was recorded for all plantations in 2016 and unaudited data for all plantations is presented
- Basal stem rot in all replanted blocks under study in Milne Bay ranges from 0.2 to 1% disease incidence
- In 2016 disease incidence in younger (age range) plantings at Higaturu approached 5%
- Mature blocks at Poliamba are above the a manageable threshold of 10% although removals were completed for confirmed infections in all blocks surveyed in 2016
- Disease incidences in Numundo E fields under study are now approaching 40 and 50%
- Adequate sanitation in the 2 years prior to replanting in all plantations should be maintained
- Control of BSR in all immature replanted blocks must be implemented
- Basal stem rot is increasing in the disease trial at GPPOL but no clear correlations with susceptible progeny are evident as yet; good yields are being obtained for the 7 year-old palms, even for progenies with diseased individuals
- Yield loss is not evident in a yield monitoring trial at Numundo F2a where disease incidence is above 15% and good yields of over are being obtained for healthy palms which appear to be compensating; differences in yields between diseased and healthy palms are significant but correlation of total yield with disease are not evident yet
- Use of *Trichoderma* as prophylactic treatment against *Ganoderma* may not be viable; environmental conditions and frequency and timing of treatments appear limiting
- Large numbers of poisoned palms are being colonised by *Ganoderma* in out-grower replanted blocks in WNB and Milne Bay; implementation of a control programme in poisoned and underplanted blocks to prevent increasing spore inoculum is planned
- Disease reports *of Ganoderma* in out-grower replanted blocks continue to increase in WNB and an active program of removals has been established
- New results on the *Ganoderma* infection process on oil palm reveal root infection may be preferable to bole invasion; further studies should elucidate this mechanism
- Overall, disease levels in all plantations are still at a manageable level and the majority of replanted blocks are not showing significantly higher levels of disease than first plantings which might be a reflection of good site preparation

D.2. Epidemiology and control of basal stem rot

D.2.1. Summary

- 2010/11 replanted fields in Milne Bay have disease levels of 1% although confirmed infections have only been recorded in 2 study blocks

- Comprehensive sanitation in areas scheduled for replant in all plantations reqires constant vigilance

D.2.2. Introduction

Monitoring of *Ganoderma* disease progress continued in 2016 in all plantations. Data used in this report has been supplied by Higaturu Oil Palms Ltd. (to December 2016), Milne Bay Estates Ltd. (to November 2016) and Poliamba Ltd. (to December 2016). Data is unaudited except for selected Divisions in Milne Bay. Disease incidence is based on original stand and plantation means are based on the average planting density of the blocks surveyed.

D.2.3. Disease progress in first and second generation oil palm

D.2.3.1. *Milne Bay Estates*

Mean disease levels for all Divisions in Milne Bay in 2016 are shown in Figure 37. In 2016, blocks in all Divisions had 1 or 2 surveys completed. In addition, some areas were replanted or prepared for replanting (Bomata, Salima and Tamonau) and survey data was incomplete and is not included in the summaries.

Among the replanted areas, blocks in Kwea Division again recorded higher disease levels than Giligili, Naura or Bunebune. The total number of confirmed infections for MBE in 2016 was 1,648 palms (excluding Bomata, Salima, and Tamonau) with Borowai recording the highest numbers of diseased palms. An additional 1,384 suspect palms were recorded. Removals were not completed in all divisions and 'productive' suspects continue to be left in the field in replanted blocks at Kwea and Naura.

D.2.4. Disease progress in replanted fields

Disease incidences in selected replanted blocks under study are shown in Figure 38. The data represents mostly symptomatic palms but 2 confirmed *Ganoderma* infections have been identified in Blocks 6404 and 7501, planted in 2011 and 2010 respectively. The highest incidences of suspect palms have been recorded in the 2 blocks at Giligili (Blocks 7213 and 7214, 2012 plantings) where disease incidence is already 1%.

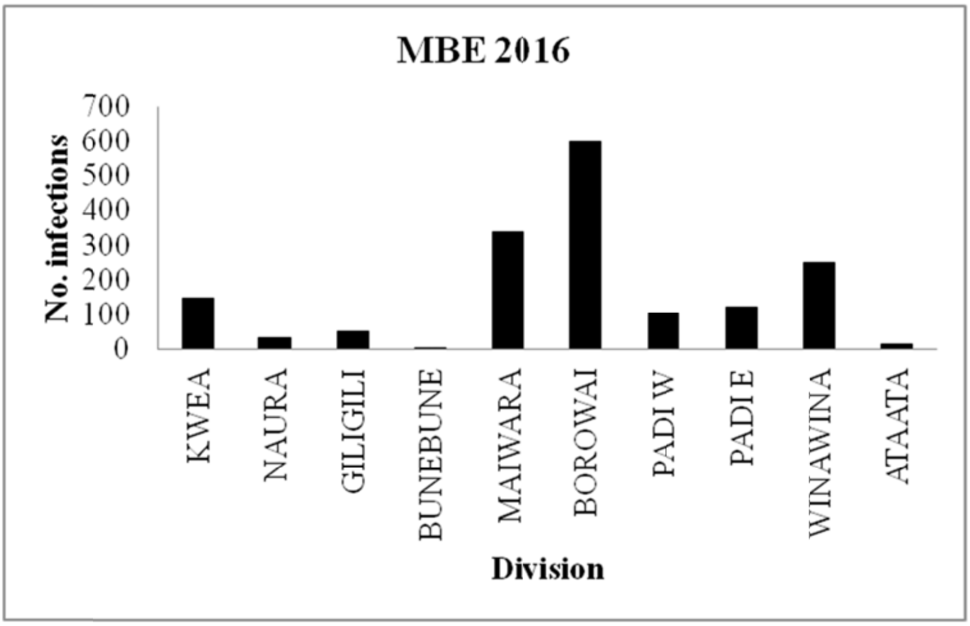

Figure 37 Number of confirmed *Ganoderma* infections for all Divisions at Milne Bay Estates in 2016.

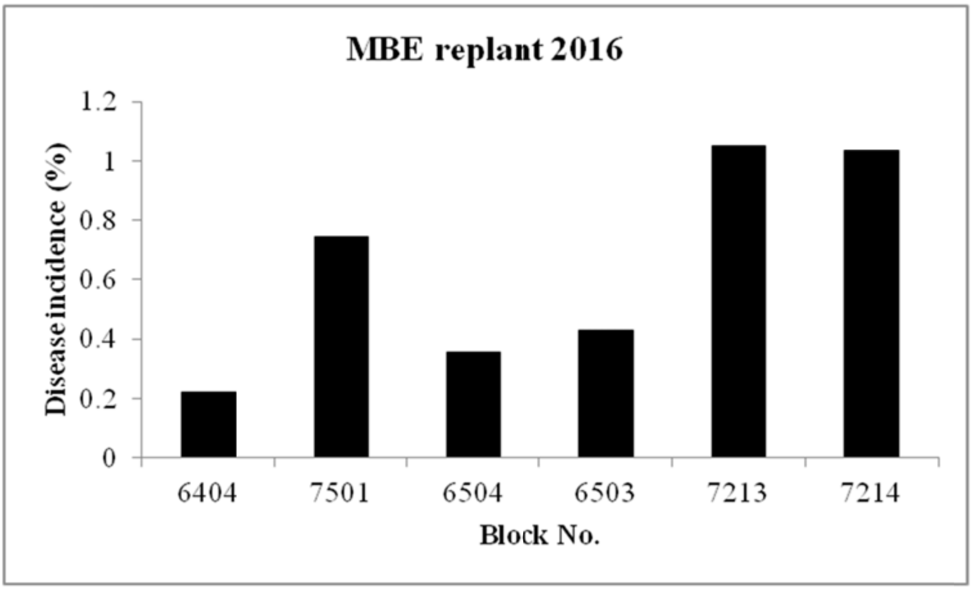

Figure 38 Incidence of basal stem rot in selected replanted blocks under study at Milne Bay Estates in 2016.

D.2.4.1. *Higaturu Oil Palms Ltd.*

Mean disease incidence for Higaturu Plantation in 2016 was 0.25%, slightly lower than in 2015; but the difference is not significant. Incidence of basal stem rot for the different Estates at Higaturu Plantation, excluding Mamba is shown in Figure 39. Sumberipa recorded the highest disease incidence of all the estates at 0.45% in 2016. Mean disease levels for all other estates were below the plantation mean in 2016.

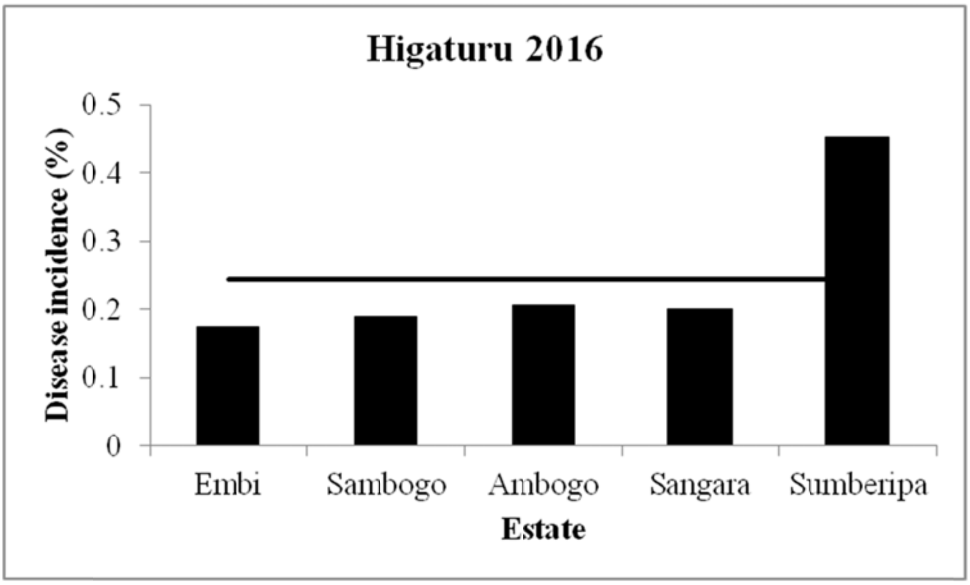

Figure 39 Incidence of basal stem rot at Higaturu Oil Palms in 2016 for each estate.
The bar is the mean. n =167 blocks.

Disease data for blocks at Embi Estate is shown by year of planting in Figure 40. Only 2 blocks at Embi recorded above the Higaturu Plantation mean in 2016. These blocks are the oldest plantings.
Incidence of basal stem rot in several blocks at Ambogo Estate were higher than the plantation mean of 0.25% (Figure 41). Most of the blocks with elevated disease levels were 2002 and 2004 plantings. The significance of this is unknown but could be related to previous block history or carry-over of palms not detected in the 2015 surveys.

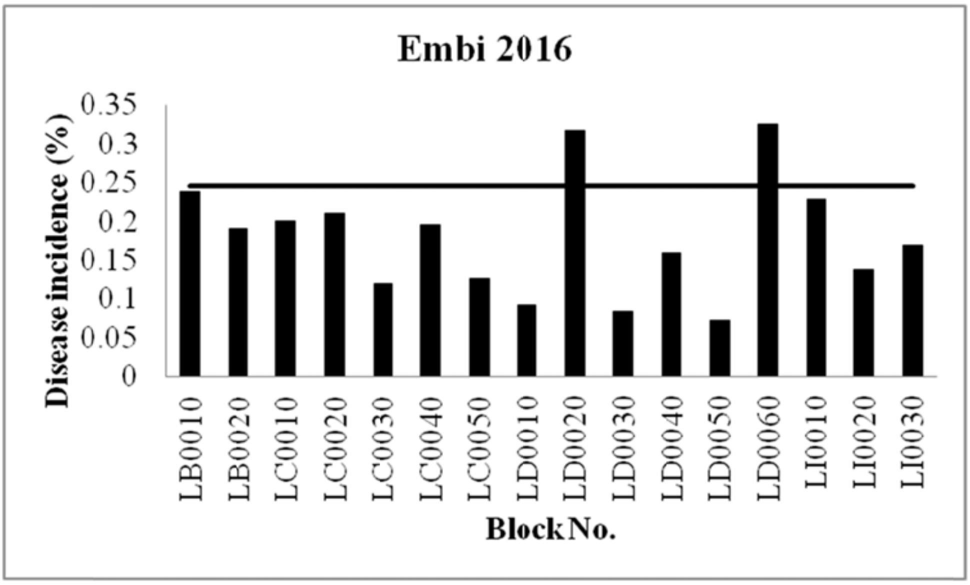

Figure 40 Annual incidence of basal stem rot at Embi Estate, Higaturu in 2016.
The bar is the plantation mean.

The majority of blocks Sangara (Figure 42) recorded disease levels below the plantation mean although a few recorded almost twice this level.
In contrast, over 76% of blocks at Sumberipa recorded disease levels above the plantation mean (Figure 43).
Most of the blocks at Sambogo recorded below the plantation mean (Figure 44).

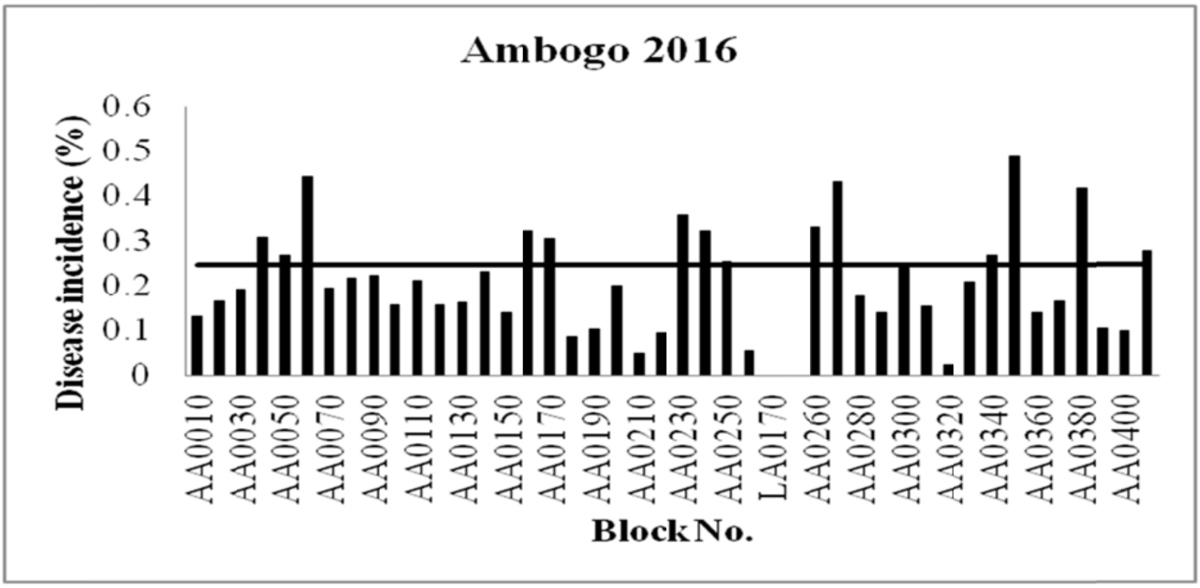

Figure 41 Annual incidence of basal stem rot at Ambogo Estate, Higaturu for 2016.
The bar is the plantation mean.

Cumulative disease progress for all ages of palms at Higaturu is shown in Figure 45. All ages of palms have disease incidences under 5%. The 2002 plantings have the highest levels of disease with over 4%. The true disease levels in the older plantings (1999-2001) are probably higher than shown. The 2004 and 2005 plantings have lower levels of disease than the 2002 plantings at the same age. Disease has also been recorded for the blocks planted in 2011 with confirmed (evidence of brackets) infections in 2 blocks. These blocks are located at Sumberipa Estate which consistently records high disease levels in palms of all age groups.

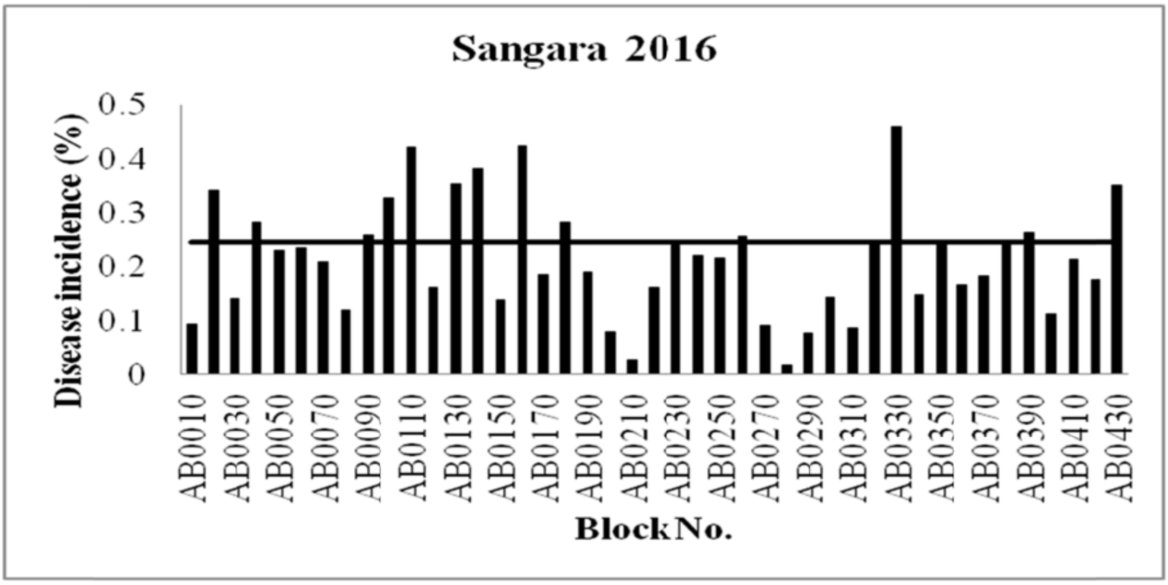

Figure 42 Annual incidence of basal stem rot at Sangara Estate, Higaturu Oil palms in 2016.
The bar is the plantation mean.

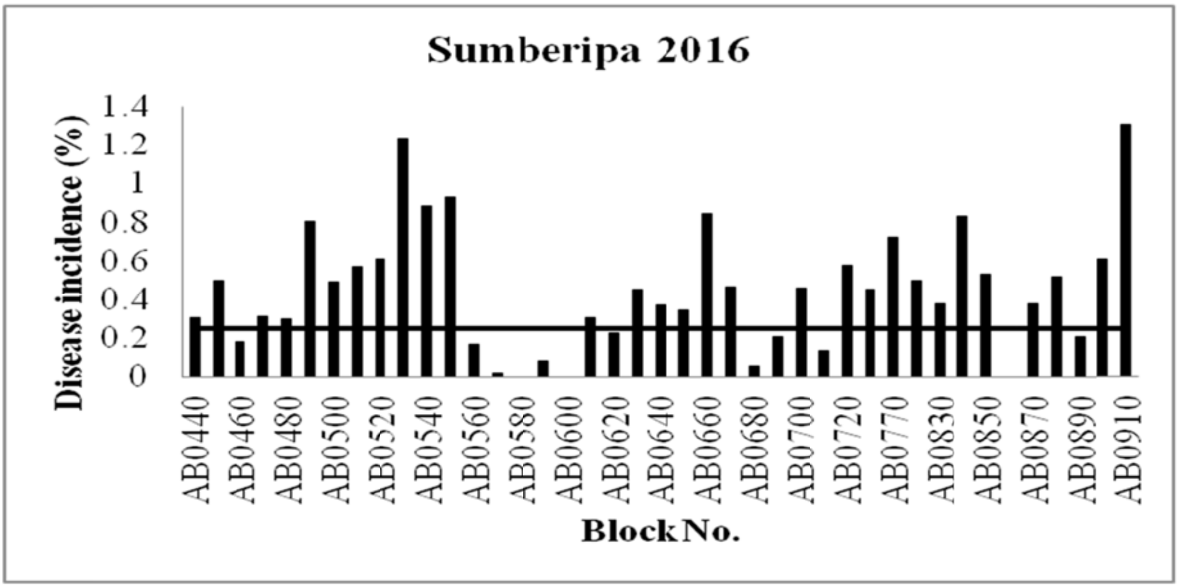

Figure 43 Annual incidence of basal stem rot at Sumberipa Estate, Higaturu Oil Palms in 2016.
The bar is the plantation mean.

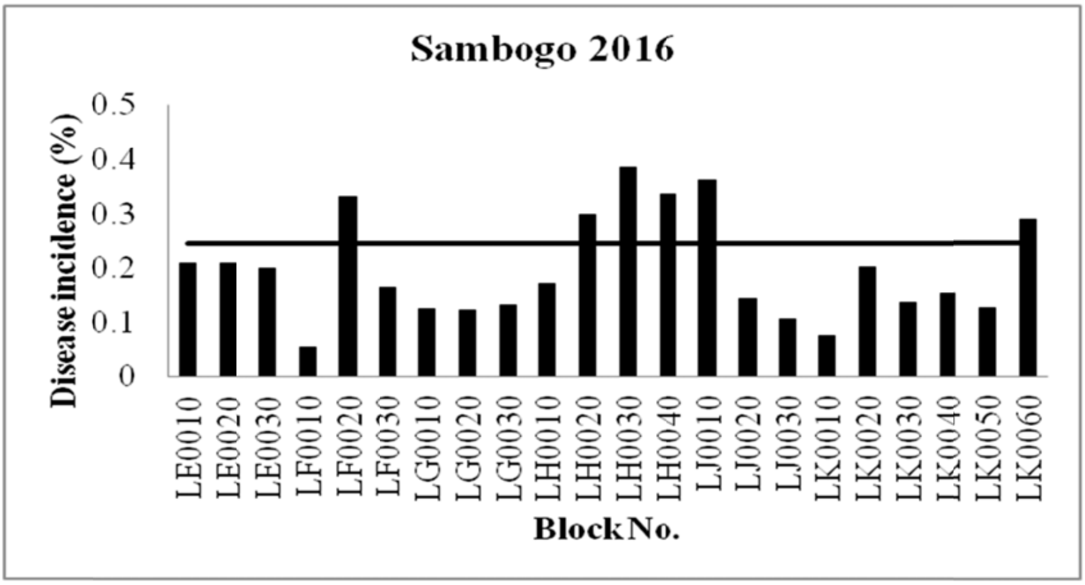

Figure 44 Annual incidence of basal stem rot at Sambogo Estate, Higaturu Oil Palms in 2016.
The bar is the plantation mean.

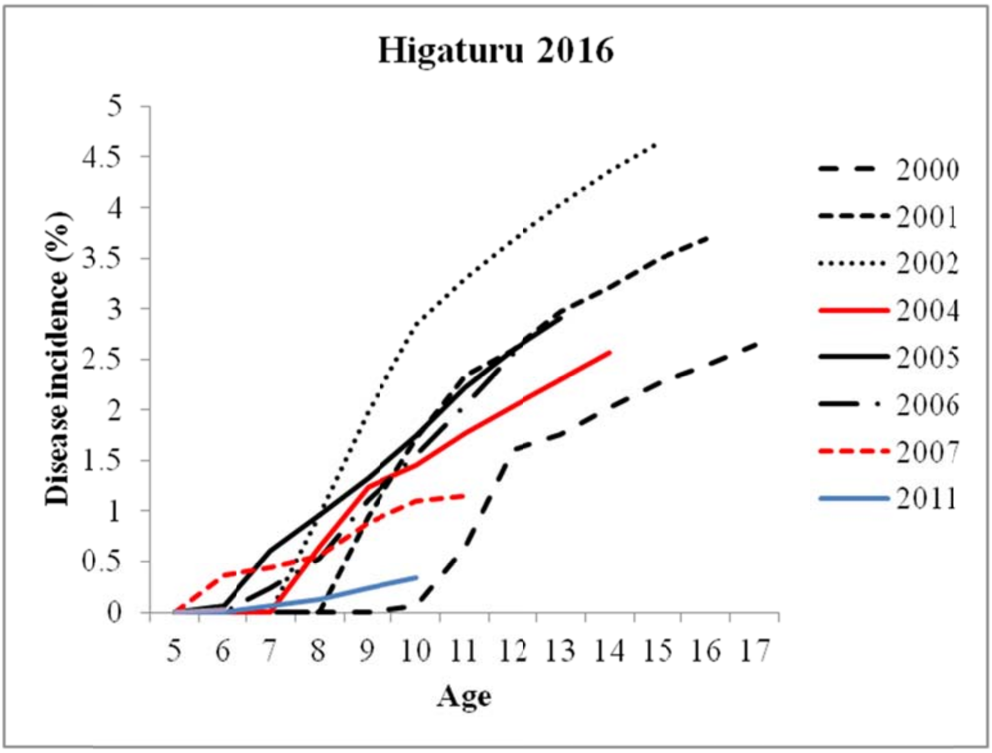

Figure 45 Cumulative disease progress (2009-2016) in palms of different ages planted at Higaturu Oil Palms
n=167 blocks).

D.2.4.2. *Poliamba Ltd.*

Mean disease incidence for Poliamba was in the vicinity of 1% in 2016 based on unaudited data (Figure 46). Madak Estate which now has mostly 1999 planted blocks recorded above average disease incidence (1.4%) and Noatsi recorded just above the plantation average with 1.1% disease incidence recorded for a single survey in 2016. The remaining Estates surveyed had disease levels below the plantation mean in 2016.
Dalom, Kimadan, Lamasong, Maranawei, Poli and Rangalis Divisions recorded above average incidences in 2016 (Figure 47). Most of these Divisions are in Madak Estate but Lamasong and Poli are in Noatsi Estate and were replanted in 2016. Individual blocks in Poli recorded elevated levels of disease some as high as 5%.

Round 2 surveys were not conducted at Bolegila, Libba and Lossu due to replanting hence, the low disease levels recorded for the blocks in these Divisions. This has also depressed the plantation average for this year.
Disease surveys for 2012 replants at Maramakas and Lakurumau were not implemented in 2016.

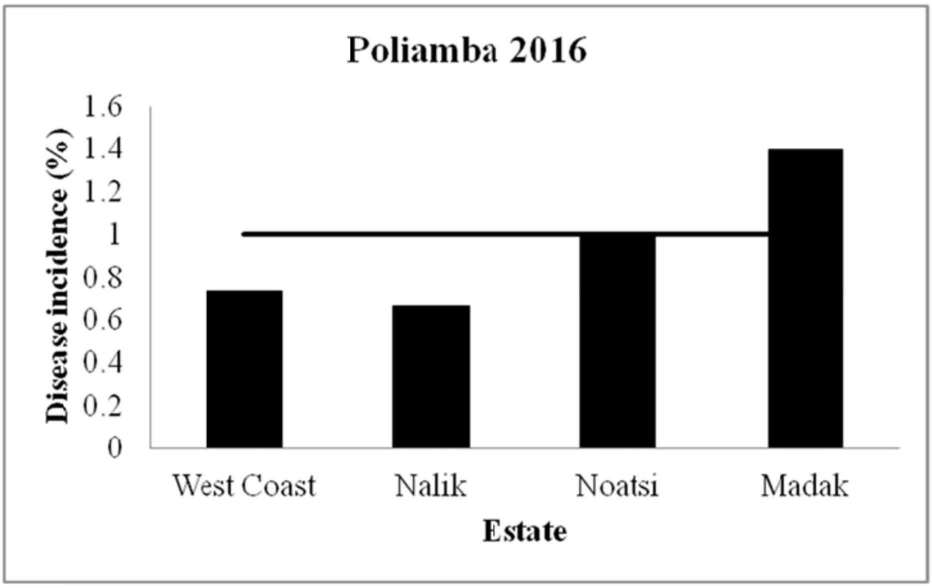

Figure 46 Mean *Ganoderma* disease incidences recorded for 4 estates at Poliamba Ltd. in 2016.
The bar is the plantation mean. n=92 blocks.

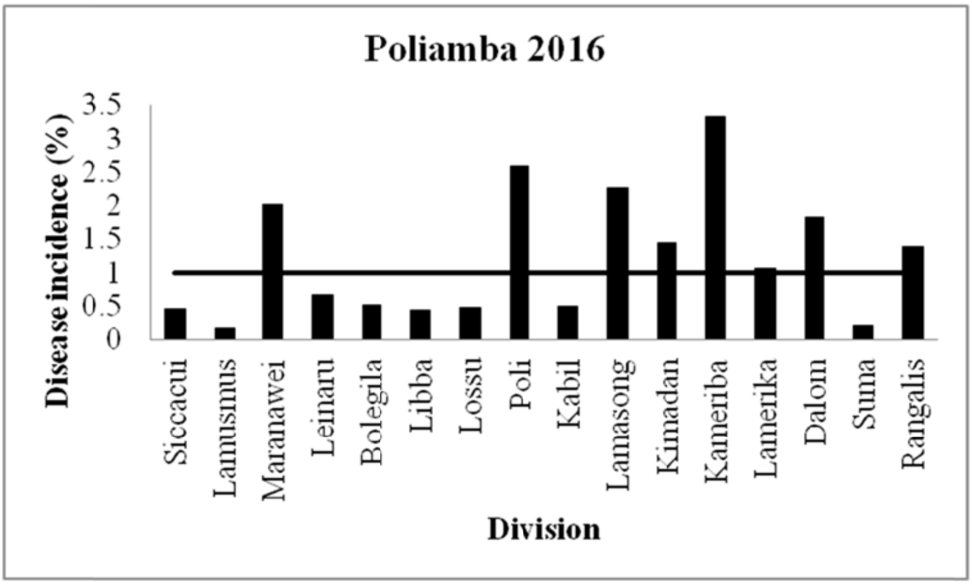

Figure 47 Mean incidences of basal stem rot in all Divisions at Poliamba Estate in 2016.
The bar is the plantation mean. n=92 blocks.

Ganoderma incidence for 1997, 1998 and 1999 plantings at Poliamba are above the plantation mean for 2016 (Figure 48). Palms planted in 1997 and 1999 recorded the highest disease incidences (2%), twice that of the plantation mean. 1997 plantings are all in West Coast whilst 1999 plantings are mostly in Madak Estate.

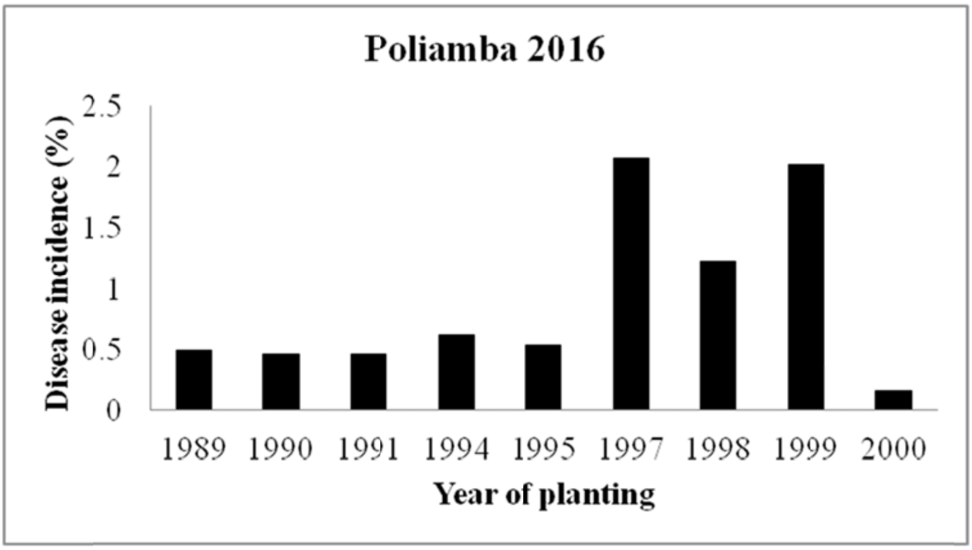

Figure 48 Incidence of basal stem rot in 2016 for oil palms planted in different years at Poliamba Plantation.
n=92 blocks

Cumulative disease incidences for all plantings at Poliamba are shown in Figure 49. Disease levels in the year 2000 plantings, located at Siccacui in West Coast Division recorded low levels of disease in 2016 and previous records are not available to verify the cumulative disease levels in 2016. The older plantings at Poliamba, 1989-1991 probably have significantly higher cumulative disease levels than shown but audits of these field have not been done to assess the true values. 1994 plantings appear to be tracking at a constant rate however older and younger plantings have increases in disease rates above 3% incidence. This may be due to increased vigilance and recording during surveys but could also be typical of the BSR epidemic with secondary spread occurring after this level of infection. The high disease rates in the youngest plantings is probably due to earlier surveys being implemented in these blocks rather than a differences in the epidemic compared to older plantings.

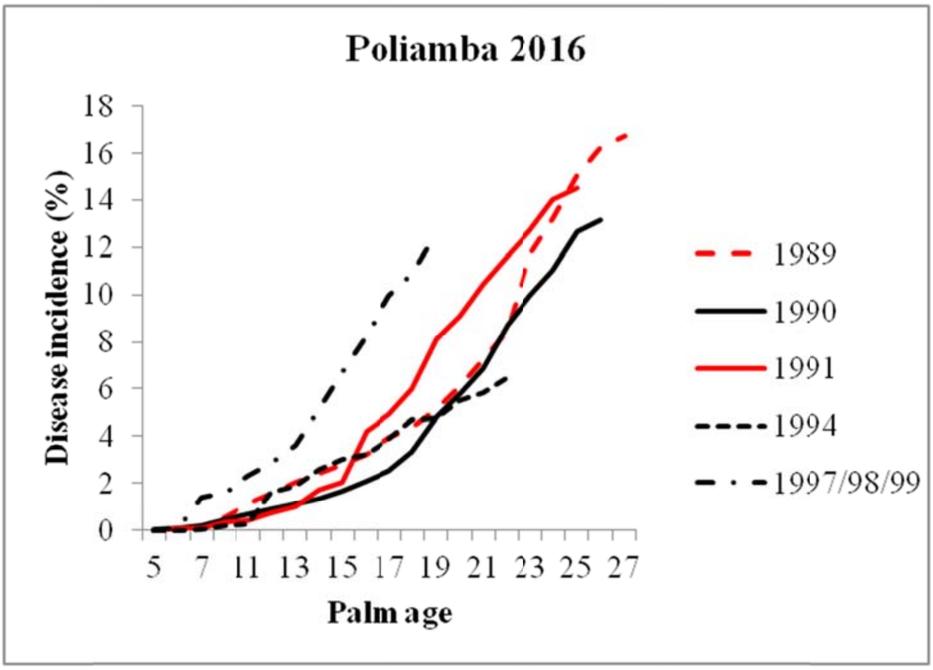

Figure 49 Cumulative disease incidences for palms of different ages at Poliamba Plantation in 2016.

D.2.4.3. *Numundo E fields*

Cumulative monthly disease incidences for both E4 and E5 Fields in 2016 are shown in Figure 50. Over 130 palms were identified with *Ganoderma* symptoms or brackets in each block indicating that the disease rate in these blocks is not decreasing and the epidemic has not reached its asymptote.

Annual disease incidence was slightly lower for E4 in 2016 at 1.7%, (down 0.3%) compared to 2015 and higher in E5 with 3.7%, (up 1.1%) of palms infected in 2016 (Figure 51).
Cumulative disease incidence in 2016 is now 38.1% in Field E4 and 48.4% in Field E5.**Error! Reference source not found.** Actual incidence may be higher but audits were not completed for both fields at the time of this report (Figure 52).

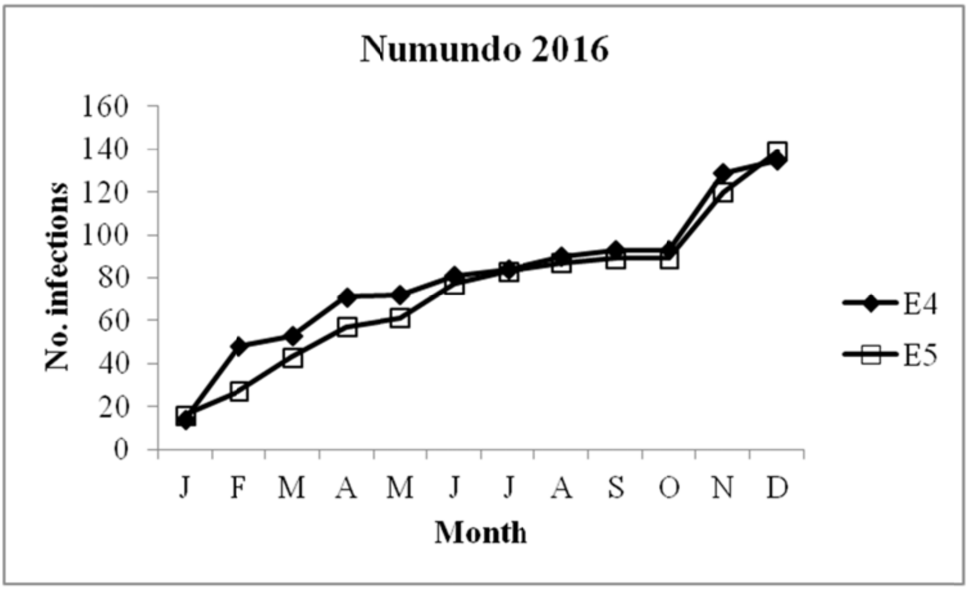

Figure 50 Cumulative monthly disease incidence for Fields E4 and E5 at Numundo Plantation in 2016.

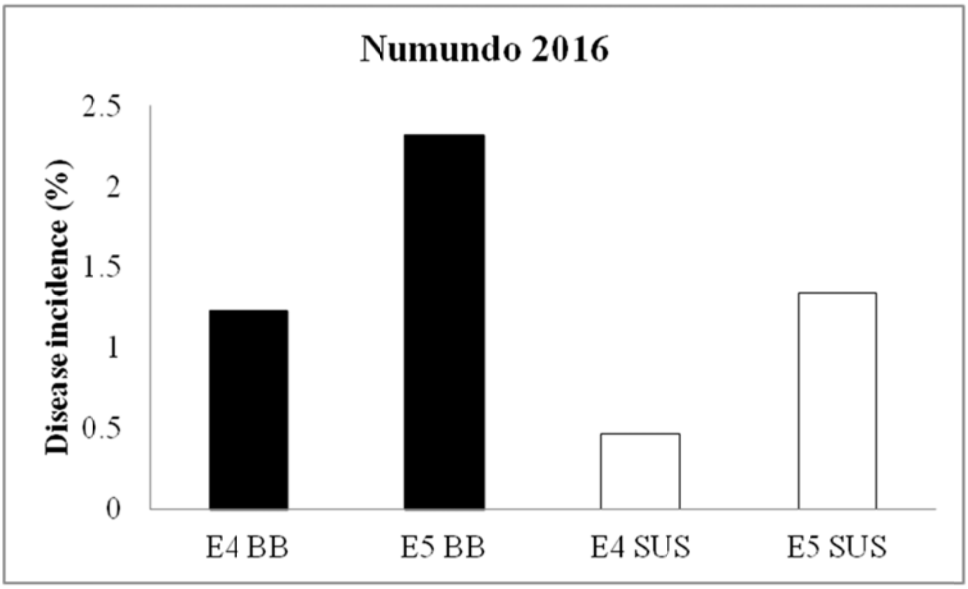

Figure 51 Incidence of confirmed basal stem rot and symptomatic palms identified at Numundo Fields E4 and E5 in 2016.
BB=brackets; SUS=suspect palms without brackets.

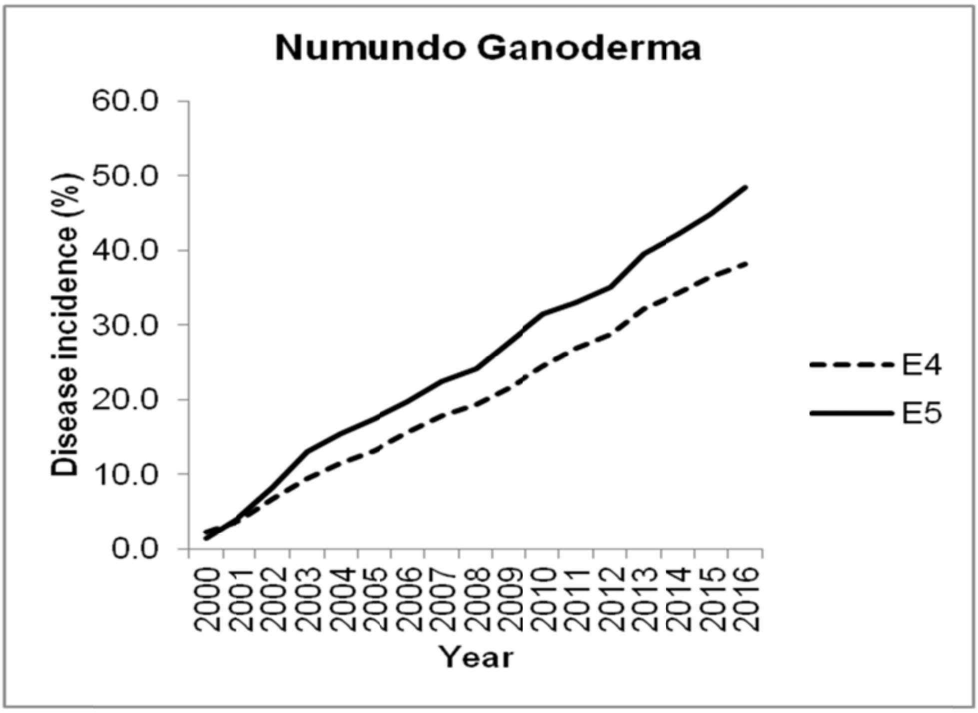

Figure 52 Cumulative disease incidence for Numundo Fields E4 and E5 from 2000-2016.
(2000-2006 OPRS data, 2006-2016 PNG OPRA data).

D.2.5. Smallholder research

D.2.5.1. *Monitoring in poisoned replanted blocks*

Monitoring of *Ganoderma* bracket formation continued in out-grower underplanted blocks at Kapore, Tamare, Siki and Poinini in 2016. Brackets of *G. boninense* are becoming common in all blocks that have been poisoned and underplanted in WNB. A total of 332 *Ganoderma* brackets were recorded for Block 017-0275 at Poinini, 159 for Siki and 47 and 11 brackets respectively for the blocks at Kapore. Palms in the Poinini and Siki blocks were poisoned in June 2012 and August 2013. The palms at Kapore were poisoned in June 2015 (Block 001-0286) and November 2014 which is the reason for their lower bracket numbers. The majority of brackets on the palms were on the lower 1-2m of palms except for Kapore Block 001-0286 where the brackets have been observed higher on the stem (>2m).

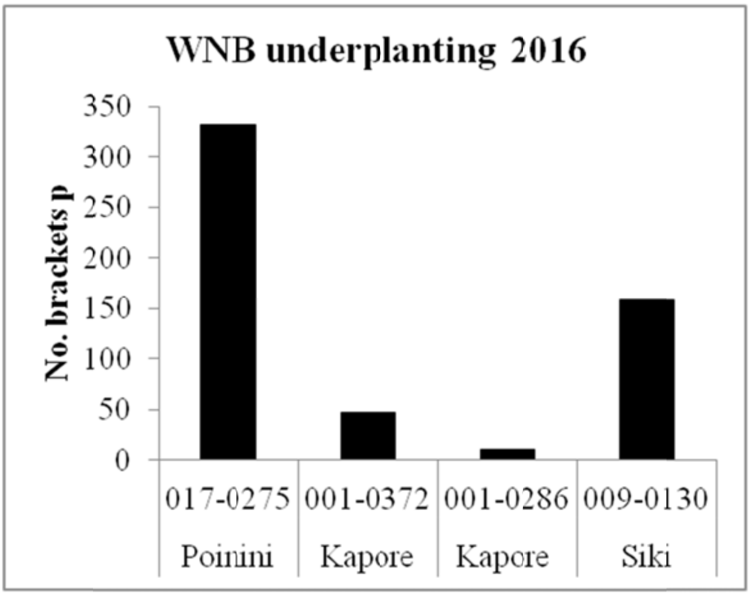

Figure 53 Number of brackets recorded on poisoned palms in replanted blocks at Poinini, Kapore and Siki in 2016.

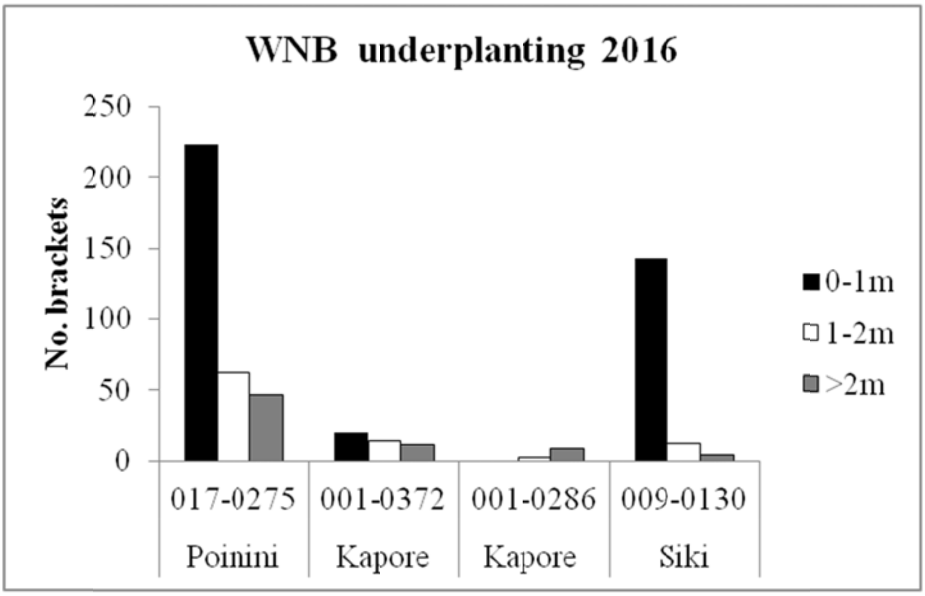

Figure 54 Number of brackets recorded with their locations on poisoned palms in replanted blocks at Poinini, Kapore and Siki in 2016.

D.2.5.2. *Out-growers Trichoderma trials*

The three remaining trials using *Trichoderma* spp. as a prophylactic treatment against *Ganoderma* establishment on poisoned palms were sprayed a total of 3 times with *Trichoderma* inoculum and bracket formation monitored monthly in 2016.

Trial 1 at Gabugabuna was abandoned as the palms were felled in the block. Trial 2 at Maryanene recorded 7 of palms with brackets that had *Trichoderma* treatment and 8 for control palms (Table 60). Trial 2 at Maryanene received first treatments in June 2015 and has had a total of 6 treatments up to September 2016. The bracket formation on treated palms was twice that of the control (Table 1).

Trial 3 at Maryanene was established in February 2016 and new *Ganoderma* brackets have formed on palms under both treatment and control with treated palms again exceeding the controls in the number of *Ganoderma* brackets recorded. Another trial at Naura was established in June 2016 and treatments were suspended for this trial at the end of 2016. This trial had 2 treatments of *Trichoderma* and in this

case the number of brackets was lower than that of the controls (Table 1). In all trial blocks, the number of palms that developed brackets also appeared non-significant between treatments.
All trials were closed in 2016 and palms will be monitored for bracket formation only. New trials are planned for implementation in WNB.

Table 60 Total number of brackets recorded on poisoned palms treated with *Trichoderma* spp. and total number of treated and untreated palms with brackets in each trial at VOP blocks in Milne Bay in 2016.

Trial No.	Location	No. *Ganoderma* brackets		No of palms with *Ganoderma* brackets	
		Control	Treatment	Control	Treatment
2	Maryanene 15001	83	200	7	8
3	Maryanene 15002	51	89	10	7
4	Naura 4023	292	189	29	21

D.3. Oil palm yield and disease in NUMUNDO F2a

D.3.1. Introduction

Yield from a total of 25 harvests were recorded for the trial at Numundo F2a from January to December 2016. During the same period, disease status of palms was recorded as well as any palms removed due to *Ganoderma* infection. Production data are corrected for dead palms in the trial at each harvest but *Ganoderma*-infected palms at all stages of infection have been pooled for the analysis.

D.3.2. Results

Total yields (kg/palm) for both healthy and *Ganoderma*-infected palms over all harvests in 2016 are shown in Figure 55. Average palm production generally followed a similar pattern with not all harvests showing significant differences between diseased and healthy palms. This may be due to the different stages of *Ganoderma* infection observed over the period of recording. Palms in the early stages of infection may still produce a high number of bunches but production will gradually reduce as disease progresses. Separation of the palms with more advanced disease would show greater differences. Even so, production per healthy palm per harvest was 10±0.2kg (252.7+5kg) in 2016 compared to diseased palms which produced 5.9±0.2kg/palm/harvest equating to 147.5±3kg/palm/year. Some outwardly healthy palms may alreadybe infected with *Ganoderma* contributing to the low yields at each harvest but annual yields are almost double those of Ganoderma –infected palms.
Mean bunch weights for healthy palms increased insignificantly from 2015 to 28.9±0.2kg whilst bunch weights of infected palms also increased (by 2.1±0.2kg from 2015) to 27.3±0.2kg in 2016. Mean bunch weights between healthy and diseased palms were not significantly different ($p<0.05$) (Figure 56).
Bunch number per hectare per harvest in 2016 decreased from 2015 for healthy palms with a mean of 43 bunches per ha/harvest and 34 bunches per ha/harvest for diseased palms in the trial. Total BN/ha for healthy palms was 1018 bunches and for diseased palms was 728 bunches in 2016, a significant difference in bunch production.

Production for healthy palms also increased by 2.2t/ha in 2016 to 33.0±0.2t/ha (based on healthy individuals only) in 2016 indicating that compensation is occurring. In contrast, production for standing *Ganoderma*-infected palms decreased to 19.8±0.1t/ha **Error! Reference source not found.**) .The difference between *Ganoderma*-infected and healthy palm yields was significant ($p<0.01$) in 2016.

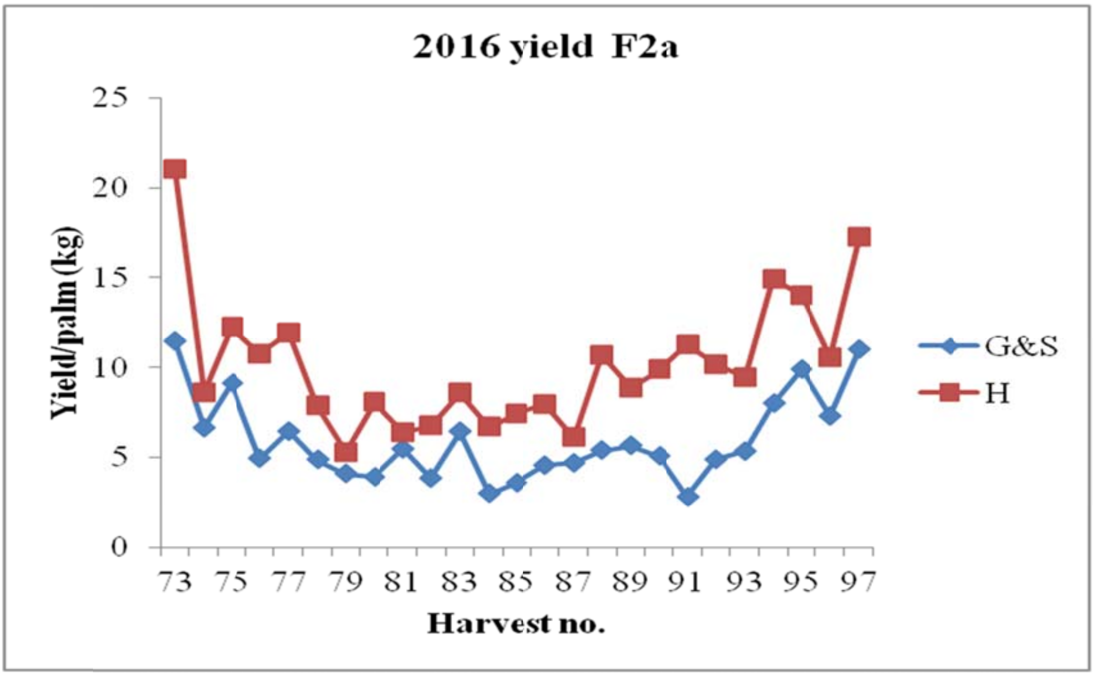

Figure 55 Yield (kg/palm) for healthy and *Ganoderma*-infected palms over 25 harvests in Field F2a, Numundo Plantation in 2016.

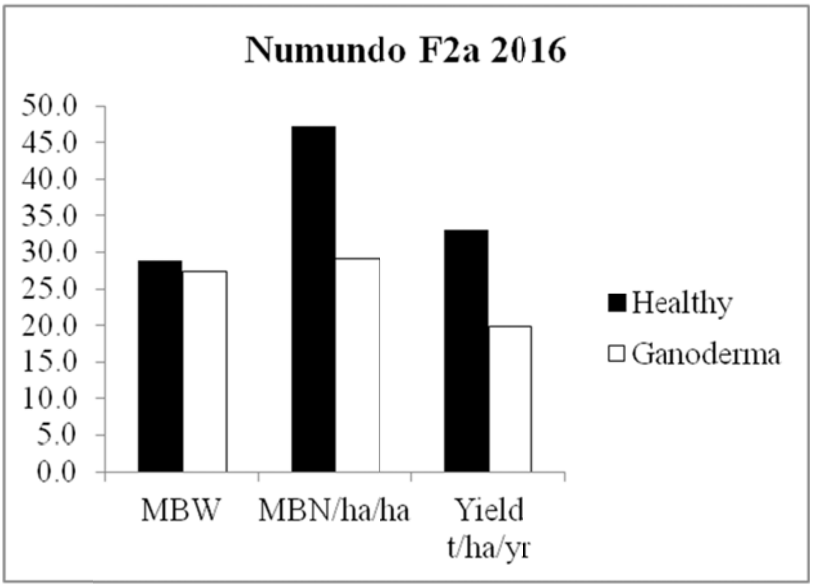

Figure 56 Mean bunch weights (kg), mean bunch number/harvest and production (t/ha) for healthy and *Ganoderma*-infected (including suspect) palms in Field F2a, Numundo Plantation in 2016.

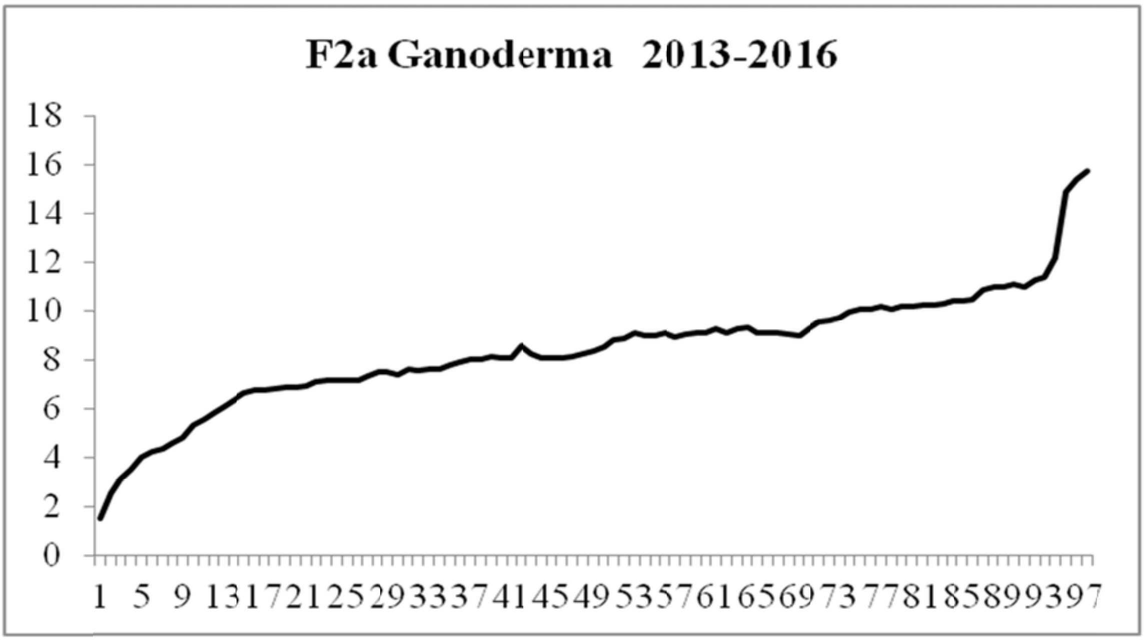

Figure 57 Cumulative disease incidence (2013-2016) of basal stem rot in a yield monitoring trial at Field F2a, Numundo plantation.

Cumulative disease incidence in the area of the trial only is above 15% (Figure 57). This is still considered below the threshold where yield losses become evident and the yield data for 2016 reflect this.

Poor correlation was observed between disease incidence and bunch weights (Figure 58), bunch numbers (Figure 59) and yield (Figure 60) when 2016 data was added to previous years data (2013-2015), at the current levels of *Ganoderma* infection. Presently, none of the variation in bunch numbers, bunch weights and yield is attributable to disease.

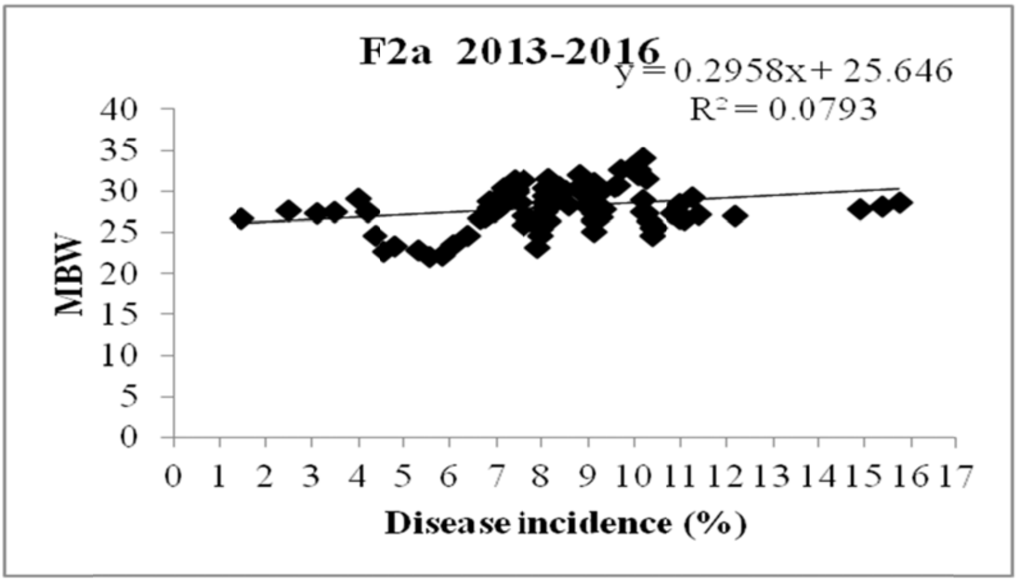

Figure 58 Correlation between mean bunch weights of oil palms and incidence of basal stem rot in Field F2a, Numundo Plantation from 2013-2016.

n=97 harvests.

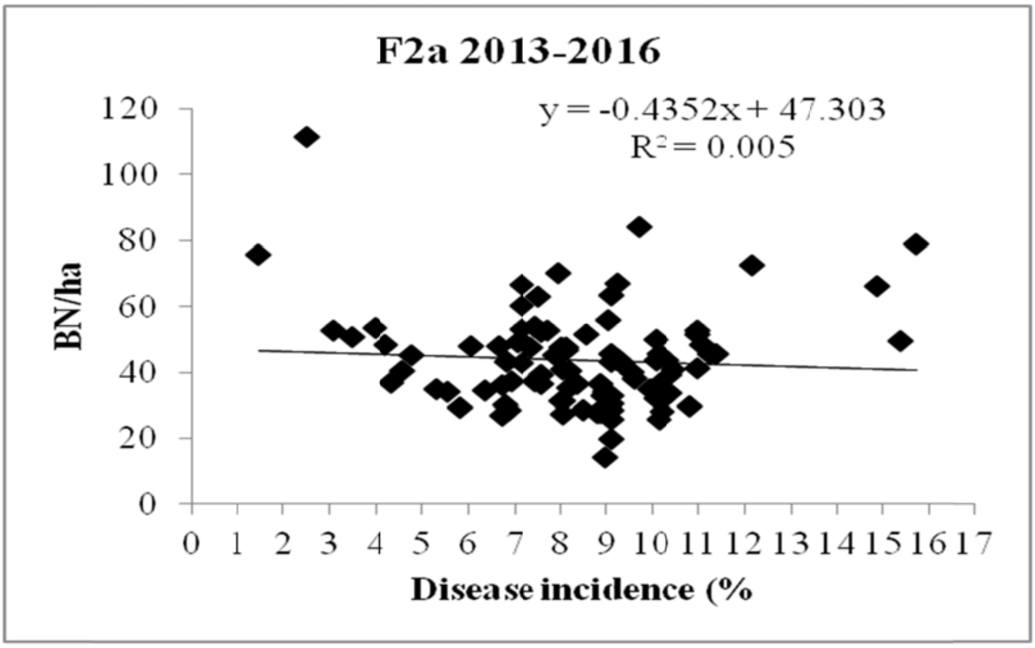

Figure 59 Mean bunch numbers (per ha/harvest) and disease incidence for the period 2013-16 in Field F2a, Numundo Plantation.
n=97 harvests.

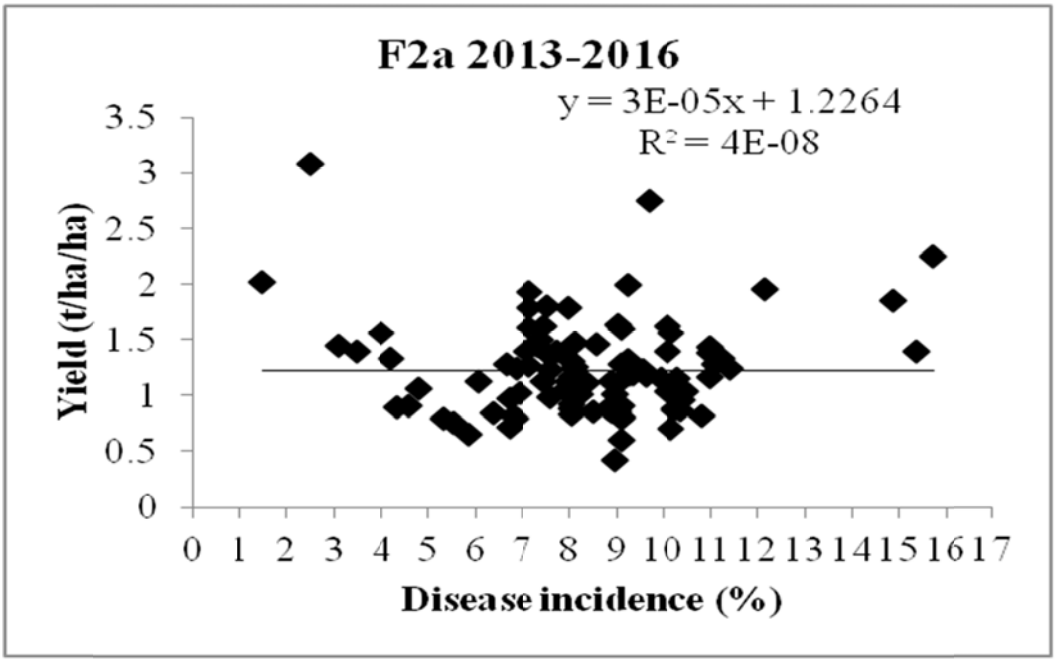

Figure 60 Correlation between yields of oil palms and disease incidence in Field F2a, Numundo Plantation from 2013-2016.
NB: t/ha/ha = tonnes/ha/harvest. n=97 harvests.

D.4. Disease resistance/susceptibility screening

D.4.1. Introduction

This research involves the nursery screening of 81 progenies planted in field trials at GPPOL in Solomon Islands to assess field resistance and also screening of Dami special families for disease

susceptibility or resistance. In addition, molecular analyses of the same progenies are being carried out externally in order to isolate any molecular genetic factors that may be of relevance in resistance /susceptibility mechanisms of oil palm. This is a longer term goal and this part of the research is supported by ACIAR with collaboration with the University of Queensland.
No significant developments in the research were reported in 2016 for the external activities.
In 2016 a single nursery trial of a subset of the families planted in the GPPOL field trial were planted and monitored throughout 2016.

D.4.2. Results

D.4.2.1. *Nursery screening*

A small trial with only 7 progenies/parents available for testing was implemented in 2016. A total of 49 mortalities were recorded in this trial in 2016. Monthly data from weekly recordings of seedling mortalities is presented in Figure 61. The highest mortalities were recorded 6 months after inoculation and may suggest that this is the ideal period for *Ganoderma* pathogenicity under the conditions of the test. However, seedling deaths continued to be recorded after this period indicating that the *Ganoderma* inoculum is still viable after 12 months.

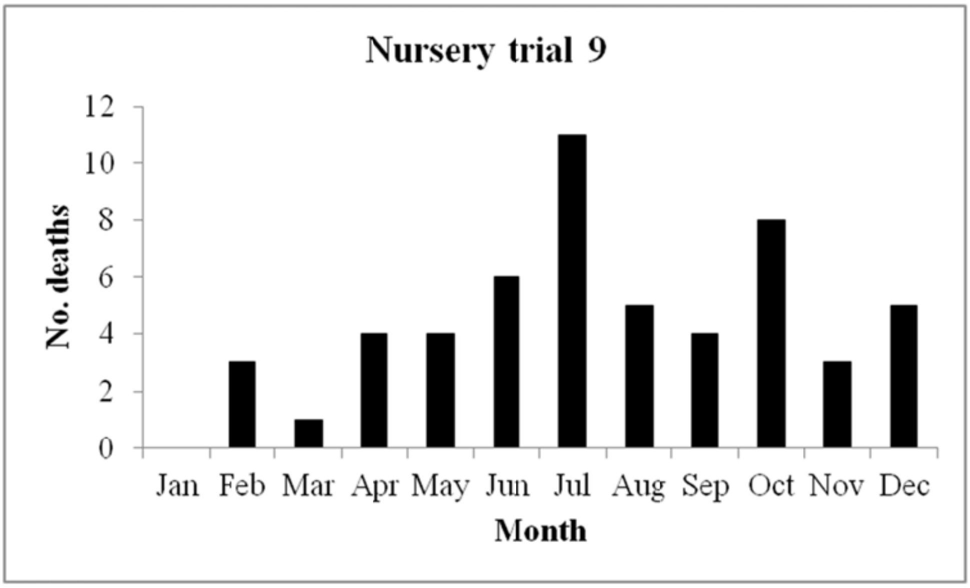

Figure 61 Monthly mortalities of seedlings in a nursery trial planted in 2016 on a subset of families also planted in a field trial at GPPOL.

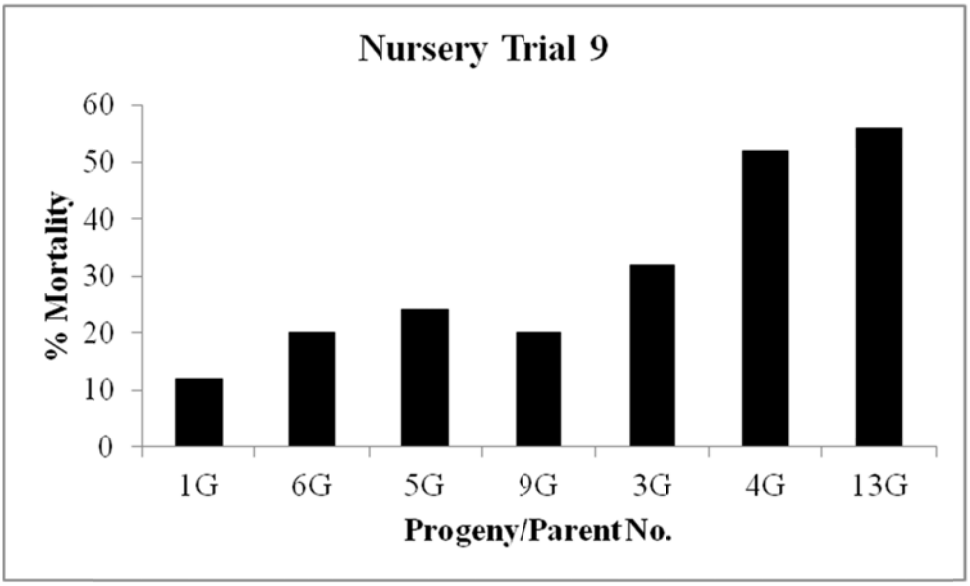

Figure 62 Mortalities recorded in a nursery trial of selected families also planted in a field trial at GPPOL after 12 months.
(n=250).

The progenies with the highest mortalities were 4G and 13G. The results are shown in Figure 62. Both progenies have different parents. The progeny 1G (4019.25.06) expressed the lowest mortality and is a self and a parent used in several other crosses but not in any of the crosses in Trial 9. In earlier trials reported in 2015, the performance of Progeny 1G was variable showing resistance in one trial and susceptibility in the other. This trial is still open and results will be finalised in 6 months.

D.5. Microscopy studies –Ganoderma-oil palm early infection (Emmanuel Gorea)

D.5.1. Introduction

The current study utilises *in-vitro* pathogenicity testing using small inoculum in a controlled growth conditions. The current study sets out to determine what occurs in oil palm and *Ganoderma* during early stages of BSR establishment and disease progress. Bright field and fluorescence microscopy with dual staining techniques were employed to visualise physical changes that may be associated with defence or pathogenicity of oil palm and *Ganoderma* respectively during the early stages of establishment and development. The *Ganoderma*-oil palm pathosystem has not been studied in detail and information regarding colonisation, infection process and symptom expression (both macro and micro) is poorly understood. Information gathered from this work will contribute to the field of knowledge regarding the *Ganoderma*-oil palm pathosystem.

D.5.2. Materials and methods

D.5.2.1. *Inoculum preparation*

Fifteen grams of sorghum (*Sorghum bicolor*) grains of Tx430 were placed in a glass jar and hydrated with an equivalent amount (1g/1ml) of sterile distilled water and autoclaved at 121^{o}C for 30 min. The sterile sorghum grains were then inoculated with mycelia from the leading edge of a PDA plate colonised with *Ganoderma* isolate, GB3039 obtained from PNG OPRA, PNG. The inoculated grains were placed in a dark cupboard at room temperature to allow for colonisation of substrate for approx. 1 month, or until fully grown over. Similarly, plate cultures of *Ganoderma* were grown on PDA and incubated with the same conditions as the sorghum grains and allowed to colonise the media for two weeks in preparation for inoculation trials.

D.5.2.2. ***Staining and microscopy***

The polychromatic dye toluidine blue was used to visualise general root and bole anatomy of oil palm for possible structural changes as a result of *Ganoderma*-oil palm interaction. Sectioned specimens were stained with toluidine blue (0.1% w/v), mounted with 30-50% glycerol on a clean slide, cover slip placed onto the specimen and viewed under bright field.

Fungal hyphae were stained with calcofluor white for visualisation of fungal hyphae under fluorescence microscopy. Stained tissues were observed using a ZEISS AXIO Fluorescence Microscope. Dual stained tissues were first observed under bright field followed by fluorescence microscopy using the DAPI filter and UV lamp with an excitation wave length of 365 nm and emission wave length of 420-470 nm. Images were taken using the mounted camera on the microscope (ZEISS AXIO Cam MRc).

D.5.3. Results

Although initial site of inoculation was at the lower bole fungal hyphae were generally observed to favour primary and lateral root as opposed the entry site of inoculation at the injured bole. Initial penetration was observed in the epidermal layer and sclerenchyma ring (
Figure 63) comprising the outer cortex (
Figure 63 A, B, D). In lateral roots fungal hyphae were observed to be associated with non-fluorescent region of the lateral root when stained with calcofluor white and viewed under UV light. This non-fluorescent region of sclerenchyma was also observed not to absorb toluidine blue and often maintained a brown pigmentation under bright field microscopy (
Figure 64
Figure 63).

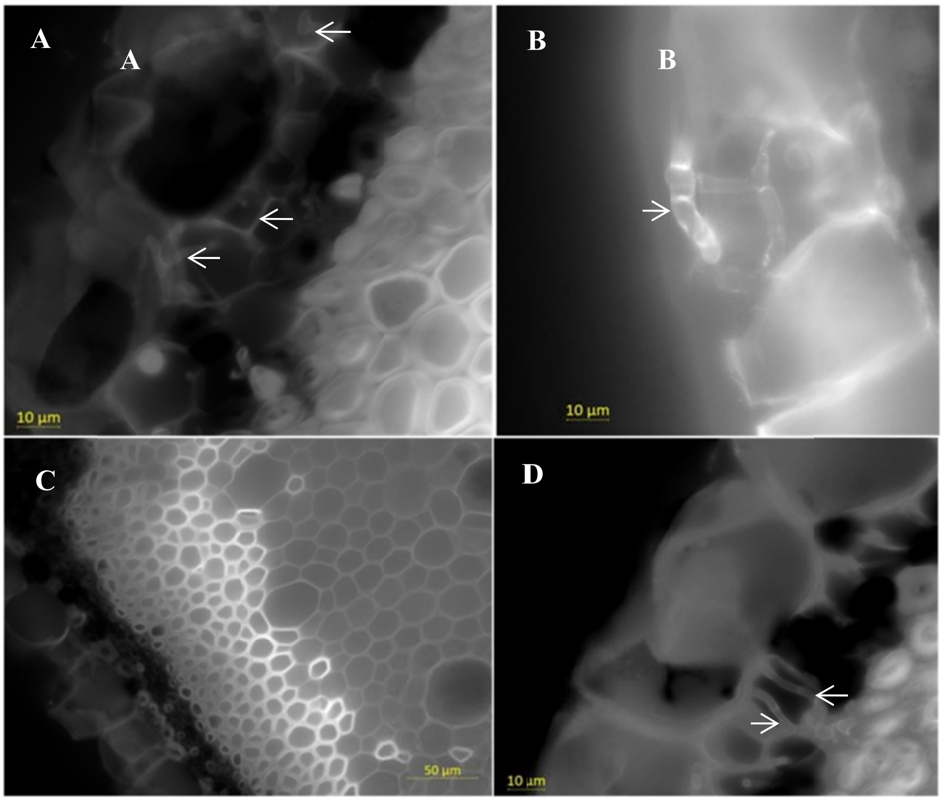

Figure 63 Oil palm root epidermis showing controls and Ganoderma inoculated plants. All root samples were stained with calcofluor white to visualise fungal hyphae in roots.
(A) Oil palm root epidermis and sclerenchyma ring tissue with multiple fungal hyphae (arrows). (B) High definition image showing fungal hyphae fluorescing in root epidermis of Ganoderma inoculated oil palm. (C) Control root showing no fungal hyphae in epidermis or non-fluorescent sclerenchyma ring. (D) Root tissue showing fungal hyphae in epidermis/sclerenchyma ring region

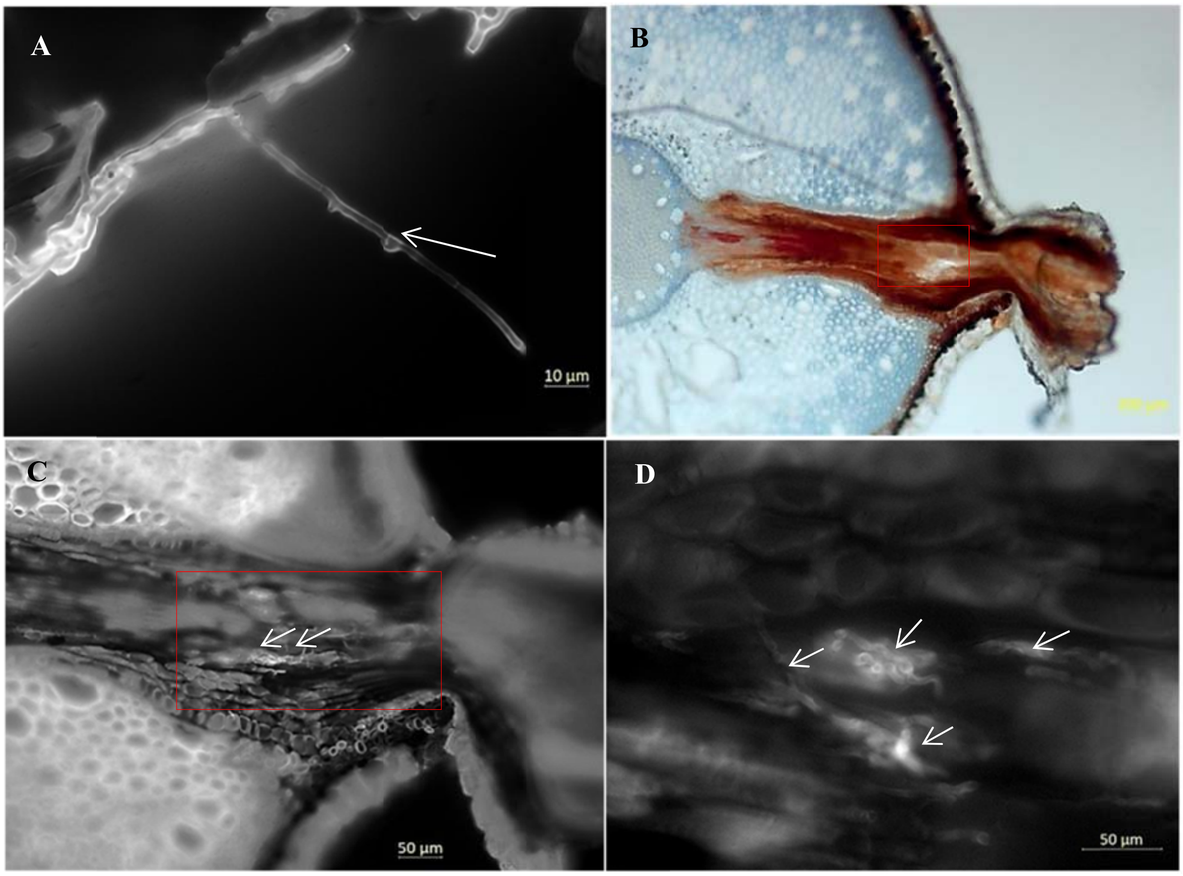

Figure 64 Ganoderma inoculated oil palm seedlings showing hyphal colonisation of lateral root emerging from primary root.
(A) Hyphal structures with clamped connections under UV fluorescence. (B) Bright field image of primary with emerging lateral root, red square indicating region of fungal invasion. (C) High magnification image of (B) showing hyphae (arrows) in lateral root tissue. (D) High magnification image of lateral root under UV fluorescence showing hyphae indicated by arrows.

At the bole and the root-bole interface tissues hyphae were seen in lateral roots (Figure 65 C-D) as well as the brown pigmented parenchyma tissue of the bole region (Figure 65 A, B). These brown pigmented tissues where hyphae were observed appear non-fluorescent when viewed under fluorescence after staining with calcofluor white.

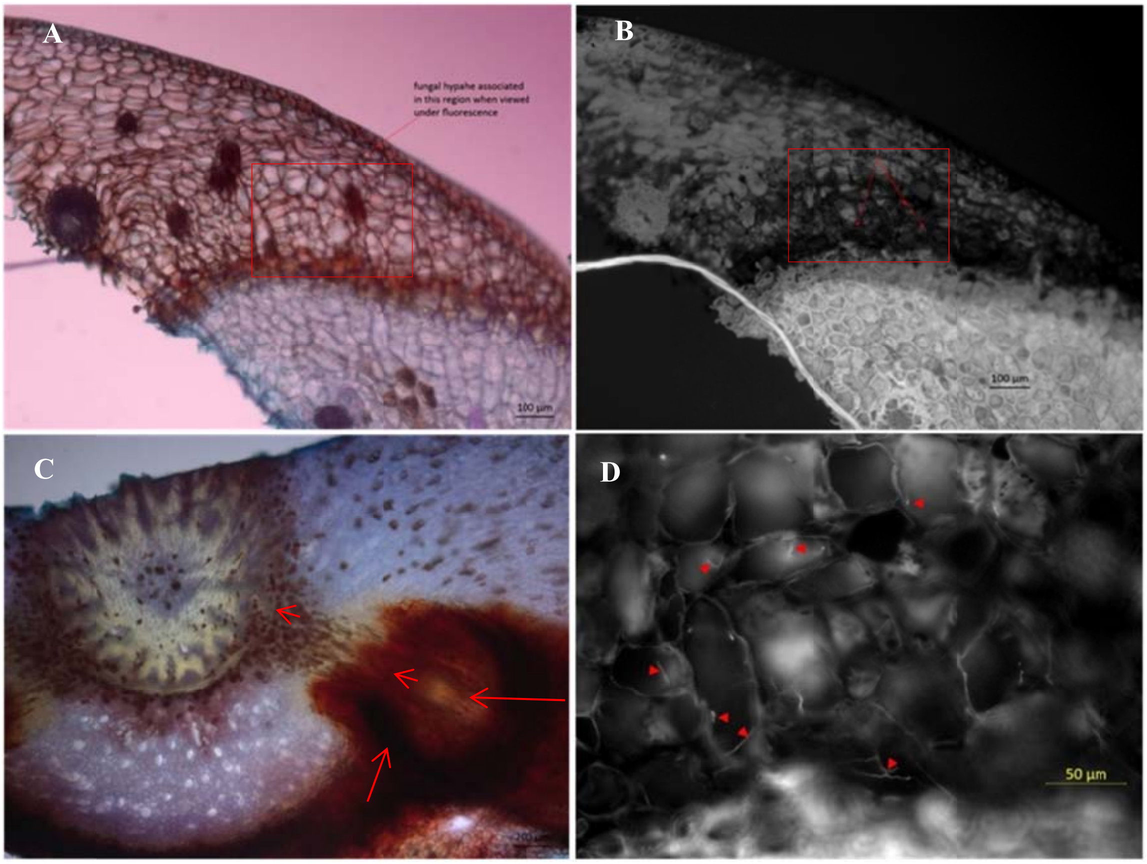

Figure 65 Bole and root-bole interface tissue of *Ganoderma* inoculated oil palm seedling showing brown pigmented tissue under bright field and non-fluorescent under UV light.
(A) Bright field and (B) UV fluorescence image showing bole tissue region of hyphal association (square). (C) Root-bole interface region under bright field showing brown pigmented tissue of lateral root that showed hyphae (arrows) under fluorescence after staining with calcofluor white as shown in image (D).

This study involved early infection progress by *Ganoderma* in oil palm seedlings and as such it was expected that macroscopic symptoms, such as internal lesion of both root and bole, would not be obvious. However, at the microscopic level, evidence of early internal rot was observed on a few root and root-bole interface sections as demonstrated in Figure 66 B & C, where decayed tissue or lesions appeared to be non-fluorescent under bright field after staining with calcofluor white. As depicted in Figure 66 A & C, the non-fluorescent cells showed thin-walled cells that are observed to be degraded, adjacent to healthy cell that fluoresce brightly with thicker cell walls (Figure 66 C). Furthermore, the root-bole interface region as shown in Figure 66 A shows the presence of hyphae inside of a cell surrounded by several cells that show partial degradation of cell walls by appearing to having pockets in their cell walls or simply having discontinuous cell walls.

Comparison of controls to inoculated test plants showed no phenotypic host defence response such as thickening of cell walls in regions associated with fungal invasion. The formation of specialised hyphal structures such as appressoria or haustoria were not observed during this work however, hyphal clamp connections were observed in one instance of a root sample with hyphae in the lateral root region.

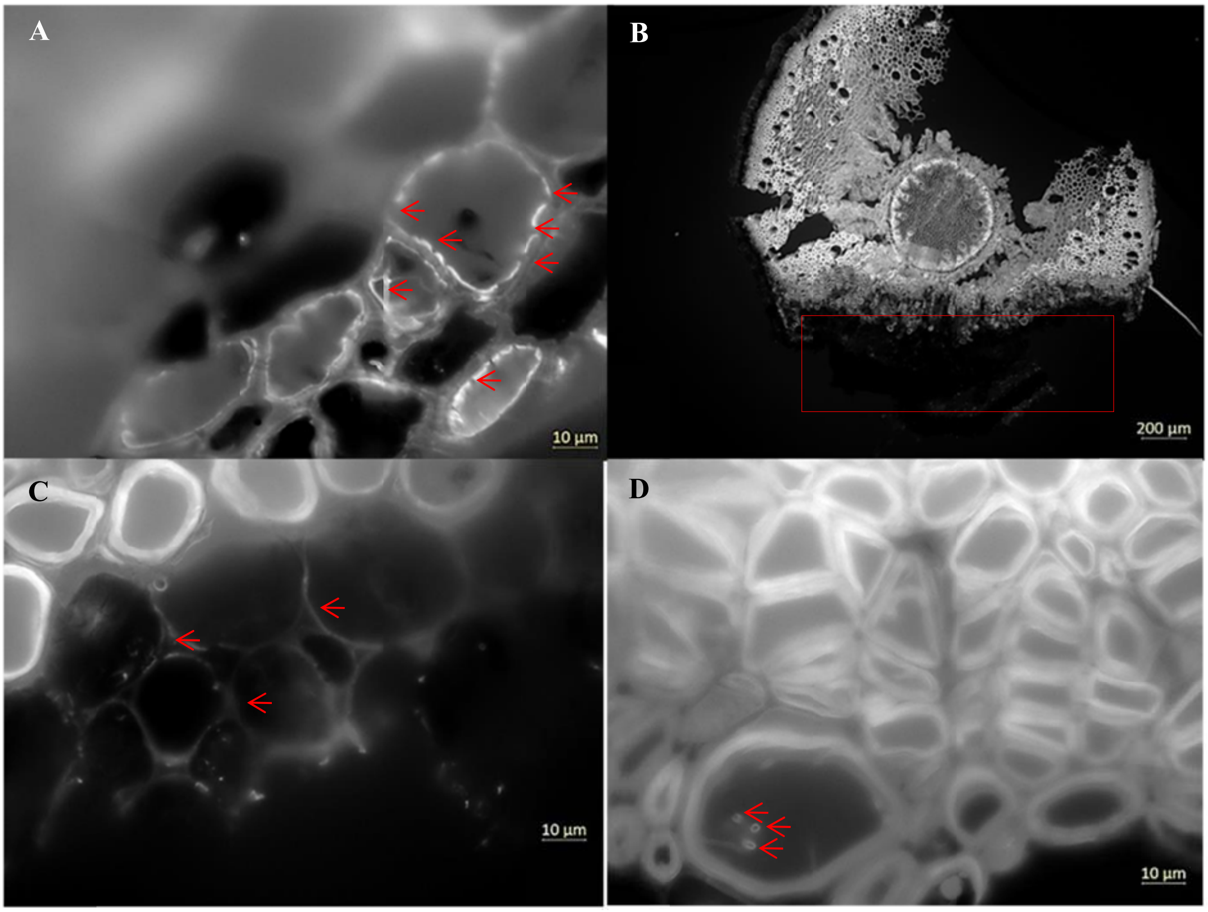

Figure 66 Ganoderma inoculated oil palm seedlings showing root and root-bole interface region and root tissue cell wall degradation.

(A) Root-bole interface region showing degraded cell walls with multiple pockets (arrows) in cell walls. (B) Cross-section of root from inoculated oil palm showing non-fluorescent region (rectangle) of lesion. (C) Image (B) at x100 magnification showing interface between decayed tissues of non-fluorescence (arrows) adjacent to thick fluorescent cells that appear to be loosely arranged. (D) x100 magnification of (B) showing hyphae (arrows) inside of brightly fluorescing cell

D.5.4. Discussion

In root tissue, *Ganoderma* was associated with the sub-epidermal tissue composed of a 'corky' layer of sclerenchyma cells with thick suberized (Abdul-Khalil et al. 2010). secondary cell walls *Ganoderma* was also observed in the brown pigmented tissue in the root-bole interface region. Both of these cell types in the root and the bole appeared brown under bright field microscopy regardless of dyes used, and did not seem to absorb stains of any sort. The brown tissue pigment is possibly due to deposition of polyphenols which is a common feature of palm root tissue. Furthermore, these cell types did not fluoresce under UV light possibly indicating that either these cells are dead, or that the stains are masked by polyphenols. The assumption that the non-fluorescent region/brown pigmented tissue as being dead is highly possible as lesions caused by injury or fungal invasion are commonly observed in plant tissues as brown discolorations. Polyphenols in angiosperms are toxic to fungi; however, these can be broken down by wood decay fungi (Schwarze, 2007).

The lack of advanced host cell wall degradation and movement of *Ganoderma* into the cortex is suggestive of early or slow infection progress given an incubation period of more than five months. Although no physical-wall related responses were visualised in the host, it is still possible that the host may be eliciting a chemical defence response (Rees et al. 2009). This however, remains unknown at this point and may be resolved with a multi-disciplinary approach either employing molecular and or biochemical studies.

D.5.5. Conclusion

Overall this study presents a first account of early infection progress in oil palm seedlings by G. *boninense*. Bole inoculations revealed that *Ganoderma* grew faster in the roots, both primary and lateral roots and the presumably dead region of root-bole interface region, colonising the bole at a later stage. Moreover, the information gathered from this study has set a foundation for future *Ganoderma*-oil palm interaction studies and has contributed new knowledge with respect to the *Ganoderma* infection process.

D.6. Field disease-screening trials

D.6.1. Disease incidence

Two field trials were planted in 2010 at Ngalimbiu Plantation in Solomon Islands with planting material bred at Dami Research Station, WNB. Palm health status has been monitored since establishment of the trials. Yield recording commenced in 2013. Also in 2013, vegetative measurements (height and girth only) commenced and measurements will be repeated biennially. Disease levels in both field trials at Ngalimbiu differ markedly with Trial 1 recording a total of 6 confirmed infections and Trial 2 a total of 26 cases of basal stem rot, excluding guard row palms from 2013-2016 (Figure 67). Palms with symptoms only have not been included here.

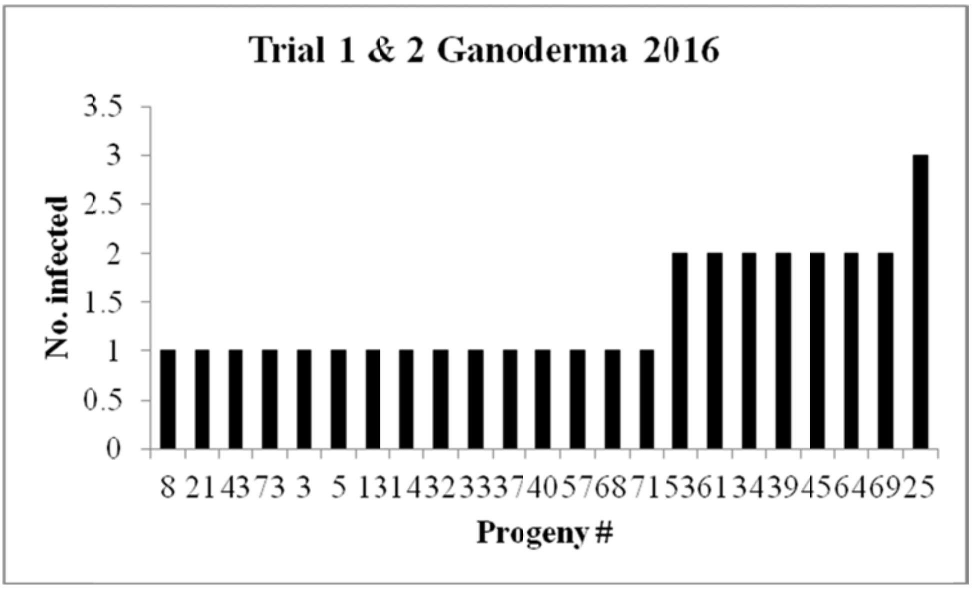

Figure 67 Numbers of each progeny infected in all blocks in Trials 1 and 2 (Field 12 and 13) at Ngalimbiu Plantation, GPPOL for the period 2013-2016.

Progenies 53, 5 and 61 have mortalities in both fields. The remaining infected progenies are recorded from different fields. Although Progeny 25 has recorded three confirmed infections, this number is still low and does not indicate susceptibility. When all infections, including symptomatic palms are considered the data might reveal some segregation. This will be done after further monitoring whereby symptoms can be progressively charted and confirmed as indicative of basal stem rot.

D.6.1.1. *Yield studies*

Trial progeny yields were recorded throughout 2016 in all blocks. Yields are based on standing palms, including those diseased.

Bunch weights ranged from 8.7 to 15.1±0.5kg for progenies planted in Trial 1, Field 12 in 2016 with a mean of 11.7±0.5kg (Figure 68). Progenies with the highest bunch weights were #43 and #38 with mean bunch weights of around 15±0.5kg. Progeny 80 yielded the smallest bunches in 2016.

Yields calculated on an annual basis for the 81 Dami progenies in the same trial (Trial 1, Field 12) are shown in Figure 69. Mean yield for all progenies planted in 14 plots was 25.6t±**1**.1/ha, the same as in 2015. The highest producing progeny in Field 12 was 54 with approximately 34.9±1.6t/ha. This progeny also produced good yields in 2015 with 31±1.t/ha. The lowest production in 2016 was recorded for progeny 74 (17.4±0.8t/ha).

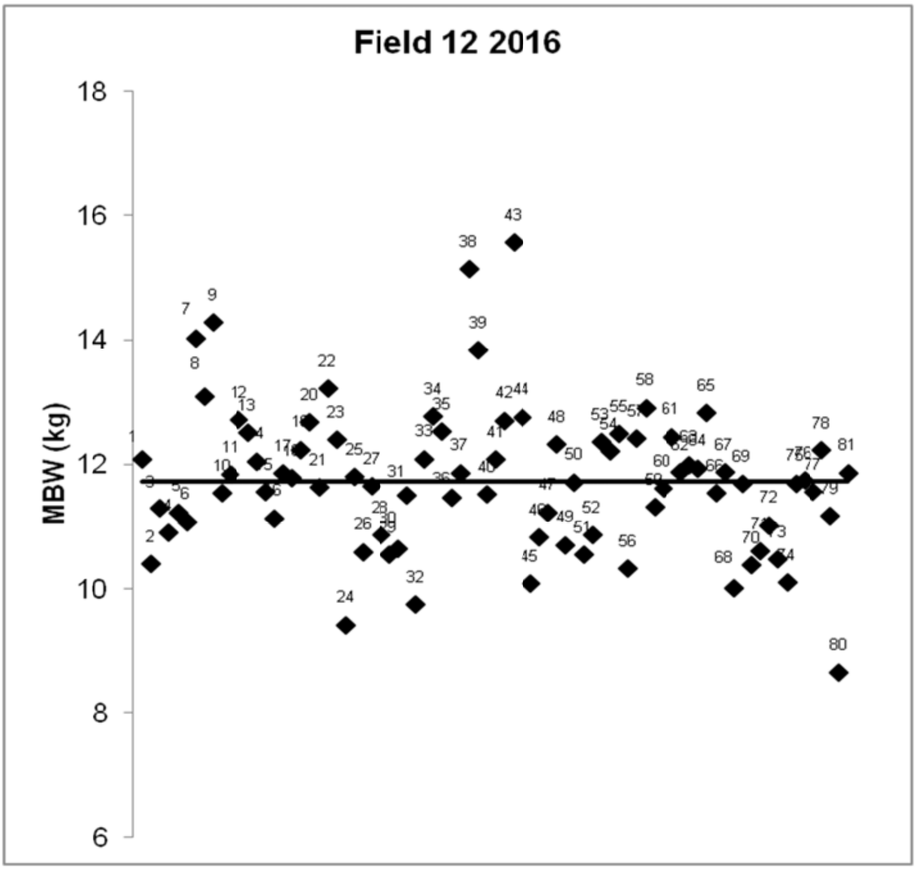

Figure 68 Mean bunch weights recorded in 2016 for 81 progenies (n=1121) from Dami (OPRS) planted in Field 12, Ngalimbiu Plantation (GPPOL), Solomon Is.
The bar is the mean for all progenies.

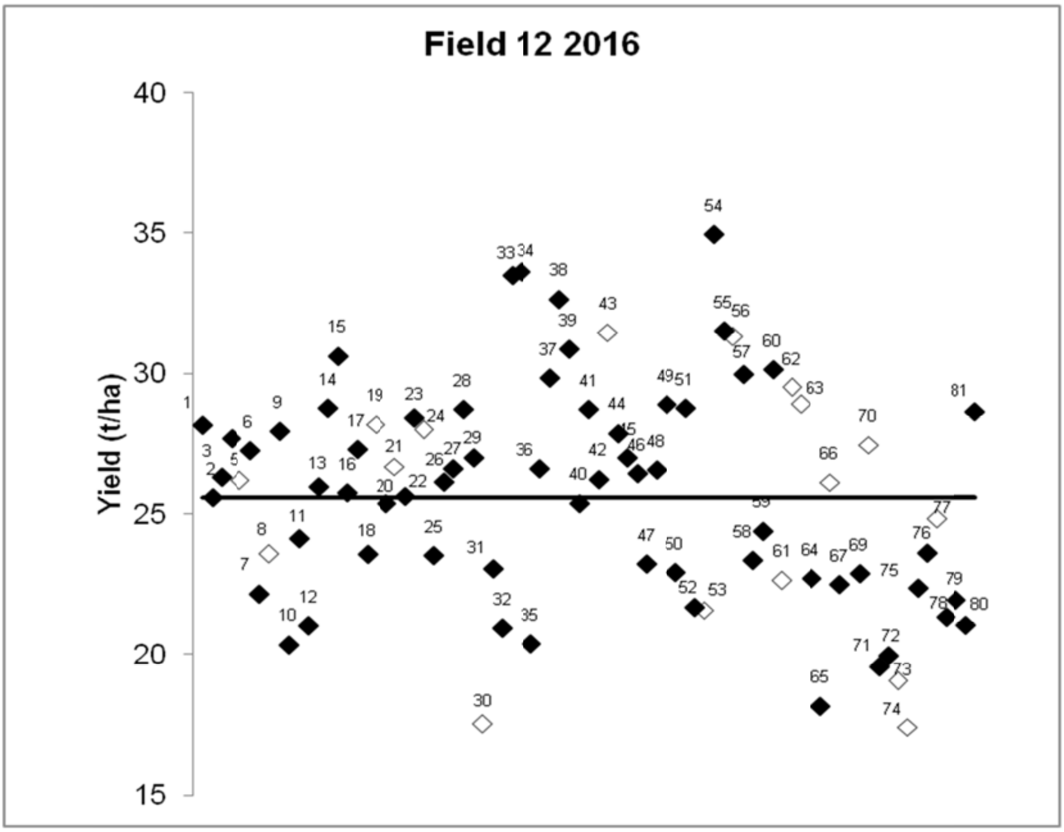

Figure 69 Mean yields recorded in 2016 for 81 progenies (n=1121) from Dami (OPRS) planted in Field 12, Ngalimbiu Plantation (GPPOL), Solomon Is.
Ganoderma-affected progenies are shown as clear labels. The bar is the mean for all progenies.

Bunch size ranged from 10.0±0.5 to 15.6±0.5kg in Field 13 with a mean bunch weight of 12.2±0.5kg for all progenies (Figure 70). Progeny with the largest bunches were #38 (also for Field 12) and #41. Average production in Field 13 for 2016 was 28.5±1.7t/ha for all progenies combined, slightly but not significantly higher than yields obtained for Field 12 (Figure 71). In 2016, the highest producing progeny was again progeny 15 with 35.4±2.1t/ha with progeny 38 also translating bunch weights to a high yield of 34.6±2.1t/ha. The lowest yielding progenies were #65 and #69 with averages of 20.7±1.2t/ha, despite having reasonably good size bunches of over 11±0.5kg.
As in 2015, progenies obtained similar yields in both trials with those performing below or above the mean in Field 12 performing similarly in Field 13. The difference in the mean yields between the 2 trials was not significant ($P<0.01$) despite the higher number of palms recorded as diseased in Field 13.

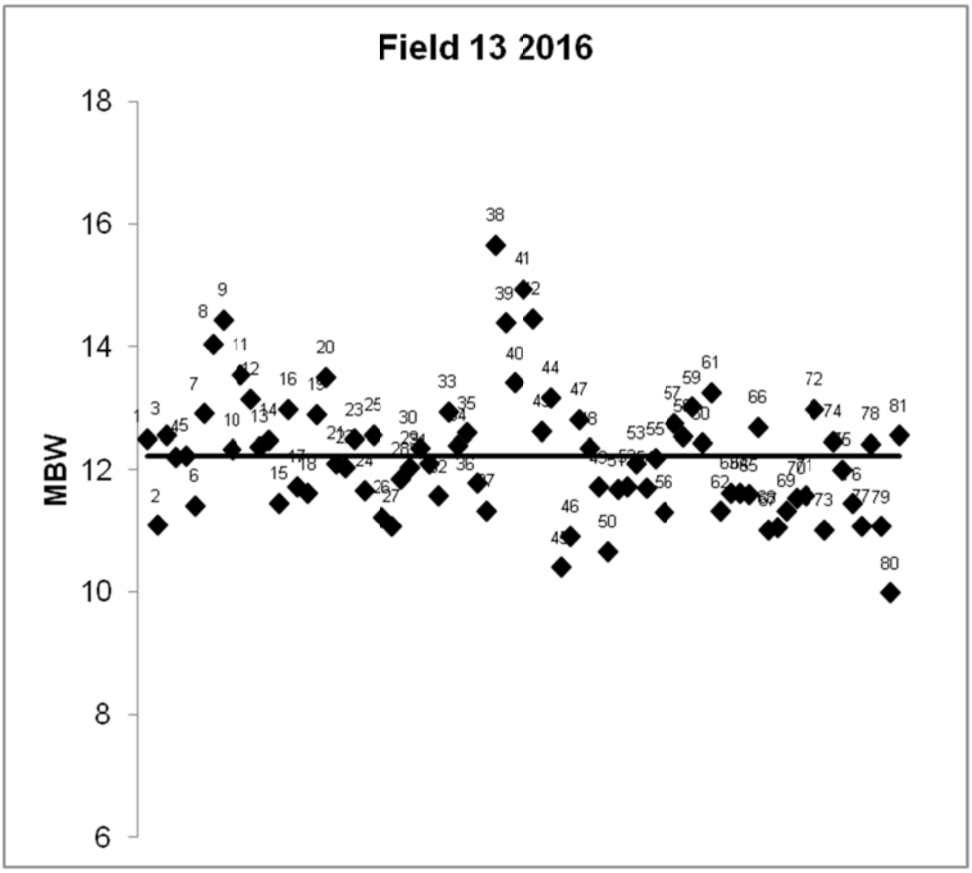

Figure 70 Mean bunch weights obtained in 2016 for 81 (n=1115) progenies from Dami (OPRS) planted in Field 13, Ngalimbiu Plantation (GPPOL), Solomon Is.

The bar is the mean for all progenies.

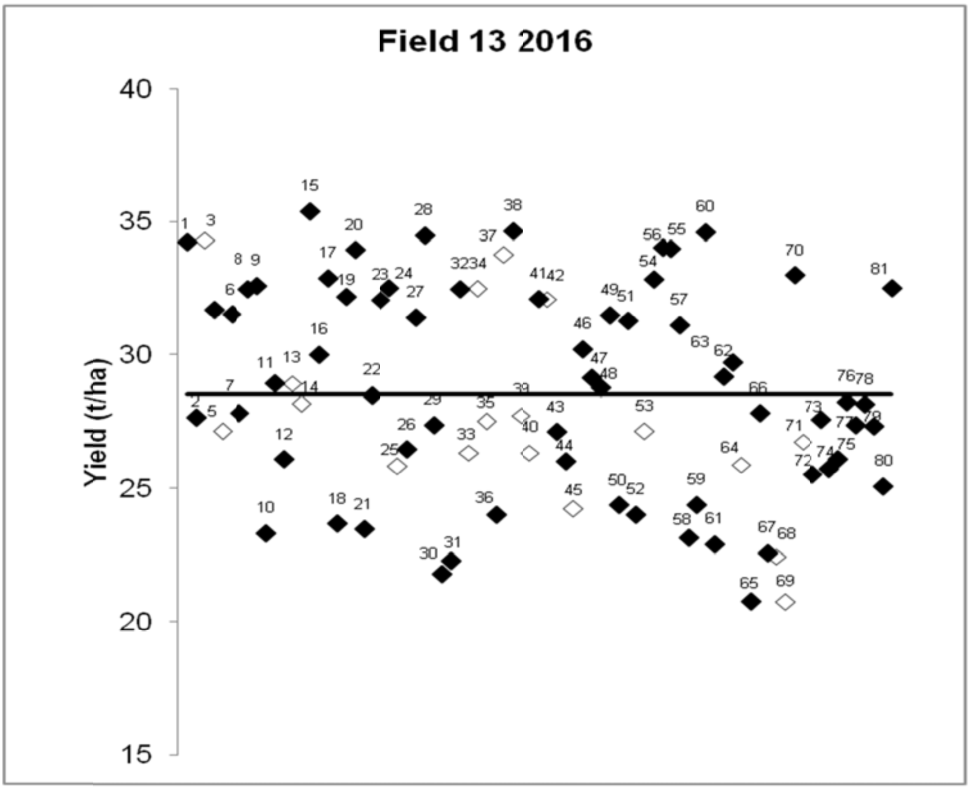

Figure 71 Mean yields obtained in 2015 for 81 progenies (n=1115)) from Dami (OPRS) planted in Field 13, Ngalimbiu Plantation (GPPOL), Solomon Is.
Progenies with diseased or dead palms are shown as clear labels. The bar is the mean yield for all progenies.

Progressive data on vegetative measurements was collected in 2016 but is not presented here.

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E. SMALLHOLDER AND SOCIOECONOMICS RESEARCH

HEAD OF SECTION IV: STEVEN NAKE

E.1. Section overview

The core objective of Smallholder and Socioeconomic Research (SSR) section is to develop and provide appropriate extension interventions that will enhance smallholder oil palm productivity and strengthen the economic, environmental and social well-being of the smallholder sector. The objective will be achieved by investigating and addressing cross-cutting agronomic and socioeconomic issues underpinning both productivity and production in smallholder blocks.

In 2016, there were staff movements between project sites. Paul Simin was transferred to Hargy Oil Palms, Bialla to take over OIC responsibilities. Merolyn Koia was relocated from Higaturu sub-station in Popondetta to Dami Oil Palm Research Station in WNB to assist with socioeconomic research in West New Britain. Emmanuel Germis was awarded with a 2 year scholarship under the John Allwright Fellowship. He left for Perth, Australia in July for post-graduate studies (MPhil by Research). Four staffs were made permanent in Dami.

Activities for 2016 centered around four main projects; (i) demonstration of best management practices in smallholders, (ii) assessing smallholder nutrient status through leaf, (iii) soil sampling and (iv) extension services through field days and block demonstrations and (v) ACIAR funded project (ASEM/2017/072) on “Strengthening livelihoods for food security amongst oil palm and cocoa communities in PNG”. This project will close end of 2017. Two socioeconomic projects were carried out in 2016. A socioeconomic household baseline survey was conducted for smallholders in Milne Bay and a case study on regular and irregular users of fertilizer in Hoskins, WNB.

The first phase of our research has already been achieved by proving without doubt from the results of the BMP blocks that there is huge potential for smallholder yields to be improved beyond current actual yields. This is the key message driven to all smallholders during the weekly field trainings organized by the section. The second phase of our research is to quantify the impact of our work and that will be our main focus from 2017 onwards.

E.2. New Britain Palm Oil WNB

Steven Nake, Paul Simin, Leonard Hura

E.2.1. SSR101abcde: Demonstration of best management practices in smallholder blocks, Hoskins Project

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

E.2.1.1. *Summary*

Best management practices of oil palm were demonstrated in more than 30 smallholder oil palm blocks in Hoskins Project, WNB since 2009. Eight years after the project implementation, the results continue to be very promising. The block standards (upkeep) have improved considerably. Though the mean yield have declined in 2016, the committed BMP blocks continue to maintain their production at levels above 20 t/ha. Apart from the agronomic benefits, the economic benefit of this technology (BMP) is immense. Adoption of BMP can increase income up to three-fold. Therefore, BMP is the way forward for oil palm smallholders.

E.2.1.2. *Introduction*

The smallholder sector in Hoskins project makes up 42 % of the total area planted with oil palm but produces only 32 % of the total crop. PNGOPRA fertiliser trials in NBPOL plantations prove yields of 20 t/ha are achievable. The smallholder sector holds the key to a substantial untapped potential in production hence the benefits of increased yields from the smallholder blocks can be substantial and are very important for the oil palm industry.

The objective of this project is to convert low yielding into well-managed high yield blocks and demonstrate to smallholder growers the oil palm best management practices can contribute to better yields.

E.2.1.3. *Materials and Methods*

Block selection and establishment

Block visits were carried out with OPIC officers to identify poorly managed blocks with obvious symptoms of nitrogen (N) deficiency (oven canopy, small bunches, small fronds, yellowing of leaves, die back of leaflets or fronds). When identified, the production history (last 5 years) is then consulted to determine the average block productivity. Depending on the productivity, we then decide whether to accept or reject the block for this project. We try as much as possible to select blocks with very low yields so that impact of this project is obviously seen by the block owner and surrounding blocks.
Table 61 shows list of both current and closed BMP blocks in Hoskins Project.

Table 61 List of BMP blocks established in Hoskins

No	Block	Trial code	Area	Scheme	Division	Year of initiation	Status
1	023-0138	**SSR101a**	Waisisi	**CRP**	Siki	2009	Closed
2	003-0980	SSR101d	Sarakolok Sect 7	LSS	Nahavio	2009	Current
3	252-0016	SSR101e	Kukula	VOP	Salelubu	2009	Current
4	250-0114	SSR101e	Ubae	VOP	Salelubu	2009	Current
5	240-0921	SSR101e	Mamota Sect 8	LSS	Salelubu	2009	Current
6	274-0026	SSR101e	Marapu	VOP	Salelubu	2009	Closed
7	004-1186	SSR101c	Buvusi Sect 6	LSS	Buvusi	2009	Current
8	006-1719	SSR101b	Kavui Sect 7	LSS	Kavui	2009	Current
9	004-1169	SSR101c	Buvusi Sect 5	LSS	Buvusi	2010	Current
10	021-0209	SSR101a	Rikau	VOP	Siki	2011	Closed
11	039-0092	SSR101a	Koimumu	VOP	Siki	2011	Current
12	009-1055	SSR101a	Siki	LSS	Siki	2011	Current
13	014-0126	SSR101b	Mai	VOP	Kavui	2011	Current
14	011-0165	SSR101b	Buluma	VOP	Kavui	2011	Current
15	006-1637	SSR101b	Kavui Sect 11	LSS	Kavui	2011	Current
16	017-0008	SSR101b	Gaongo	VOP	Kavui	2011	Closed
17	242-0458	SSR101e	Silanga	VOP	Salelubu	2011	Current
18	006-0202	SSR101b	Kavui Sect 4	LSS	Kavui	2014	Closed
19	006-1854	SSR101b	Kavui Sect 12	LSS	Kavui	2014	Closed
20	020-0020	SSR101a	Gule	VOP	Siki	2014	Current
21	042-0003	SSR101a	Gavaiva	VOP	Siki	2014	Closed
22	009-2235	SSR101a	Siki	LSS	Siki	2014	Current
23	017-0098	SSR101b	Gaongo	CRP	Kavui	2014	Current
24	004-1216	SSR101c	Buvusi Sect 4	LSS	Buvusi	2014	Closed
25	004-1171	SSR101c	Buvusi Sect 5	LSS	Buvusi	2014	Closed
26	005-2115	SSR101c	Galai 2	LSS	Buvusi	2014	Closed
27	005-1590	SSR101c	Galai 2	LSS	Buvusi	2014	Current
28	005-1570	SSR101c	Galai 2	LSS	Buvussi	2014	Current
29	002-0475	SSR101d	Tamba Sect 5	LSS	Nahavio	2014	Current
30	002-0561	SSR101d	Tamba Sect 6	LSS	Nahavio	2014	Current
31	255-0018	SSR101e	Kae	VOP	Salelubu	2014	Current
32	016-0172	SSR101d	Morokea 2	CRP	Nahavio	2015	Current
33	044-0082	SSR101a	Kololo	VOP	Siki	2015	Current
34	013-0001	SSR101b	Kwalekessi	VOP	Kavui	2015	Current
35	015-0005	SSR101b	Banaule	VOP	Kavui	2015	Current
36	256-0042	SSR101e	Sisimi	VOP	Salelubu	2015	Current
37	250-0038	SSR101e	Ubae	VOP	Salelubu	2015	Current
38	047-0003	SSR101c	Lilimo	VOP	Buvussi	2016	Current
39	005-2118	SSR101c	Galai 2, Sect 19	VOP	Buvussi	2016	Current
40	019-0051	SSR101d	Tamambu	VOP	Nahavio	2016	Current

Block Upkeep

Monthly work targets were issued out to all BMP blocks every month and includes upkeep work that required immediate attention as per the end of the month block inspection. This includes upkeep work such as pruning (either full or selective), slashing, circle and paths cleaning, frond alignment, upkeep on cover crop and herbicide application.

Fertiliser Application

In 2016, Urea was applied to all the blocks at the rate of 1.5 kg per palm per year. Three (3) large empty tinned fish (425 grams ~ 0.425 litres) of urea was applied per palm. Demonstration of fertilizer application was done before BMP growers did the application.

Harvesting

Frequent harvesting is part of BMP and there is zero tolerance on skipped harvesting. All blocks are expected to do over 20 harvests in a year.

Data collection

Monthly production data from the SHA database are summed up for the entire year and converted into tonnes per hectare (t/ha). Leaf sampling was done in 2016.

E.2.1.4. ***Results and Discussion***

SSR101a – Siki Division

One of the 6 BMP blocks in Siki Division was closed end of 2015 resulting in 5 blocks remaining (Table 61).The yields for these blocks from 2013 to 2016 are presented in. Blocks 009-2235, 009-1055, 044-0082 exhibited yield increases ranging from as low as 0.7 t/ha to as high as 3.3 t/ha between 2015 and 2016. These 3 blocks have demonstrated consistent yield increase in the last 3 years with blocks 009-1055 and 044-0082 producing 21.6 and 26.5 t/ha respectively. In contrast, yields from blocks 039-0092 and 020-0020 declined in 2016 to below 15 t/ha. Block 020-0020 had 5 records of skipped harvests while declining yield for block 039-0092 was a result of over aging palms. The palms are 22 years old and have become too tall to harvest. The mean for the project (Siki) generally showed an inclining yield trend from 2013 to 2016.

Table 62 Annual Production (t/ha) BMP blocks in the Siki Division from 2012 to 2016

	Yields (t/ha)			
Block	2013	2014	2015	2016
039-0092	21.9	19.5	15.6	13.8
020-0020	13.1	14.7	16.6	14.2
009-2235	9.6	12.6	14.2	17.2
009-1055	24.3	23.6	20.4	21.6
044-0082		15.4	23.2	26.5
Siki Mean	17.2	17.2	18.0	18.7

SSR101b – Kavui Division

Kavui division has 7 existing BMP blocks (Table 63). The division has some of the best blocks under the BMP programme. These are blocks 011-0165, 014-0126, 006-1637, 006-1719, 017-0098 and 015-0005. These 6 blocks have continued to maintained high field standards and are harvesting frequently. As a consequence, all have produced over 20 t/ha in 2016. The yields from blocks 011-0165 and 006-1719 declined drastically in 2016 because they yielded well over 30 t/ha in 2015.

The mean yield for the division (Kavui) showed high yields over 20 t/ha being maintained over the last 4 years.

Table 63 Annual Production (t/ha) BMP blocks in the Kavui Division from 2013 to 2016

	Yields (t/ha)			
Block	**2013**	**2014**	**2015**	**2016**
011-0165	28.8	30.3	30.4	21.1
014-0126	17.5	19.3	20.9	22.3
006-1637	15.7	20.2	22.6	20.5
006-1719	31.3	31.8	32.2	22.9
017-0098			22.2	37.7*
013-0001			16.6	10.6
015-0005			14.1	20.1
Kavui Mean	**23.3**	**25.4**	**24.0**	**22.2**

**Although out of the range, the data is accurate*

SSR101c – Buvussi Division

Table 64 shows the production for the existing 6 blocks in Buvussi Division. Blocks 004-1169 and 004-1186 were the first two BMP blocks in Buvussi. After 6 years, Block 004-1169 continued to produced significantly high yields (32.2 t/ha) in 2016. The yield from Block 004-1186 increased slightly by 0.2 t/ha in 2016 after it plummeted to 17.2 t/ha in 2015. Block 005-1590 continued to produce over 20 t/ha in 2016. Block 005-1570 increased its production by 1.5 t/ha in 2016 but unfortunately struggled to push its yields to over 15 t/ha. The 3rdphase of this block was recently planted and has not reached the prime productive age. Additionally, the second phase was thinned due to high density planting and resulted in half of the initial planting density.

Blocks 047-003 and 005-2118 were established in 2016 and have yielded reasonably well in their first year, however, it is too early to verify if the better yields are a result of improved management.

Table 64 Annual Production (t/ha) BMP blocks in the Buvussi Division from 2013 to 2016

	Yields (t/ha)			
Block	**2013**	**2014**	**2015**	**2016**
004-1169	24.9	29.0	25.0	32.2
004-1186	20.2	29.2	17.2	17.4
005-1590	12.7	22.7	22.0	22.8
005-1570		5.2	9.3	10.8
047-003				15.0
005-2118				12.4
Buvussi Mean	19.2	21.5	18.4	18.4

SSR101d – Nahavio Division

Nahavio division has 5 BMP blocks. Blocks 003-0980, 002-475 and 002-561 were initiated prior to 2013, while blocks 016-0172 and 019-0051 were set up in late 2015. The three old BMP blocks recorded increase in their yields from 2015 to 2016. The yield increased represented a percentage of 8.2 – 20.5% yield increase. Block 003-0980 was one of the first BMP blocks that was established in 2009 but still struggling to push its yields above 20 t/ha, because phase 1 and 3 (4 hectares) are over-age palms. Due to lost title, these two phases could not be replanted. The low productivity in other two blocks (002-561, 002-561) blocks is compounded by 1-2 phases of over-aged palms. We expect to see an increase in yield in 2017 in the two recently initiated BMP blocks (016-0172 and 019-0051). The mean yield for the division (Nahavio) is 15.0 t/ha which is well below the 20t/ha mark.

Table 65 Annual Production (t/ha) BMP blocks in the Nahavio Division from 2013 to 2016

	Yields (t/ha)			
Block	**2013**	**2014**	**2015**	**2016**
003-0980	14.8	12.5	13.4	14.6
002-475	7.3	9.1	12.8	16.1
002-561	12.7	13.3	10.4	15.9
016-0172				12.2
019-0051				16.4
Nahavio Mean	**11.6**	**11.6**	**12.2**	**15.0**

SSR101e – Salelubu Division

Five of the BMP blocks (252-0016, 240-0921, 242-0458, 256-0042, 250-0038) increased their yields in 2016 while the other two blocks (250-0114, 255-0018) experienced yield drop (Table 66). Blocks 252-0016, 240-0921, 242-0458 and 250-0038 produced yields greater than 20 t/ha in 2016(Table 66). The highest yield of 25.9 t/ha was recorded from Block 250-0458. Yield from block 255-0018 continued to plummet from 10.9 t/ha in 2015 to 10.0 t/ha in 2016. This was due to poor crop recover as a result of neglect by the block owner to implement BMP on the block. The recently established blocks (256-0042 and 250-0038) responded positively to BMP with a reasonable yield increments within a short period of time (2 years).

Table 66 Annual Production (t/ha) BMP blocks in the Salelubu Division from 2013 to 2016

	Yields (t/ha)			
Block	**2013**	**2014**	**2015**	**2016**
250-0114	34.6	26.8	32.4	18.5
252-0016	15.4	19.2	19.3	25.6
240-0921	25.6	25.2	21.7	25.6
255-0018	11.1	11.3	10.9	10.0
242-0458	28.9	18.5	21.1	25.9
256-0042			14.6	16.8
250-0038			11.0	20.2
Salelubu Mean	**23.1**	**20.2**	**18.7**	**20.4**

General Impact of improved best management practices (BMP)

Figure 73 compares the mean yields from the BMP blocks with the Hoskins Project from 2014 to 2016. The BMP yields were obviously higher than the project yields in all the 3 years. Adoption of BMP in the smallholder blocks resulted in yield increment of about 5 t/ha. This implies that the smallholder blocks have potential to increase their yields by another 5 t/ha if best management practices are implemented.

Figure 73 shows the yields overtime as the blocks were converted into BMP blocks from year 1. Generally the yields exhibited an ascending trend with time (years), despite the slight decline in the 6th and 8th year after initiation. There was a steady increase between the 1st to 5th year after initiation. Marked yield increments were observed between year 1 and year 3(8 t/ha increase), which represented 40 % yield increase. The rapid response by the yield during the first 2-3 years was driven mainly by improvement to the block standards and frequency of harvest which resulted in high crop recovery.

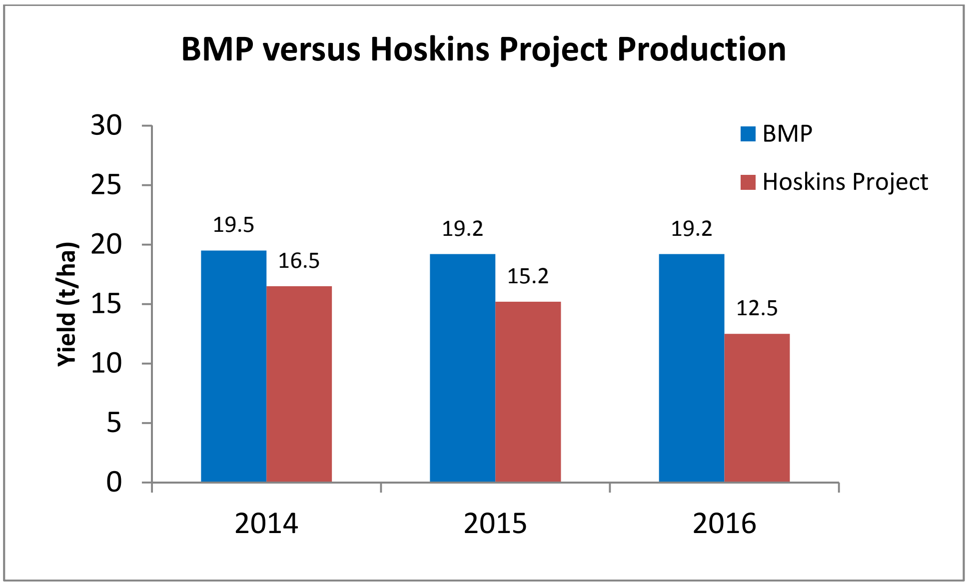

Figure 72 BMP trials mean yields versus overall mean yield for smallholders in Hoskins, WNB

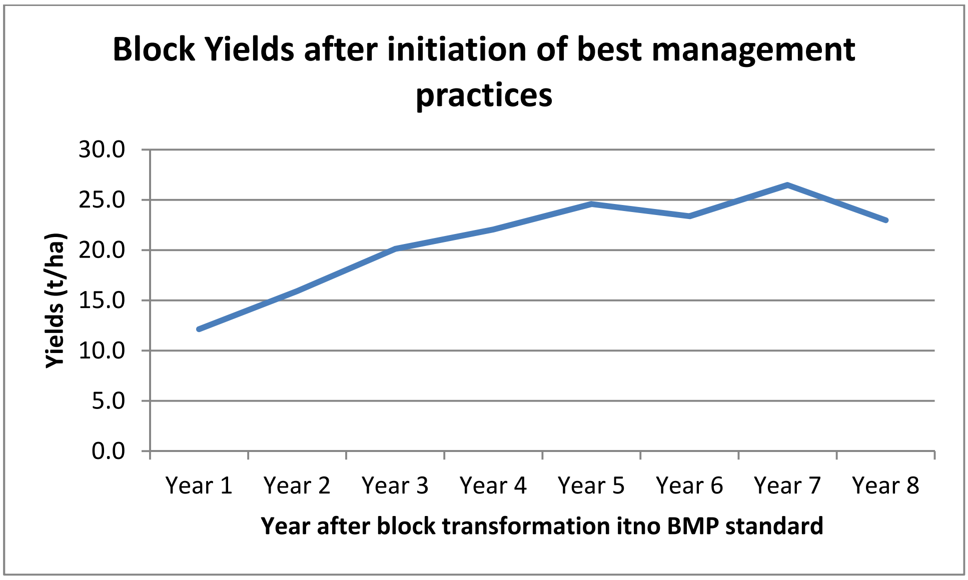

Figure 73 Yearly production (t/ha) trend for all BMP blocks in Hoskins from establishment

Is maintaining a smallholder block on BMP standard economical?

BMP comes at a cost and the question that any smallholder will raise if the economics behind the technology. Table 67 and Table 68 summarises the cost of implementing BMP and both the agronomic (yield) and economic benefit. BMP increases yield by two-fold (100 %) and income (Kina) by three-fold (Table 68). Therefore, adoption of BMP by smallholders is profitable.

Table 67 Cost of block activities and chemicals used on 1 ha of a BMP block

Activities	**Rounds per year**	**Mandays required**		**Est. Daily hours**	**Total hours**	**Rate (K)**	**Total cost (K)**
		Per round	**Per year**				
Slashing	4	2	8	8	64	2.50	160
Spraying	3	1	3	8	24	2.50	60
Pruning	4	2	8	8	64	2.50	160
Harvesting	26	1.5	39	8	312	2.50	780
Fertilising	1	2	2	8	16	2.50	40
						Total (K):	*1,200*
Chemicals	**Rounds per year**	**Qty (litres/bag) required**		**Cost/litre (K)**	**Cost/bag (K)**	**Total Cost (K)**	
		Per Round	**Per Year**				
Glyphosate	3	3	9	10.78		97.02	
Urea fert	1	4	4		69.00	276	
					Total (K)	*373*	
CombinedCost	**K1200+K373 = K1573**						

Table 68 Comparison between BMP and Non-BMP block

	BMP Block	Non-BMP Block
Cost of block upkeep (1 ha)	K1573	K1, 202
Yield (t/ha) (5 year data)	19 t/ha/year	9t/ha/year
FFB income (Kina)	K3984	K1887
Breakeven point	K2411	K685

External factors masking the positive effect on oil palm yield by best management practices

Despite the positive impact by implementation of best management on oil palm as seen in Figure 72 and Figure 73, there is large yield variation between the blocks ,(Table 62, Table 63, Table 64, Table

65 and Table 66). While some of these blocks have yielded well over 20 t/ha, others continued to produce below 20 t/ha. A few blocks have done well by producing over 30 t/ha, demonstrating the potential yield for smallholders. Until the external factors impeding effects of BMP are not resolved, the potential yield for the project will never be achieved (realised). The common ones are discussed here.

Over-aged palm stands

Smallholder growers have difficulty harvesting over-aged palms (23-36 years) because the palms at this age become too tall to be harvested with their tools. In most cases, zero (nil) to less than 50 % of these tall palms are harvested and this contributes directly to yield reduction. The Hoskins project current has over 4,000 ha of overage palms (LPC report, 2016). Similarly, 11 out of the 30 current blocks under the BMP project have 1 or 2 phases that are also over-aged and due for replanting. This is the reason why the BMP blocks mean yield (Figure 72) was consistent throughout the 3 years.

Two main factors contribute to over-aged oil palm stands. Firstly, insecure lease titles for LSS and CLUA for VOP and CRP blocks. As a requirement for RSPO, both titles and CLUA must be secure before the replanting process (palm poisoning, lining and planting of seedlings) can go ahead. Secondly, resistance by younger households (generations) to replanting because of short-term loss of income. This is normally the case in over populated blocks.

Crop shifting

Crop shifting does not affect the agronomic yield of the blocks but affects yield data on the database. All BMP blocks are in very good condition in terms of block upkeep, and expect yields to follow suit. Unfortunately, some of the blocks have low yields because there was no yield data for some of the months because crop was diverted to other neighbouring blocks to avoid debt repayment. This malpractice gives a false impression of the blocks in terms of outcome of implementation of BMP on these blocks.

Prolong neglect of fertiliser and irregular harvesting

The positive outcome of BMP will only be evident if the blocks are fertilised every year and frequently harvested. These three practices go hand-in-hand. If one is missing, the other two will not work. Smallholders must be encouraged to do at least 24 harvest in a year to reap the benefit of fertiliser application and best management practices.

E.2.1.5. ***Conclusion***

There is huge potential for smallholder crop to be elevated beyond current yields. The results from this project have shown yield beyond 20 to 30 t/ha achievable if the smallholder blocks are managed well by adopting the recommended best management practices. These management practices include regular weed control either by chemical control or slashing particularly within the circles and the paths, pruning, boxing of cut fronds, establishing cover plants at the replanting phase, fertiliser application and regular harvesting. Best Management Practices is the way forward for smallholders for yield intensification. Apart from the agronomic benefits, the technology is also economical. Adopting BMP on a smallholder block can increase income by three-fold.

E.2.2. SSR104: Assessing Leaf and Soil Nutrient Status in Smallholders, Hoskins Project

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

E.2.2.1. ***Summary***

Leaf sampling was conducted in 143 smallholder blocks to assess their foliar nutrient levels. Samples were processed and dispatched to Hill Laboratory in New Zealand for analysis. Laboratory analysis revealed that Leaf N, P, K were below their respective optimum level. Leaf B was slightly low in some blocks while others were with the adequate level. In contrast, leaf Mg and rachis K were above the optimum level. The concentration of leaf N, P and K were lower than in 2013. This implied that the concentration of these essential elements in the leaf have dropped with time. It would be interesting to see if the declining trend continues in 2017.

E.2.2.2. *Introduction*

There are three important diagnostic tools to determine palms health status. They are; (i) visible symptoms of nutrient deficiency or excess; (ii) plant (leaf) analysis, and (iii) soil analysis (Asher *et al*, 2002). Leaf analysis was developed primarily to provide information on the nutrient status of the oil palms as a guide to nutrient management (fertiliser management tool) for optimal oil palm growth and production. Leaf analysis is also used to protect the environment from over-fertiliser application (Asher *et al*, 2001). For smallholders, there is a need to come up with site specific recommendations for fertilizer application hence this project was initiated in 2013 to determine both foliar and soil nutrient status of smallholder blocks in Hoskins Project, West New Britain.

E.2.2.3. *Materials and Methods*

One hundred and forty-three (143) smallholder blocks were randomly selected from the five divisions (Siki, Kavui, Buvussi, Nahavio and Salelubu) (Table 69). The selected blocks were within the prime age group. Blocks with immature and over-aged palms were not selected. In each block, both leaflet and rachis samples were taken from marked palms. The sampling points (palms) were identified using sampling intensity of 5x5 and 5x3 depending on the size of the block. A 5x5 sampling intensity would mean that every 5th palm in every 5th row is sampled. Apart from leaf sampling, leaf measurements were also taken from frond 17.

The samples are then brought back to the office for processing. After processing, they are oven-dried at 70^{o}C, ground, packed and dispatched to Hill Laboratory in New Zealand for analysis.

Table 69 Break up of Smallholder blocks utilized for leaf sampling in 2016

Division	**Number of sampling blocks**
Siki	33
Kavui	27
Buvussi	28
Nahavio	29
Salelubu	26
Total:	***143***

E.2.2.4. *Results and Discussion*

The leaf and rachis nutrient concentrations are presented in Table 70 and compared against the published optimum nutrient level (Fairhurst, 1997). Leaf N, P, K for all divisions are below the optimum level. For leaf B, only Nahavio and Siki divisions are above the optimum level of 15 ppm, the other 3 divisions (Buvussi, Kavui and Salelulu) are below the optimum level. Leaf Mg levels in all divisions are just above the level of adequacy (0.20 %). Rackis K is levels are well above the optimum level.

The nutrient levels for the individual blocks are shown in Figure 74 to Figure 79. For leaf N, only 9 blocks (6.3%) were above the optimum level. The rest of the 134 blocks (93.7%) were below 2.45 %, which is the optimum level for N. Furthermore, the leaf N from 15 of these blocks were below 2 %. Therefore N in general was low in more than two thirds of the blocks sampled. Similarly, P levels from only 15 blocks (10.5%) were above adequate level of 0.145 %, while 128 blocks (89.5%) were P deficient. Leaflet P ranged from 0.108 to 0.156%.

Leaf K ranged from 0.43 to 0.82 %, with mean of 0.60%. More than 80% of the sampled blocks (115) were K deficient, with 92 blocks (64%) with leaf K between <0.60% and <0.65%. Leaf B ranged from 9 to 23 % with a mean 14.5 %. While 77 of the blocks were above the adequacy level for leaf B (15 ppm), 66 blocks were B deficient. Over 63% of the blocks (91 blocks) had B levels between <14 ppm and <16 ppm.

Leaf Mg from half of the blocks (72) were in the <0.25 % category. Despite that, 90 blocks were well above the optimum level of 0.20%, while 53 blocks were Mg deficient. Rachis K ranged from 1.01 to 2.45 % which a mean of 1.67 % which is well above the optimum level of 1.20%. Only 7 blocks (2.7%) were below 1.2%, while the majority of the blocks above the adequate level. More blocks (100) had rachis K between <1.6 % to <2.0%. Generally, leaf Mg and rachis K had high proportion of blocks within the adequacy level.

Comparing 2016 nutrient levels to the results from 2013 (Table 71), Leaf N, P and K all exhibited a declining trend. Leaf N dropped from 2.25% to 2.20%, while Leaf P declined from 0.137% to 0.127%. Leaf K also plummeted from 0.84% to 0.60%. Interestingly, Leaf Mg, B and rachis K concentrations were all elevated in 2016, eventhough smallholders do not apply these elements in the form of inorganic fertilisers.

Table 70 Foliar nutrient concentrations for smallholder blocks in the 5 divisions in Hoskins Project in 2016

Divisions	Leaf N (%)	Leaf P (%)	Leaf K (%)	Leaf Mg (%)	Leaf B (ppm)	Rachis K(%)
Buvussi	2.19	0.126	0.60	0.21	14.1	1.56
Nahavio	2.30	0.131	0.61	0.20	15.7	1.93
Kavui	2.21	0.128	0.59	0.21	13.8	1.71
Siki	2.10	0.124	0.63	0.20	15.5	1.56
Salelubu	2.20	0.128	0.58	0.25	13.3	1.93
Mean	***2.20***	***0.127***	***0.60***	***0.21***	***14.5***	***1.67***
Optimum Level (Fairhurst, 1997)	**2.45**	**0.145**	**0.65**	**0.20**	**15.0**	**1.20**

Table 71 Mean foliar concentrations in 2013 and 2016

Foliar Nutrient	2013	2016
Leaf N	*2.25*	*2.20*
Leaf P	*0.137*	*0.127*
Leaf K	*0.84*	*0.60*
Leaf Mg	0.20	0.21
Leaf B	12.7	14.5
Rachis K	1.28	1.67

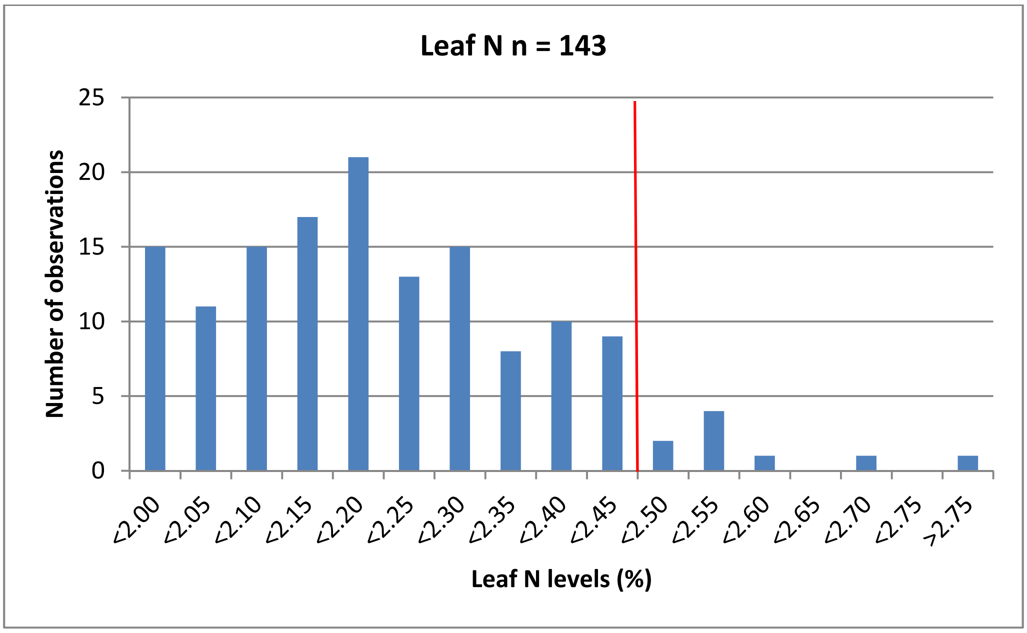

Figure 74 Leaf N concentration for the sampled smallholder blocks in 2016

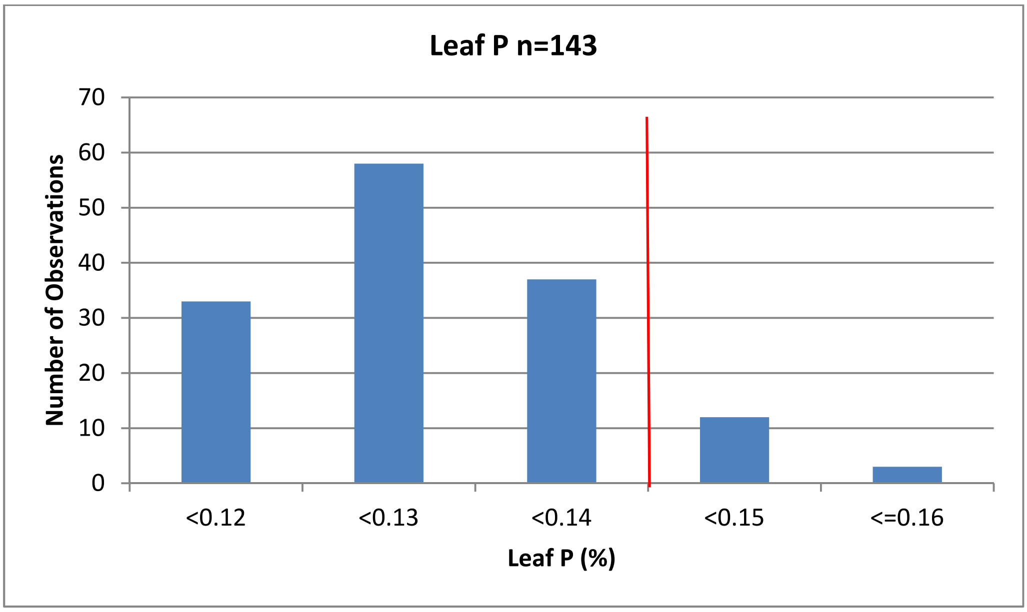

Figure 75 Leaf P concentration for the sampled smallholder blocks in 2016

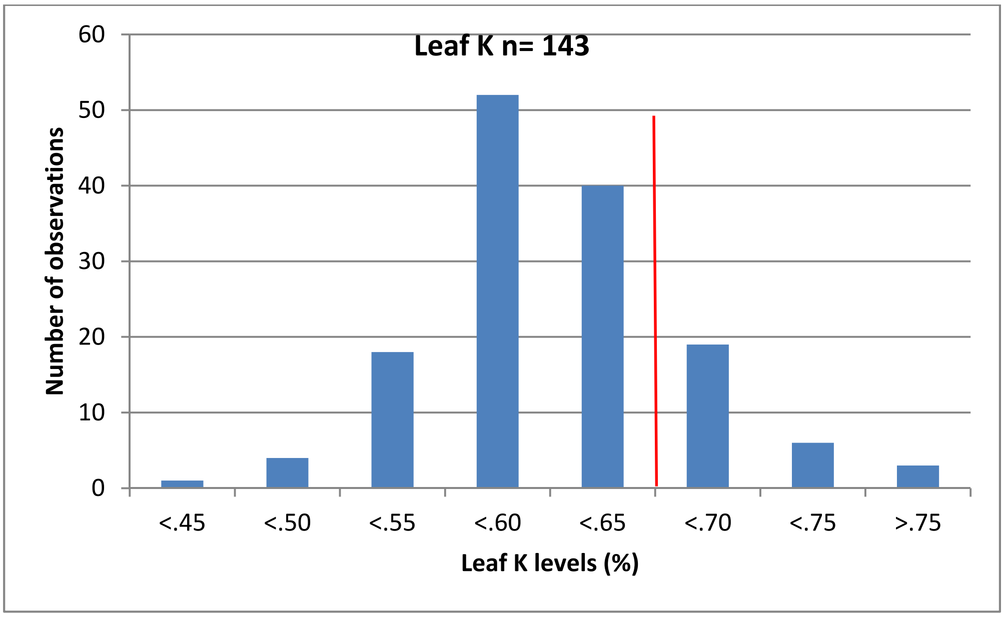

Figure 76 Leaf K concentration for the sampled smallholder blocks in 2016

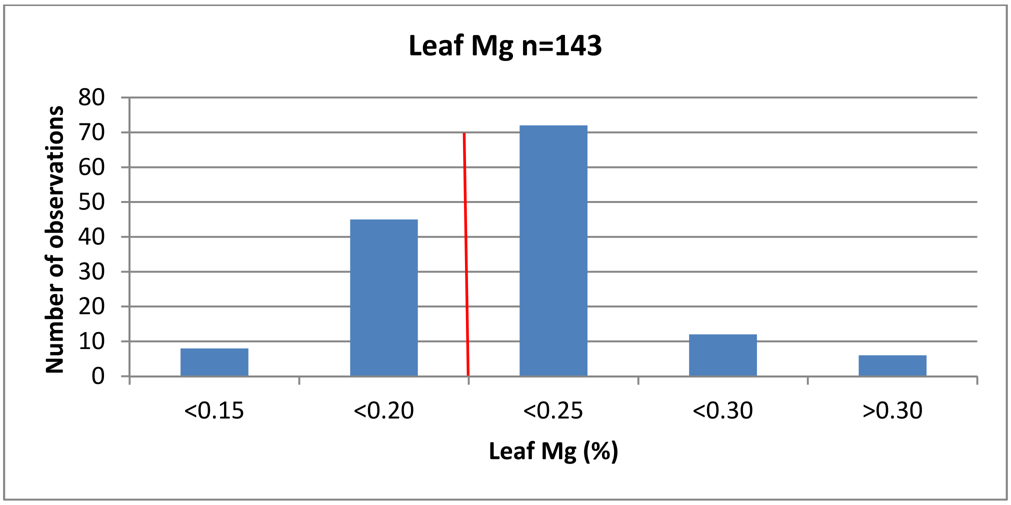

Figure 77 Leaf Mg concentration for the sampled smallholder blocks in 2016

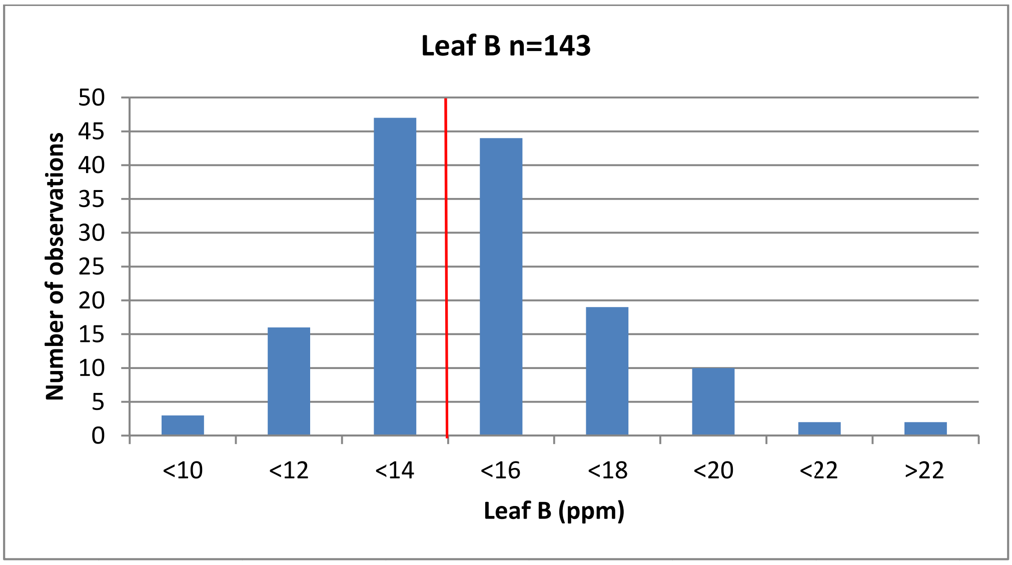

Figure 78 Leaf B concentration for the sampled smallholder blocks in 2016

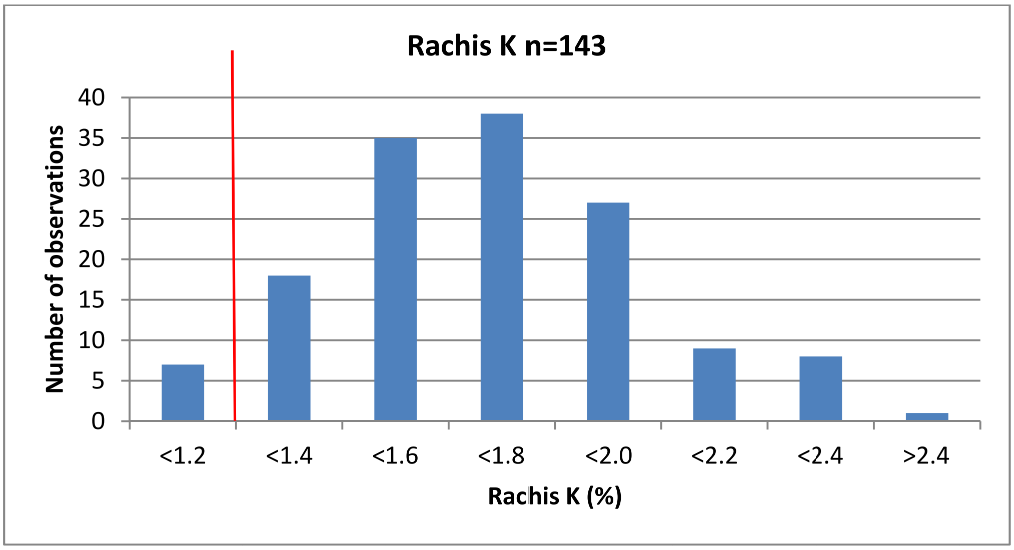

Figure 79 Rachis K concentration for the sampled smallholder blocks in 2016

E.2.2.5. *Conclusion*

Leaf N, P, K and B levels were below their respective optimum level given by Fairhurst (1997). In contrast, leaf Mg was within the adequacy level. Since 2013, the major elements (N, P, K) have been declining, whereas leaf Mg, B and rachis K levels have been elevated. There may be a possibility of reviewing fertiliser recommendations for smallholders in Hoskins if the major nutrient levels continue to plummet in 2017.

E.3. Hargy Oil Palm Limited

Steven Nake, Peter Mupa and Andy Ullian

E.3.1. SSR201abc: Demonstration of best management practices in smallholder blocks, Bialla Project

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

E.3.1.1. *Summary*

Oil Palm Best Management Practices were demonstrated on 6 smallholder blocks in Bialla project with the aim of improving yields. There was marked positive response by adopting BMP on 5 of the 6 smallholder blocks in 2016. The yield increase between 2015 and 2016 ranged from 8.7 % to 65%. The yield increment was mainly influenced by improving the block management standards. While the average yield for the smallholder blocks in Bialla was tagged at 14.1 t/ha, that of the BMP blocks was 15.0 t/ha which is above the project average. The best BMP block in the project yielded 21.4 t/ha, demonstrating yield potential in smallholders.

E.3.1.2. *Introduction*

The smallholder sector in Hargy (Bialla) makes up over 50 % of the total area planted with oil palm, with average production of 17 t/ha. Despite that PNGOPRA fertiliser trials in Hargy plantation across prove yields of over 30 t/ha are achievable. The smallholder sector holds the key to a substantial untapped potential in production hence the benefits of increased yields from the smallholder blocks can be substantial and are very important for the oil palm industry. Setting up demonstration plots and experiments in smallholder blocks is one important way of contributing to increasing both production and productivity.

The objective of this project is to convert run-down blocks with low yields into well-managed high yield blocks and demonstrate to smallholder growers the oil palm best management practices can contribute to better yields.

E.3.1.3. *Materials and Methods*

Block selection and establishment

There are currently 6 BMP blocks established in Bialla Project (Table 72). Block 380037 was closed end of 2014 because of continuous crop shifting. A new BMP block was setup in Soi LSS in 2016.

Block visits were carried out with OPIC officers to identify poorly managed blocks with obvious symptoms of nitrogen (N) deficiency (oven canopy, small bunches, small fronds, yellowing of leaves, die back of leaflets or fronds). When identified, the production history (last 5 years) is then used to calculatethe average block productivity and blocks with low yields are selected.

Table 72 List of BMP blocks established in Bialla project

No	Block	Trial code	Area	Scheme	Division	Year of initiation	Status
1	380037	SSR201c	Tianepou	VOP	Division 3	2012	Closed
2	380042	SSR201c	Tianepou	VOP	Division 3	2014	Current
3	380052	SSR201c	Tianepou	VOP	Division 3	2014	Current
4	370029	SSR201c	Galilelo	VOP	Division 3	2014	Current
5	021296	SSR201b	Barema	LSS	Division 2	2015	Current
6	040439	SSR201a	Malasi	VOP	Division 1	2015	Current
7	1631	SSR201b	Soi	LSS	Division 2	2016	Current

Block Upkeep

Monthly work targets were issued out to all BMP blocks every month and include upkeep work that required immediate attention as per the end of the month block inspection. This includes upkeep work such as pruning (either full or selective), slashing, circle and paths cleaning, frond alignment, upkeep on cover crop and herbicide application.

Fertiliser Application

In 2016, Urea was applied to all the blocks at the rate of 1.5 kg per palm per year. Three (3) large empty tinned fish (425 grams ~ 0.425 litres) of urea was applied per palm. Demonstration of fertilizer application was done before BMP growers did the application.

Harvesting

Frequent harvesting is part of BMP and there is zero tolerance on skip harvesting. Skip harvesting and crop shifting is a common problem in run-down blocks and growers are discouraged from this illegal practices.

Data collection

Monthly production data from the smallholder database are summed up for the entire year and converted into tonnes per hectare (t/ha).

E.3.1.4. *Results and Discussion*

A new BMP block was established at Soi LSS bringing the number of BMP blocks in Bialla to six. All BMP blocks except block 021296 saw an increase in their yields in 2016. The yield increments range from 9 to 65 % increased. Block 380042 yielding over 21.4 t/ha (Table 73). This block is the best managed block of all the BMP blocks in Bialla. The condition of the block in terms of palm growth has improved significantly since 2013.

In contrast, production from Block 021296 declined by 7 t/ha. Yields from 6 months were suspiciously low, meaning that the harvested crop could have been diverted out of the blocks to avoid debt repayment. The production trend in the last 4 years is depicted in Figure 80. Generally, the yields have been improved by 6 t/ha since the inception of the BMP in the selected blocks. The BMP mean yields (15.0 t/ha) in 2016 were slightly higher than the project mean of 14.1 t/ha (Figure 81). Hence, there is still room for improvement.

Table 73 Annual Production (t/ha) for BMP blocks in Bialla from 2013 to 2016

Block	Area	Yields (t/ha)			
		2013	2014	2015	2016
380042	Tianepou	8.9	7.3	12.2	21.4
380052	Tianepou	1.1	5.1	7.0	14.3
370029	Galilelo	10.6	15.8	14.7	16.1
040439	Malasi		9.5	5.5	15.7
021296	Barema		9.9	14.4	7.5
1631	Soi				15.4

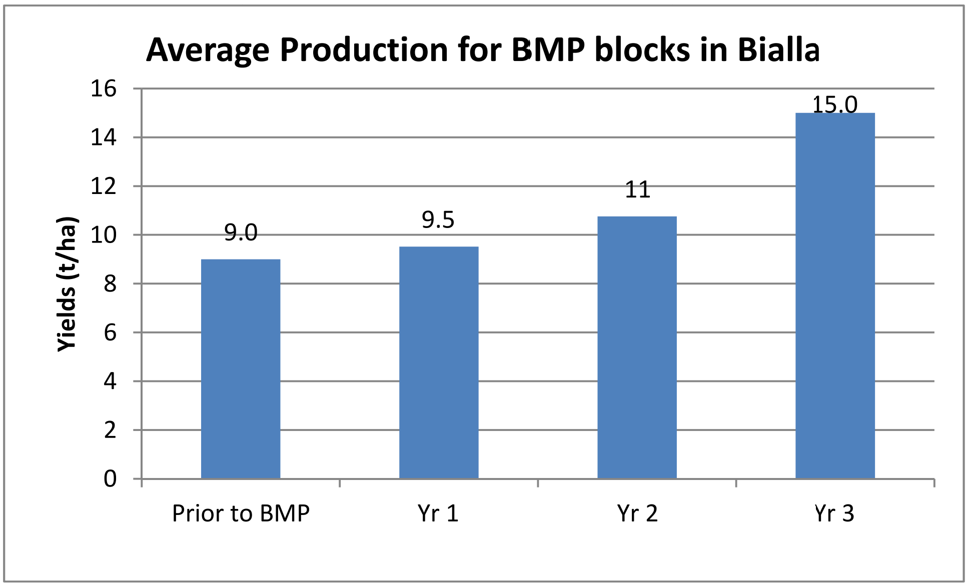

Figure 80 Average BMP block production (t/ha) before and after application of BMP

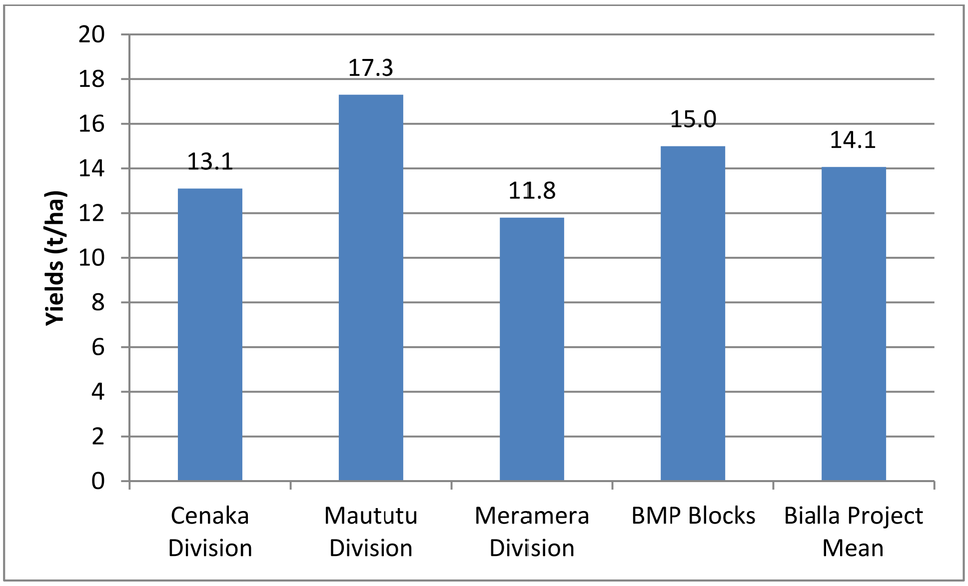

Figure 81 Smallholder production forBialla Project in 2016

E.3.1.5. *Conclusion*

2016 was a good year for the BMP blocks in Bialla, with a general yield increment of 4 t/ha. Five of the 6 blocks produced greater yields compared to the project mean yield of 14.1 t/ha. One of these blocks yielded 21.4 t/ha. Improvements made to the block standards (BMP) was the driving factor behind the yield increase. Crop diversion was observed to be one of the factors masking the agronomic benefits (yield response) of implementing BMP in smallholder blocks as evident by the BMP block at Barema (021296).

E.3.2. SSR203: Assessing Leaf and Soil Nutrient Status in Smallholders, Bialla Project

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

E.3.2.1. *Summary*

Leaf sampling was conducted in 64 smallholder blocks in Biallato assess their foliar nutrient levels. Laboratory analysis revealed that Leaf N, P, K were below their respective optimum level. The mean leaf concentration in 2016 for N, P and K were 2.15%, 0.128% and 0.57% respectively. In contrast, Mg and B concentration in the leaf and rachis K were in abundance.

E.3.2.2. *Introduction*

There are three important diagnostic tools to determine palms health status. They are; (i) visible symptoms of nutrient deficiency or excess; (ii) plant (leaf) analysis, and (iii) soil analysis (Asher *et al*, 2002). Leaf analysis was developed primarily to provide information on the nutrient status of the oil palms as a guide to nutrient management (fertiliser management tool) for optimal oil palm growth and production. Leaf analysis is also used to protect the environment from over-fertiliser application (Asher *et al*, 2001). For smallholders, there is a need to come up with site specific recommendations for fertilizer application hence this project was initiated in 2013 to determine both foliar and soil nutrient status of smallholder blocks in Bialla Project, West New Britain.

E.3.2.3. *Materials and Methods*

Sixty-four (64) smallholder blocks were randomly selected from the 3 divisions (Cenaka, Maututu and Meramera) (Table 74). The selected blocks were within the prime age group. Blocks with immature and over-aged palms were not selected. In each block, both leaflet and rachis samples were taken from marked palms. The sampling points (palms) were identified using sampling intensity of 5x5 and 5x3 depending on the size of the block. A 5x5 sampling intensity would mean that every 5th palm in every 5th row is sampled. Apart from leaf sampling, leaf measurements were also taken from frond 17.

The samples are then brought back to the office for processing. After processing, they are oven-dried at 70°C, ground, packed and dispatched to Hill Laboratory in New Zealand for analysis.

Table 74 Break up of Smallholder blocks utilized for leaf sampling in 2016

Division	**Number of sampling blocks**
Cenaka (Division 1)	27
Maututu (Division 2)	21
Meramera (Division 3)	16
Total:	***64***

E.3.2.4. *Results and Discussion*

The foliar nutrient concentrations are presented in Table 75 with published adequate levels from Fairhurst (1997). Leaf N, P, K for all divisions were deficient (below adequate level). In contrast, leaf Mg, B and rachis K were adequate. Rachis K levels were well above the optimum level.

The nutrient levels for the individual blocks are shown in Figure 82 to Figure 87. Leaf N ranged from 1.78% to 2.82% with a mean of 2.15%. Only 5 blocks (7.8%) were above optimum level of 2.45%, while the leaf N from the rest of the blocks were deficient. Fifty-six (56) blocks representing over 87% of the blocks sampled had leaf N levels between <2.0% and <2.4%. Three (3) blocks were below 1.8%.

Leaf P and K ranged from 0.112 to 0.157% and 0.40 to 0.80%, respectively. Phosphorus is known to be low in volcanic soils of Bialla because of the presence of allophone mineral which fixes P affecting its uptake by the palm roots. Only 4 (6%) and 9 (14%) blocks were above optimum leaf level for both P and K, respectively, while the both P and K in the rest of the blocks were deficient. Leaf Mg and B from 55 (86%) and 50 (78%) blocks respectively were above the adequate levels (Mg = 0.20% and B = 15 ppm). For leaf Mg, only 9 blocks were deficient of Mg while 14 blocks were deficient of B. Rachis K levels ranged from 0.68 to 2.49% with a mean of 1.64%. Over 60 blocks had rachis K between <1.50 and >2.00 %.

Table 75 Foliar nutrient concentrations for smallholder blocks in Bialla Project

Divisions	**Leaf N (%)**	**Leaf P (%)**	**Leaf K (%)**	**Leaf Mg (%)**	**Leaf B (ppm)**	**Rachis K(%)**
Cenaka	2.15	0.127	0.54	0.26	17.1	1.55
Maututu	2.22	0.124	0.56	0.25	17.4	1.67
Meramera	2.07	0.132	0.61	0.27	23.6	1.69
Mean	***2.15***	***0.128***	***0.57***	***0.26***	***19.4***	***1.64***
Optimum Level (Fairhurst, 1997)	**2.45**	**0.145**	**0.65**	**0.20**	**15.0**	**1.20**

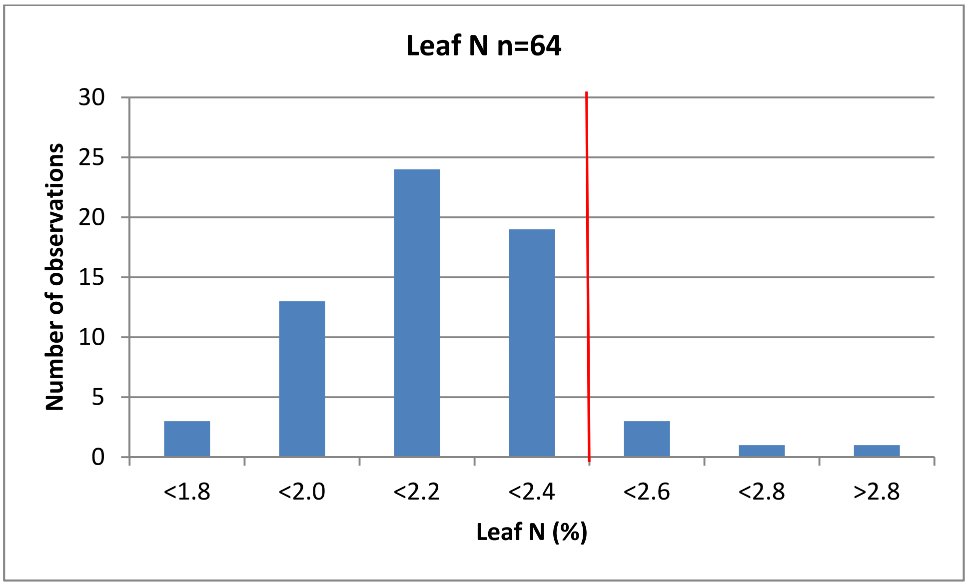

Figure 82 Leaf N concentration for the sampled smallholder blocks in 2016

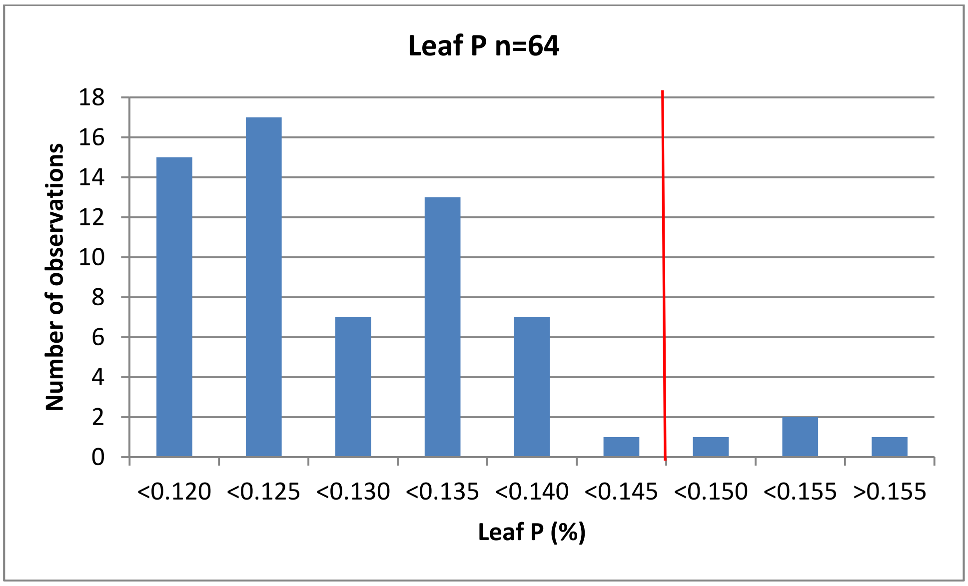

Figure 83 Leaf P concentration for the sampled smallholder blocks in 2016

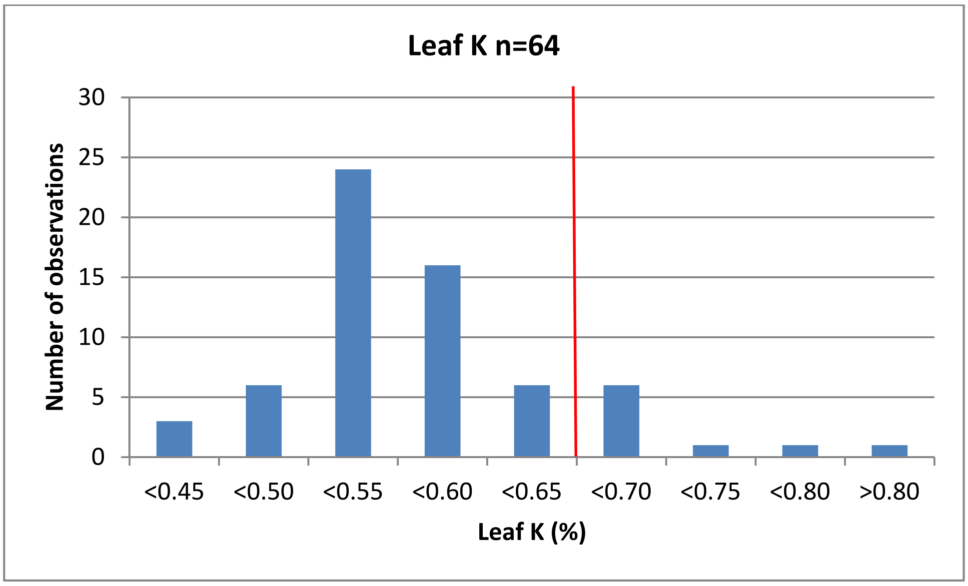

Figure 84 Leaf K concentration for the sampled smallholder blocks in 2016

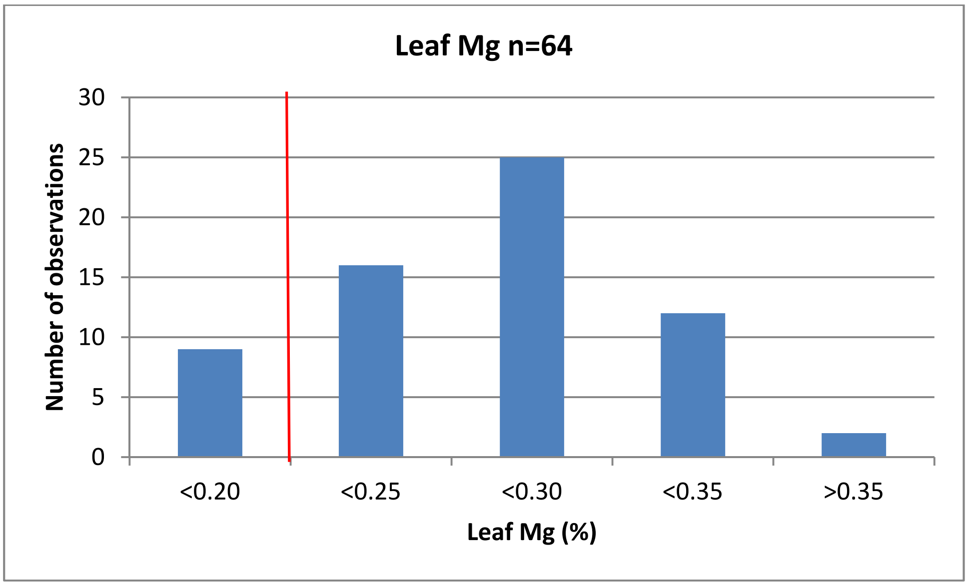

Figure 85 Leaf Mg concentration for the sampled smallholder blocks in 2016

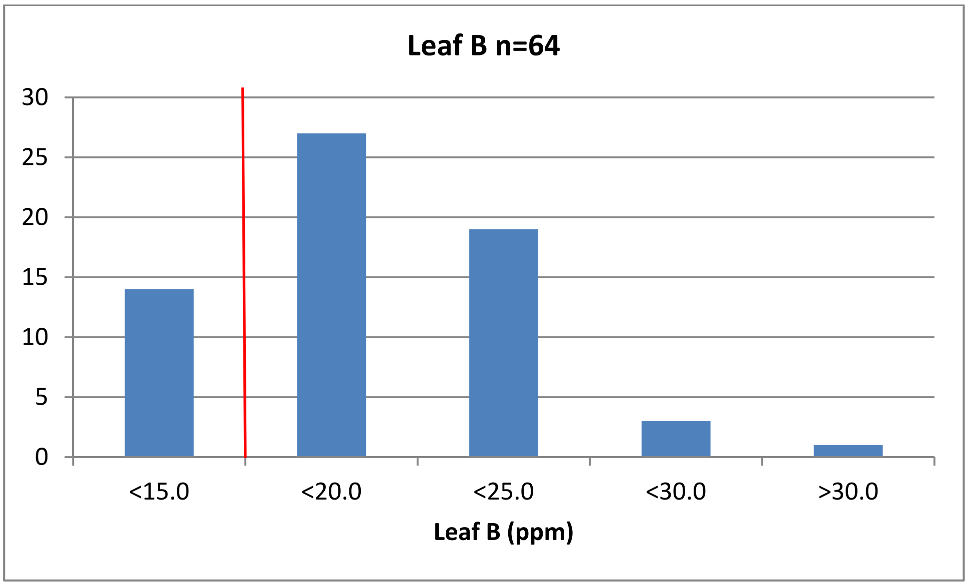

Figure 86 Leaf B concentration for the sampled smallholder blocks in 2016

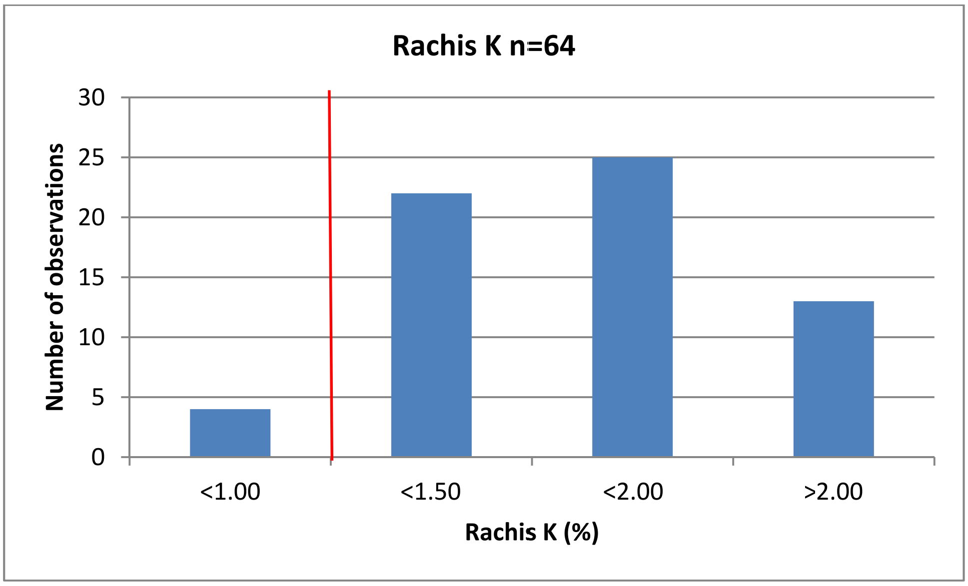

Figure 87 Rachis K concentration for the sampled smallholder blocks in 2016

E.3.2.5. *Conclusion*

Leaf N, P and K levels were deficient. In contrast, leaf Mg, B and rachis K were adequate. Allophane mineral in volcanic soils of Bialla impedes absorption of P ions by the oil palm roots, by fixing it. Low N levels could be due to nitrogen fertiliser not applied in the blocks or not managed according to the 4 Rights of fertiliser (Right type, rate, placement and timing).

E.4. New Britain Palm Oil Poliamba Limited

Steven Nake, Akia Aira and Raymond Nelson

E.4.1. SSR301abc: Demonstration of best management practices in smallholder blocks, New Ireland Project

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

E.4.1.1. *Summary*

Oil Palm Best Management Practices was demonstrated on 3 smallholder blocks with the aim of improving yields. Two of the blocks in 2016 produced yields (9.9 t/ha and 13.0 t/ha) greater than the mean yield (6.2 t/ha) for smallholders in New Ireland. Despite the positive effect of BMP on yields, crop diversion to avoid debt deduction can mask the positive impact of BMP. More training and awareness is required to educate the BMP growers on these malpractices.

E.4.1.2. *Introduction*

The smallholder sector in New Ireland makes up 32 % of the total area planted with oil palm and produces a small proportion of the total crop. PNGOPRA fertiliser trials in plantations across the country prove yields beyond 20 t/ha are achievable. The smallholder sector holds the key to a substantial untapped potential in production hence the benefits of increased yields from the smallholder blocks can be substantial and are very important for the oil palm industry. Setting up demonstration plots and experiments in smallholder blocks is one important way of contributing to increasing both production and productivity.

The objective of this project is to convert run-down blocks with low yields into well-managed high yield blocks and demonstrate to smallholder growers the oil palm best management practices can contribute to better yields.

E.4.1.3. *Materials and Methods*

Block selection and establishment

Five blocks have been established under the BMP project since its initiation in New Ireland in 2009(Table 76). Blocks S2655 and S1618 were closed in 2014 because both blocks yielded over 20 t/ha. Blocks S2818 and S1943 were established to replace the closed blocks.

Block visits were carried out with OPIC officers to identify poorly managed blocks with obvious symptoms of nitrogen (N) deficiency (oven canopy, small bunches, small fronds, yellowing of leaves, die back of leaflets or fronds). When identified, the production history (last 5 years) is then used to calculate the average block productivity and blocks with low yields are selected.

Table 76 List of BMP blocks established in New Ireland

No	Block	Trial code	Area	Scheme	Division	Year of initiation	Status
1	S2655	SSR301a	Lakurumau	VOP	North	2009	Closed
2	S1618	SSR301b	Bura	VOP	South	2010	Closed
3	S4518	SSR301c	Pangefua	VOP	West	2012	Current
4	S2818	SSR301a	Lakarol	VOP	North	2015	Current
5	S1943	SSR301b	Luapul	VOP	South	2014	Current

E.4.1.4. *Results and Discussion*

The yields for the current 3 BMP blocks in New Ireland are shown in Table 77. The yields from Blocks S2818 and S1943 were elevated in 2016 by 1.2 t/ha and 3.8 t/ha respectively. The yields from block S4518 continued to plummet in 2016 by 4.4 t/ha (56% decline). Block inspection revealed that the palms were harvested but the crop was diverted to another block. PNGOPRA's involvement in this block ceased as of December 2016and will no longer used for demonstrating BMP as of 2017. In contrary to the production issue, the overall block upkeep of this block has improved considerably since it was transformed into a BMP block in 2012.

Comparing the yields from smallholder blocks in New Ireland with the yields from the BMP blocks in 2015and 2016, the BMP blocks produced 1.1 t/ha and 2.6 t/ha more in 2015 and 2016 respectively (Figure 88).Despite that, the BMP yields are still struggling be elevated to 15 t/ha. Past results from two BMP blocks closed in 2014 revealed both blocks able to achieve reasonably high yields of over 20 t/ha. This shows the yield potential also in New Ireland. Three main driving forces behind smallholder low yields are non-application of fertilizer, crop diversion to avoid debt repayment and less time spent on the blocks to do upkeep work.

Table 77 Annual Production (t/ha) for BMP blocks in New Ireland from 2013 to 2016

	Yields (t/ha)			
Block	**2013**	**2014**	**2015**	**2016**
S4518	7.5	13.3	7.9	3.5
S2818			11.8	13.0
S1943		10.5	6.1	9.9

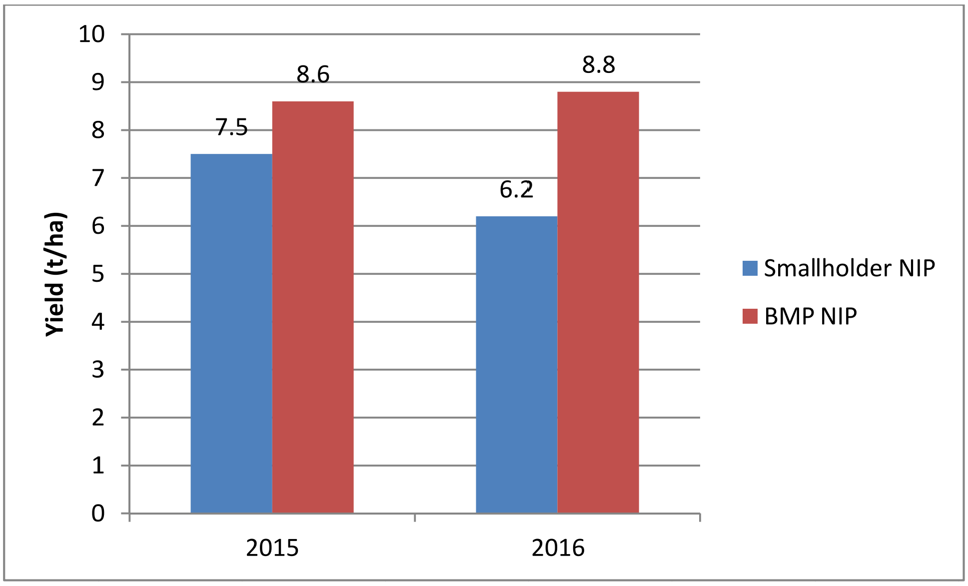

Figure 88 New Ireland Smallholder and BMP block production in 2015 and 2016

E.4.1.5. *Conclusion*

The yield increase by blocks S2818 and S1943 in 2016 depicts the importance of adopting BMP in smallholder blocks. These two blocks produced yields above the New Ireland project mean for smallholders (8.8 t/ha versus 6.2 t/ha). The declining yield in block S4518 despite improved block practices is a classic example of how crop diversion to another block can affect data quality. If crop shifting was not practiced, it is anticipated that the yields would be at reasonable level by this time.

E.4.2. SSR303: Assessing Leaf and Soil Nutrient Status in Smallholders, New Ireland Project

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

E.4.2.1. *Summary*

Smallholder leaf sampling was conducted in 39 smallholder blocks in New Ireland to determine foliar nutritional status of oil palm in smallholder blocks. The results revealed low N (2.31%) and K (0.39) in the leaflets. Rachis K was also low (0.52%). Leaflet P (0.144%) was slightly below the adequacy mark. The other essential elements (Mg, Ca and B) were adequately available in the leaflets of the oil palm. The low levels of N and K could be a result of smallholder growers' unwillingness to accept fertilizer. This needs further investigation.

E.4.2.2. *Introduction*

There are three important diagnostic tools to determine palms health status. They are; (i) visible symptoms of nutrient deficiency or excess; (ii) plant (leaf) analysis, and (iii) soil analysis (Asher *et al*, 2002). Leaf analysis was developed primarily to provide information on the nutrient status of the oil palms as a guide to nutrient management (fertiliser management tool) for optimal oil palm growth and production. Leaf analysis is also used to protect the environment from over-fertiliser application (Asher *et al*, 2001). For smallholders, there is a need to come up with site specific recommendations for fertilizer application. Hence in 2016, first leaf sampling exercise was conducted in smallholders in New Ireland.

E.4.2.3. *Materials and Methods*

Thirty-nine (39) blocks were randomly selected from the three divisions (North, South and West). The selected blocks were within the prime age group. Blocks with immature and over-aged palms were not selected. In each block, both leaflet and rachis samples were taken from marked palms. The sampling points (palms) were identified using sampling intensity of 5x5 and 5x3 depending on the size of the block. A 5x5 sampling intensity would mean that every 5th palm in every 5th row is sampled.

The samples are then brought back to the office for processing. After processing, they are oven-dried at 70°C, ground, packed and dispatched to Hill Laboratory in New Zealand for analysis.

E.4.2.4. *Results and Discussion*

Table 78 shows the analysed leaf data for the sampled blocks with the published optimum levels from Fairhurst (1997). Leaf nitrogen (N) was low in North and West Divisions, while South Division was within the optimum range. Despite that, leaflet N for the project (2.32%) was generally below the optimum level of 2.45%. Leaf P was low in North and West divisions while it was above optimum level in South division. Leaf K was deficient in all 3 divisions. Rachis which acts as the sink for K was also K deficient (0.52%). Leaflet Mg and Ca levels were excessively high. This is expected for soils in New Ireland where high Ca in these soils has resulted in low K (antagonistic effect). Leaf B (16.1ppm) was well above the level of adequacy (15.0 ppm). Generally, leaf N, P, K and rachis K were low. In contrast Mg, Ca and B were in abundance in the leaf.

The individual block nutrient levels are depicted in Figure 89 to Figure 94.

Table 78 Summary of leaflet and rachis nutrient concentrations at the Divisional Level

Division	Leaf N%	Leaf P%	Leaf K%	Leaf Mg%	Leaf Ca%	Leaf B ppm	Rachis K%
North	2.15	0.136	0.37	0.40	1.10	15.7	0.54
South	2.46	0.157	0.39	0.41	1.24	16.1	0.38
West	2.32	0.141	0.42	0.40	1.00	17.1	0.63
Project Mean	***2.31***	***0.144***	***0.39***	***0.40***	***1.11***	***16.1***	***0.52***
Optimum level (Fairhurst, 1997)	**2.45**	**0.145**	**0.65**	**0.20**	**0.50**	**15.0**	**1.2**

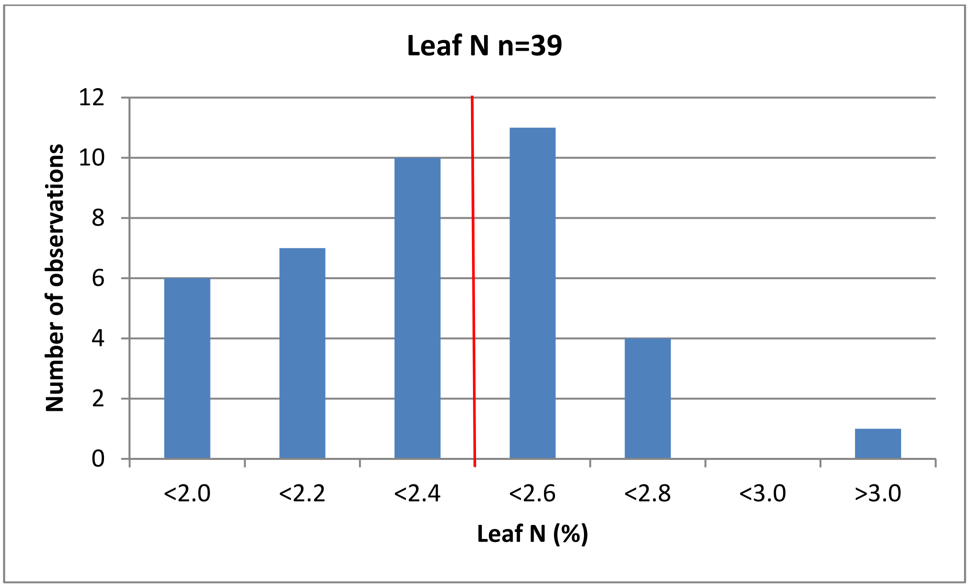

Figure 89 Leaflet N concentration for all sampled blocks in New Ireland

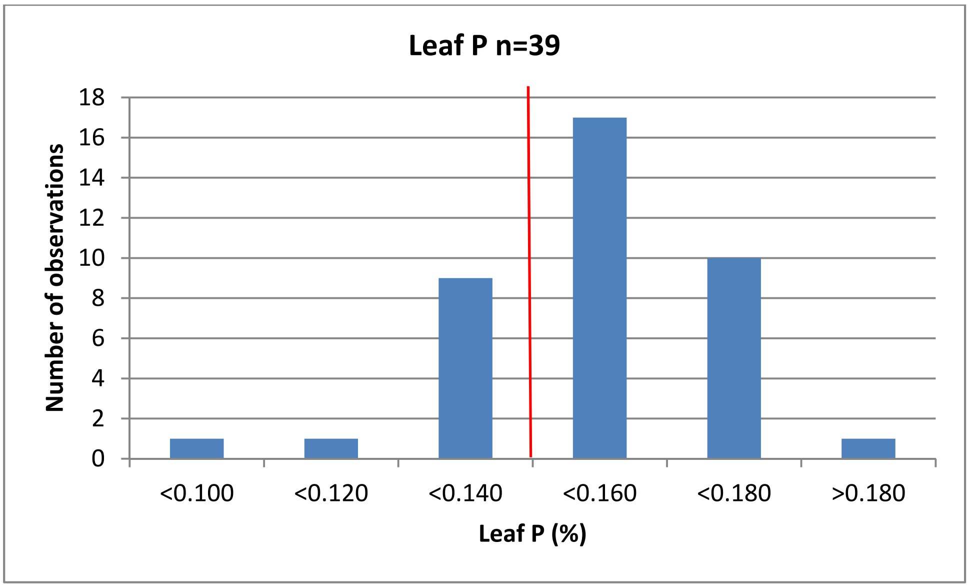

Figure 90 Leaflet P concentration for all sampled blocks in New Ireland

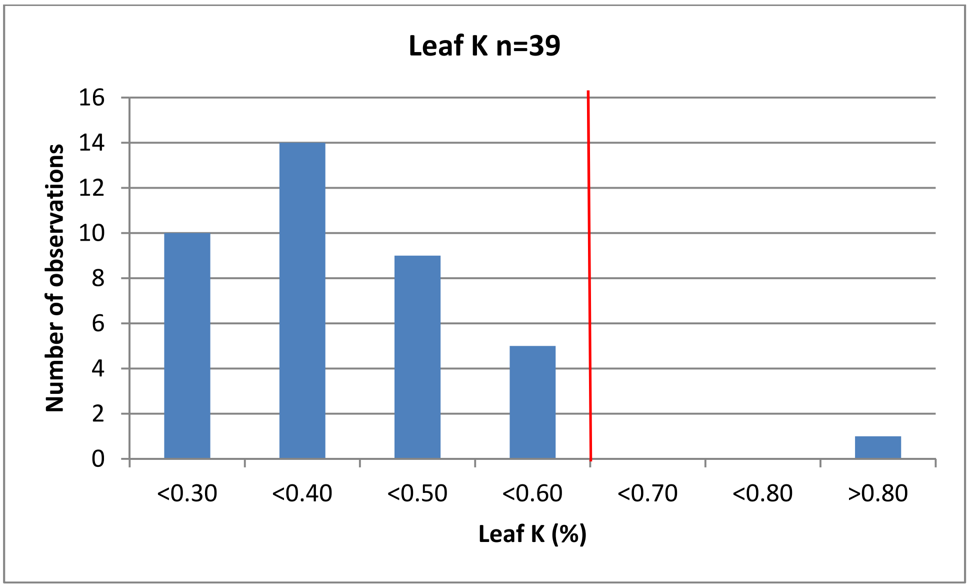

Figure 91 Leaflet K concentration for all sampled blocks in New Ireland

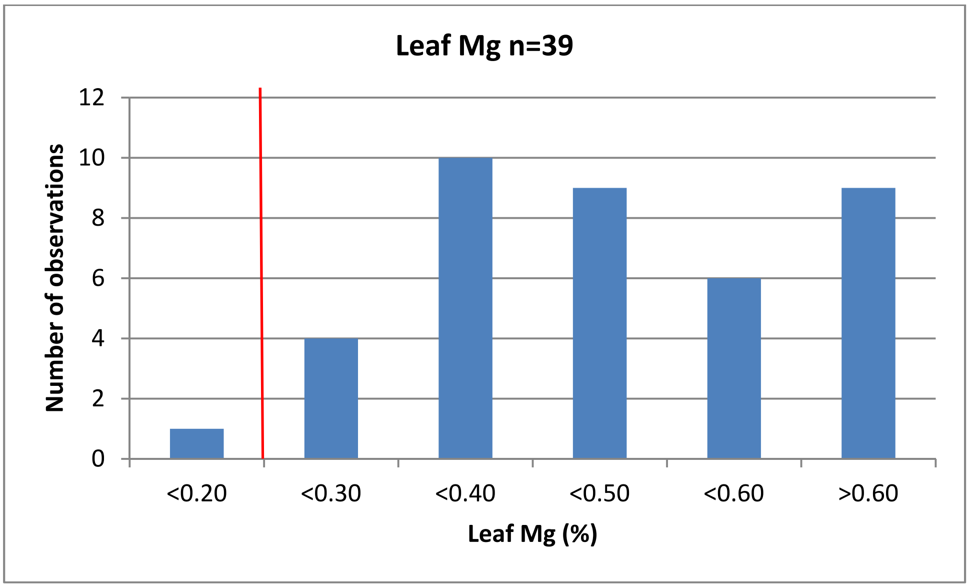

Figure 92 Leaflet Mg concentration for all sampling blocks in New Ireland

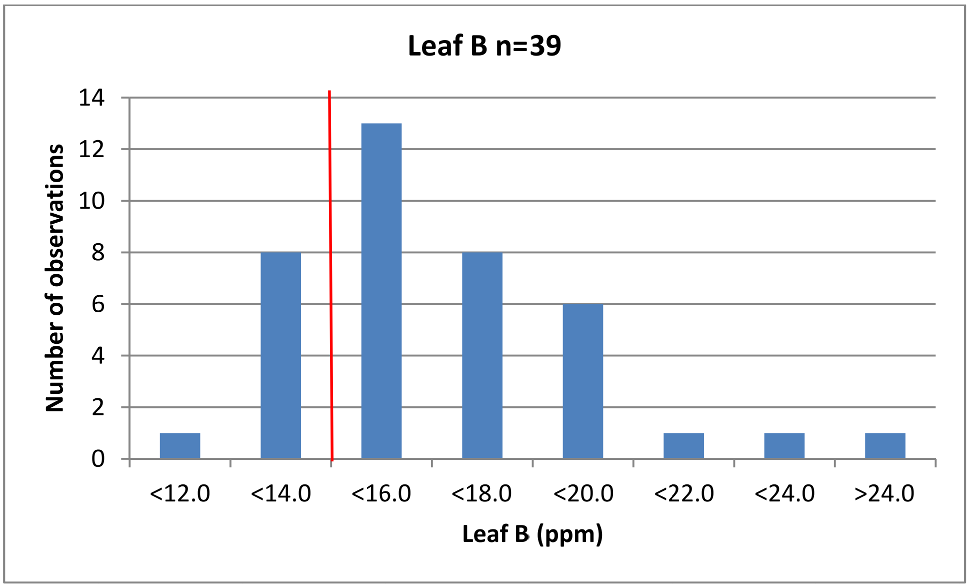

Figure 93 Leaflet B concentration for all sampling blocks in New Ireland

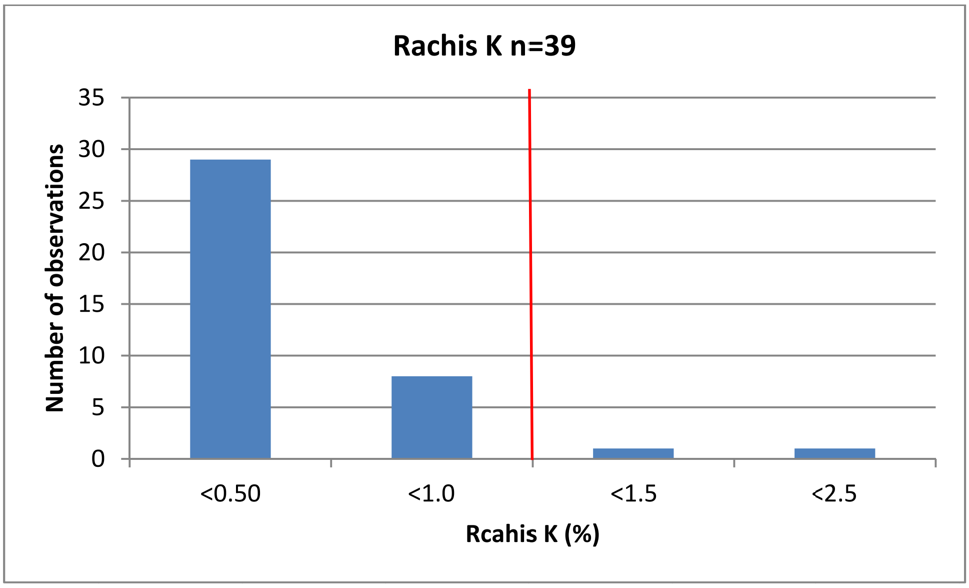

Figure 94 Rachis K concentration for all sampled blocks in New Ireland

E.4.2.5. *Conclusion*

The results revealed more than 90 % of the blocks sampled had N, P and K deficiency in both the leaflets and the rachis. The other essential elements (Mg, Ca and B) were adequately available in the leaflets of the oil palm. K deficiency is caused by high Ca in soils of New Ireland. The low levels of N and K could be a result of smallholder growers' prolonged negligence to either nitrogen and potassium fertilisers or not applying adequate amounts to sustain the growth and production of the palm. Leaf sampling will continue as an annual activity and as we collate more data we can confidently advise Poliamba Ltd and OPIC on the nutrient status of smallholder blocks and whether there is a need to review and amend the fertiliser recommendations.

E.5. New Britain Palm Oil Popondetta

Steven Nake, Merolyn Koia and Richard Dikrey

E.5.1. SSR402: Demonstration of best management practices in smallholder blocks, Popondetta

RSPO 4.2, 4.3, 5.1, 6.1, 8.1

E.5.1.1. *Summary*

The Popondetta Project has 5 blocks established to demonstrate importance of adopting best management practices. Oil Palm Best Management Practices such as proper pruning standards, blocks upkeep/sanitation, cleaned paths and circles, frequent harvesting and fertiliser application are demonstrated in these blocks. After 3 year duration of the project, the only dedicated and committed BMP block has shown consistent yield increase since 2015. In 2016, this block produced 24.6 t/ha, a reasonable high yield, and this is evidence of huge yield potential in smallholders in Popondetta. Irregular harvesting, crop shifting and prolonged absence of fertiliser application are found to be common in other blocks with reduced yields in 2016. The mean yield from the BMP blocks was 13.0 t/ha while that of the overall smallholders in Popondetta was 10.7 t/ha. There is obviously room for improvement to improve the current yields.

E.5.1.2. *Introduction*

The smallholder sector in Popondetta makes up 60 % of the total area planted with oil palm but produces less than 50% of the total crop with average yields of 13t/ha. PNGOPRA fertiliser trials in plantations across the country prove yields of 30 – 35 t/ha are achievable. The smallholder sector holds the key to a substantial untapped potential in production hence the benefits of increased yields from the smallholder blocks can be substantial and are very important for the oil palm industry. Setting up demonstration plots and experiments in smallholder blocks is one important way of contributing to increasing both production and productivity.

The objective of this project is to convert run-down blocks with low yields into well-managed high yield blocks and demonstrate to smallholder growers the oil palm best management practices can contribute to better yields.

E.5.1.3. *Materials and Methods*

Block selection and establishment

Block visits were carried out with OPIC officers to identify poorly managed blocks with obvious symptoms of nitrogen (N) deficiency (oven canopy, small bunches, small fronds, yellowing of leaves, die back of leaflets or fronds). When identified, the production history (last 5 years) is then used to calculate the average block productivity and blocks with low yields are selected.

Table 79 List of BMP blocks established in Sorovi&Ilimo Division

No	Block	Trial code	Area	Scheme	Division	Year of initiation
1	800158	SSR402	Urio	VOP	Sorovi	2015
2	850009	SSR402	Huvivi	VOP	Sorovi	2015
3	690042	SSR402	Ajeka	VOP	Ilimo	2015
4	680096	SSR402	Kanadara	VOP	Ilimo	2015
5	050400	SSR402	Sangara Top	VOP	Sorovi	2016

Fertiliser Application

In 2016, Urea was applied to all the blocks at the rate of 1.5 kg per palm per year. Three (3) large empty tinned fish (425 grams ~ 0.425 litres) of urea was applied per palm. Demonstration of fertilizer application was done before BMP growers did the application.

Harvesting

Frequent harvesting is part of BMP and there is zero tolerance on skipped harvesting. All blocks are expected to do over 20 harvests in a year.

Data collection

Monthly production data from the TSD - SH database are summed up for the entire year and converted into tonnes per hectare (t/ha).

E.5.1.4. ***Results and Discussion***

A new block was established in 2016, whereas the other 4 were all initiated in 2015. Their yields for the last 3 years (2014-2016) are shown in Table 80. Of the 5 blocks set up in 2015, block 800158 continued to elevate its yield in 2016, by 8.2 t/ha (33.3 % increase) from 16.4 t/ha in 2015 to 24.6 t/ha in 2016. The steady yield increase since its inception in 2015 is a classic example of a block adopting all necessary block management practices on their block.

For blocks 850009, 690042 and 680096, yields continued to decline due to irregular harvesting. Additionally, these blocks have not been applying fertiliser for the last 5 years. Though block upkeep has improved, the palms need fertiliser for vegetative growth and production and flowers and subsequent development of bunches. Due to high debt owed to Higaturu Oil Palms by the smallholders, fertiliser issue was put on hold for 3-4 years and this has contributed to the declining trend. This is evident in the declining overall smallholder yields in the project (Table 80). Labour shortage was also identified as another factor resulting in irregular harvesting. For example, block 690042, the owner is old-aged and harvesting is done by the sons irregularly. Block 050400 was set up in 2016 hence it is too early to say whether the current yields are a result of BMP implemented on the block.

Table 80.Annual Production (t/ha) BMP blocks from 2014 to 2016

	Yields (t/ha)		
Block	**2014**	**2015**	**2016**
800158	15.2	16.4	24.6
850009	12.8	8.5	6.1
690042	16.4	14.2	13.0
680096	11.9	6.5	2.5
050400			18.9
Smallholder Popondetta	***14.7***	***14.5***	***10.7***

E.5.1.5. ***Conclusion***

There is potential to increase smallholder yields beyond the current actual yields, as observed from block 800158 at Urio which produced 24.6 t/ha in 2016. However, high yields can only be achievable is the block is managed well at BMP standard; fertiliser is applied every year and block is harvested regularly.

E.5.2. SSR403: Assessing Leaf and Soil Nutrient Status in Smallholders, Popondetta Project

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

E.5.2.1. *Summary*

Total of 87 smallholder blocks were sampled to determine their nutritional status. Laboratory analysis revealed that essential elements (N, P, K) were in low levels within the leaves. Similarly, rachis K was also below the optimum level of 1.20%. Even though the leaf nitrogen was low, it was stillwithin 2%. Smallholder blocks in Lilimo and Saihio divisions had the lowest K levels because of the soil type and mineral composition of the soils. The soils there have high Mg and Ca which affects K uptake by the palm. Leaf Mg was in abundance. Prolonged absence of fertiliser application in most smallholder blocks in Popondetta could have contributed to the low levels of some of these nutrients.

E.5.2.2. *Introduction*

There are three important diagnostic tools to determine palms health status. They are; (i) visible symptoms of nutrient deficiency or excess; (ii) plant (leaf) analysis, and (iii) soil analysis (Asher *et al*, 2002). Leaf analysis was developed primarily to provide information on the nutrient status of the oil palms as a guide to nutrient management (fertiliser management tool) for optimal oil palm growth and production. Leaf analysis is also used to protect the environment from over-fertiliser application (Asher *et al*, 2001). For smallholders, there is a need to come up with site specific recommendations for fertilizer application hence the objective of the project was to conduct leaf sampling in Popondetta to specifically determine foliar nutrient levels of oil palm in smallholders.

E.5.2.3. *Materials and Methods*

Eighty-seven (87) blocks were randomly selected from the 5 divisions (Sorovi, Igora, Aeka, Saihio and Ilimo). The selected blocks were within the prime age group. Blocks with immature and over-aged palms were not selected. In each block, both leaflet and rachis samples were taken from marked palms. The sampling points (palms) were identified using sampling intensity of 5x5 depending on the size of the block. A 5x5 sampling intensity would mean that every 5^{th} palm in every 5^{th} row is sampled.

The samples are then brought back to the office for processing. After processing, they are oven-dried at 70°C, ground, packed and dispatched to Hill Laboratory in New Zealand for analysis.

E.5.2.4. *Results and Discussion*

The actual leaf levels against the optimum levels (Fairhurst, 1999) is shown in Table 81. Leaf N and P were both deficient for all divisions. Leaf K for Igora, Aeka, Saiho and Ilimo were deficient. Leaf Mg for blocks at Sorovi were low (0.13%) whereas the other 4 divisions were adequate. Rachis K at Sorovi division is above the optimum level, whereas the others were deficient. Ilimo and Saiho blocks were well below the optimum level (Table 81). Generally for Popondetta smallholder blocks, leaf Mg seemed to be the only nutrient adequately available. All other essential elements deficient (below adequate level).

The individual block nutrient concentrations are depicted in Figure 95 to Figure 99. Leaf N ranged from <1.8 % to >2.4%. Leaf P levels were between between <0.110 % and >0.150%. Leaf K level ranged from <0.45% to >0.75 %. The lowest levels of K were found in the blocks at Saiho and Ilimo area. Leaf Mg ranged from <0.15% to >0.35 % and varied very much between the divisions. Leaf Mg was recorded high in Aeka, Saiho and Ilimo areas. Rachis K ranged from <1.0% to >2.0% and found to be low in Illimo and Saiho areas. Low K levels in Ilimo area is caused by high Mg and Ca in the alluvial soils there, which impedes K uptake by the oil palm in this area hence K deficiency.

Table 81 Summary of leaflet and rachis nutrient concentrations at the Divisional Level

Division	**LN%**	**LP%**	**LK%**	**LMg%**	**RK%**
Sorovi	2.10	0.133	0.61	0.13	1.38
Igora	2.11	0.123	0.56	0.20	1.09
Aeka	2.10	0.125	0.54	0.26	1.06
Saihio	2.13	0.123	0.55	0.24	0.80
Ilimo	2.08	0.128	0.48	0.23	0.60
Project Mean	***2.10***	***0.126***	***0.55***	***0.21***	***0.99***
Optimum level (Fairhurst, 1997)	**2.45**	**0.145**	**0.65**	**0.20**	**1.20**

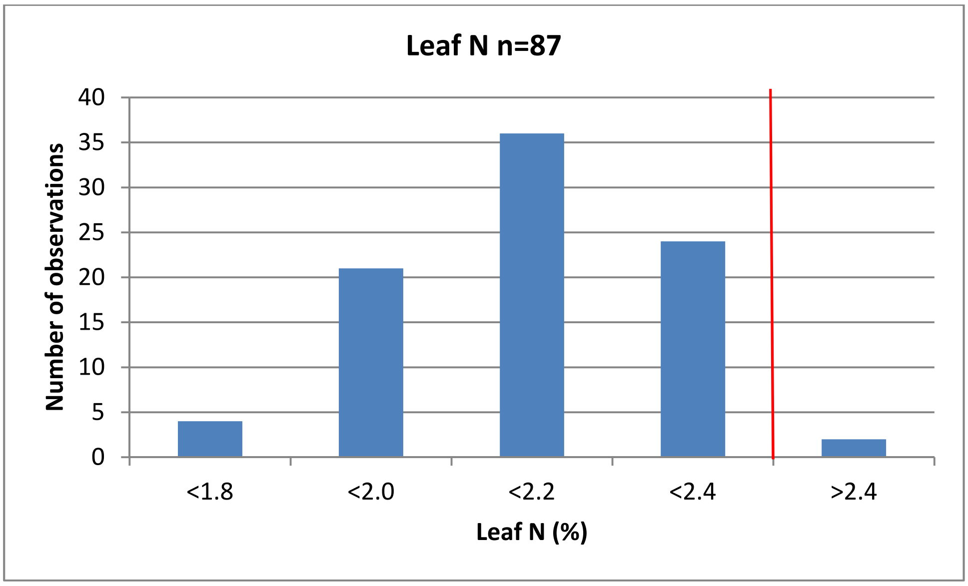

Figure 95 Leaf N concentration for all sampled blocks in Popondetta

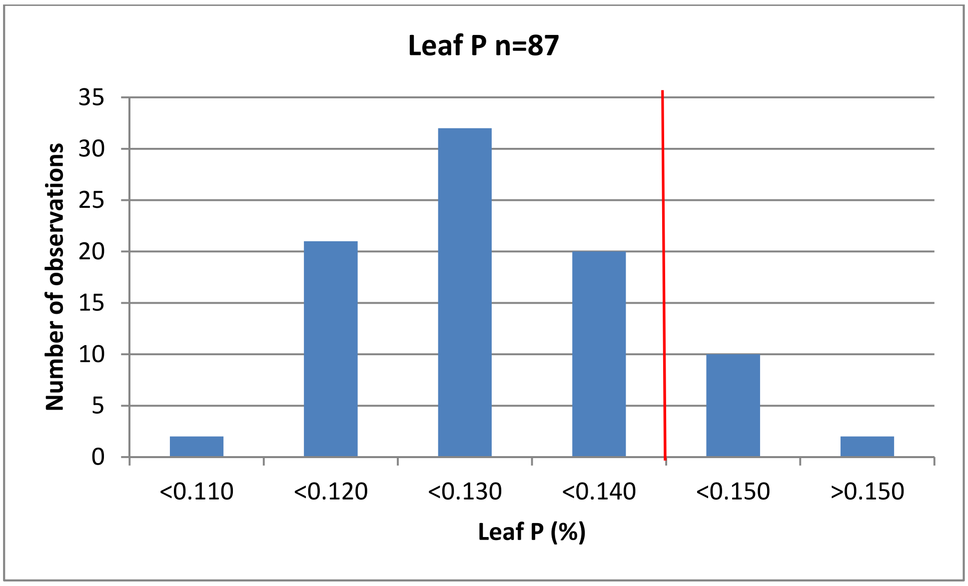

Figure 96 Leaf P concentrations for all sampled blocks in Popondetta

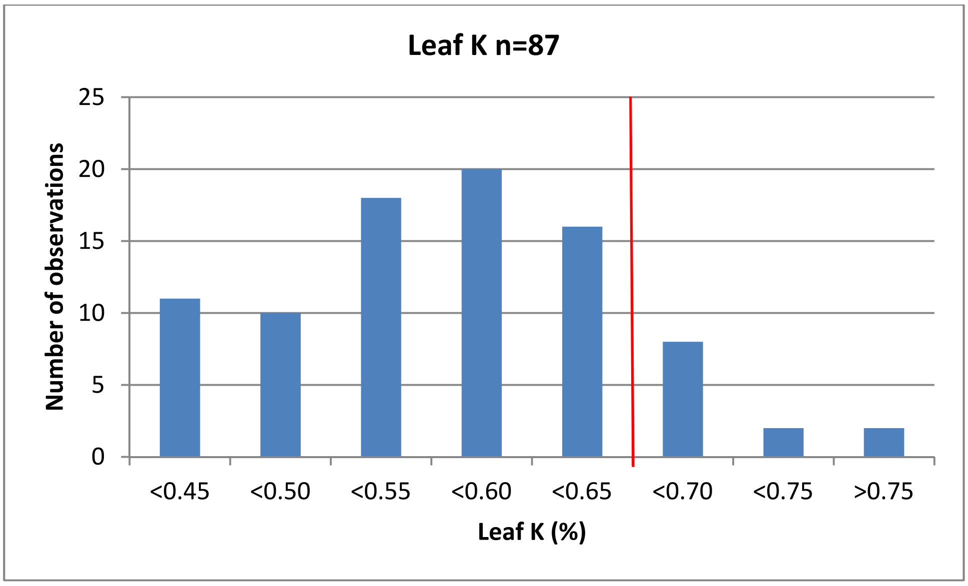

Figure 97 Leaf K concentrations for all sampled blocks in Popondetta

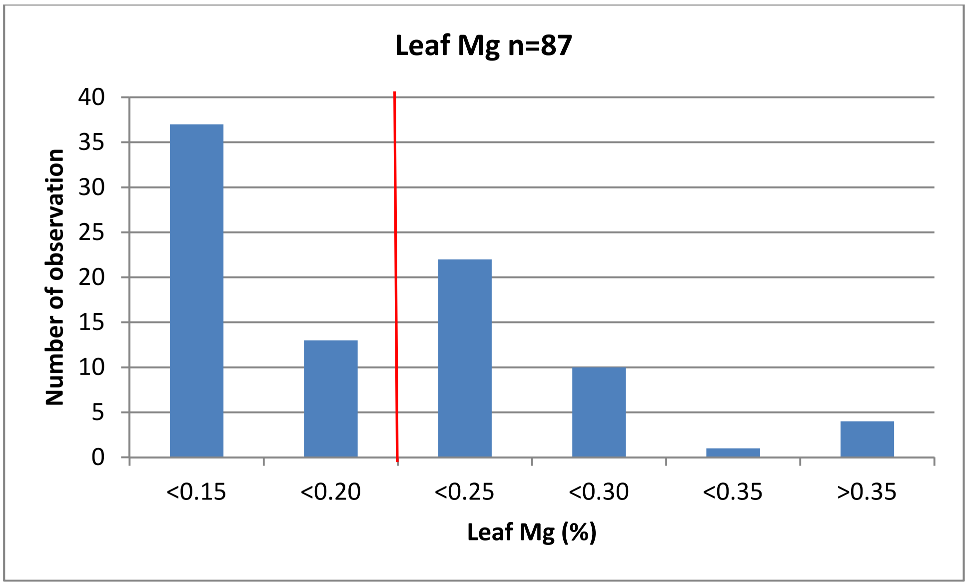

Figure 98 Leaf Mg concentration for all sampled blocks in Popondetta

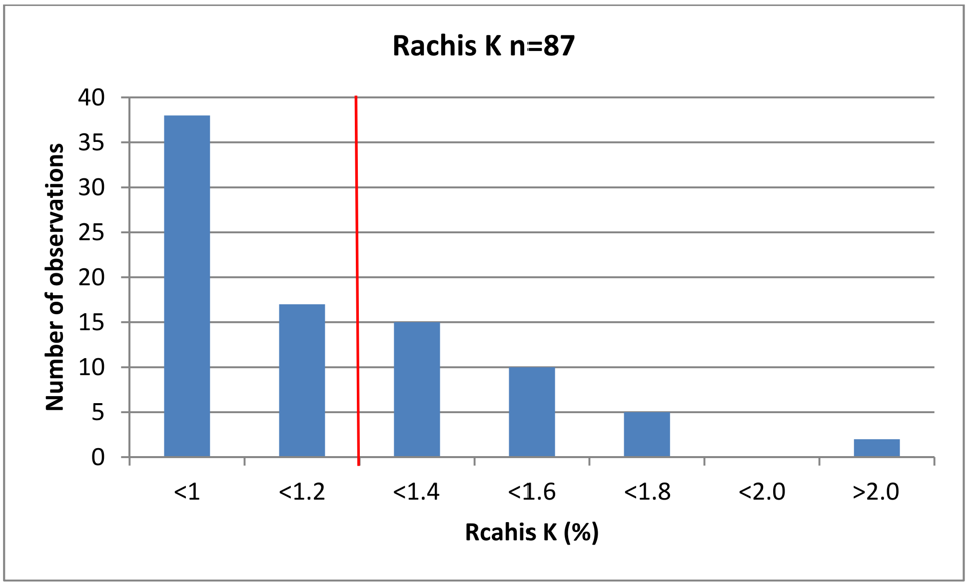

Figure 99 Rachis K concentrations for all sampled blocks in Popondetta

E.5.2.5. *Conclusion*

Leaf N levels were low by still within 2%. Leaf P and K were both deficient. Rachis K is a good indicator for K and has fallen below the optimum level as well. Smallholder blocks in Lilimo and Saihio divisions had the lowest K levels because of the soil type and mineral composition of the soils. The soils there have high Mg and Ca which affects K uptake by the palm.

Leaf sampling will continue in 2017 and the results will be plotted with time to see if the declining trend continues and to what degree. This information will assist in making management decisions as to whether there is a need to review the current smallholder fertiliser recommendations.

E.6. New Britain Palm Oil Milne Bay Estates

Steven Nake and Wawada Kanama

E.6.1. SSR501ab: Demonstration of best management practices in smallholder blocks, Milne Bay Project

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

E.6.1.1. *Summary*

The 2016 mean yields for the two BMP blocks were 4.7 t/ha lower than 2015 yield (10.5 t/ha vs. 15.2 t/ha).The response to BMP in terms of yield was affected by harvesting rounds. Both blocks have incidences of no crop recorded for 3-4 months.

E.6.1.2. *Introduction*

The smallholder sector in Milne Bay makes up 15 % of the total area planted with oil palm with yields as low as 10 t/ha. PNGOPRA fertiliser trials in plantations across the country prove yields of 30 – 35 t/ha are achievable. The smallholder sector holds the key to a substantial untapped potential in production hence the benefits of increased yields from the smallholder blocks can be substantial and are very important for the oil palm industry. Setting up demonstration plots and experiments in smallholder blocks is one important way of contributing to increasing both production and productivity.

The objective of this project is to convert run-down blocks with low yields into well-managed high yield blocks and demonstrate to smallholder growers the oil palm best management practices can contribute to better yields.

E.6.1.3. *Materials and Methods*

Block selection and establishment

There 2 BMP blocks in Milne Bay were initially established as fertiliser demonstration blocks in 2008 and later converted into BMP blocks starting 2012 to demonstrate to growers oil palm best management practices.

Table 82 SSR501ab, Block information

No	Block	Trial code	Area	Scheme	Year of initiation
1	09017	SSR501a	Figo	VOP	2009
2	19002	SSR501b	Waema	VOP	2009

E.6.1.4. *Results and Discussion*

The long term yield (t/ha) for both BMP blocks are shown in Figure 100. Block 09017suffered a huge yield loss of 10.7 t/ha in 2016 while yield from block 19022 was elevated by 1.2 t/ha to 12.1 t/ha. There was no consistent yield trend in both blocks due to lack of attention given to the project. Generally the yields have been declining since 2012. The first 4 years (2009-2012), both blocks exhibited increasing yield. During this term, the BMP blocks managed well, at the same time both blocks received fertiliser each year with PNGOPRA paying for it. After 2012, when PNGOPRA Management decided not to continue paying for the fertiliser, both blocks skipped fertiliser for 4 years (2013-2015).

The BMP block yield was higher than the overall smallholder yields in Milne Bay Project from 2014 to 2016 (Table 83). In fact the BMP yields could have been better than the actual yields obtained in 2014-2016, but that was not achieved. However, the results proved that if more time, effort and resources are put into the blocks by the smallholders, yields can be pushed beyond the current yields.

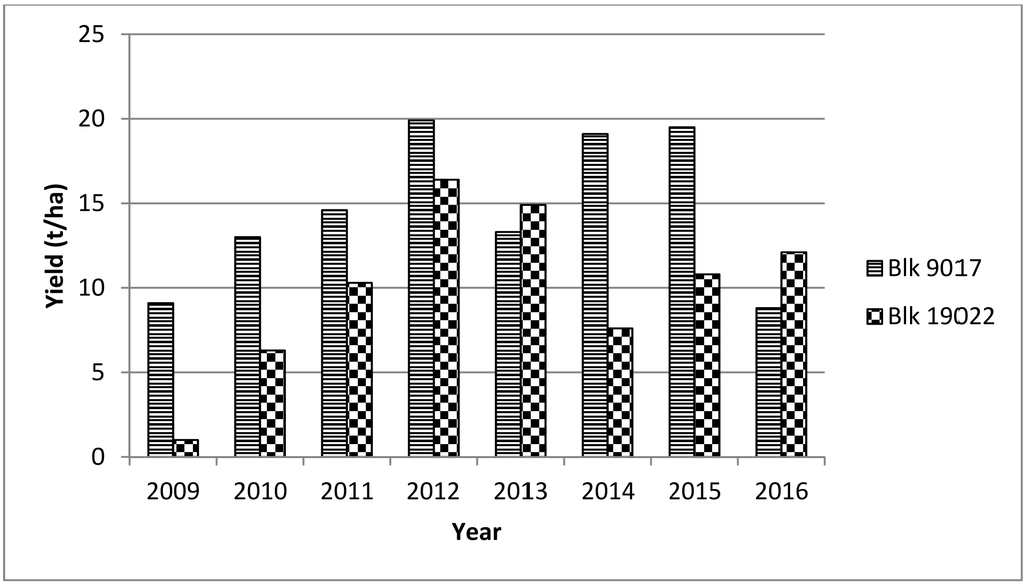

Figure 100 SSR501ab, Yields from 2009 to 2015 for blocks 09017 and 19002.

Table 83 Smallholder versus BMP block yields between 2014 and 2016.

Year	Milne Bay Smallholders	BMP Block
2014	8.9	13.4
2015	9.9	15.2
2016	8.6	10.5

E.6.1.5. *Conclusion*

Block 9017 suffered yield loss of 10 t/ha while block 19022 had its yield elevated by 1.3 t/ha to 12.1 t/ha. The increase and decline in yield experienced by both blocks relate closely to the application of BMP on the blocks. The BMP yields however were higher than the overall smallholder yields in Milne Bay. This stresses the importance of BMP on smallholder blocks.

E.6.2. SSR502: Assessing Leaf and Soil Nutrient Status in Smallholders, Milne Bay Project

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

E.6.2.1. *Summary*

Total of 75 smallholder blocks were sampled in Milne Bay to determine their nutritional status. Leaf N, P, K, B and rachis K deficient. Mean values of leaf N, P, K, B and rachis N were 2.19%, 0.136%, 0.41%, 13.9% and 1.04 % respectively.were in low levels within the leaves. Similarly, rachis K was also below the optimum level of 1.20%. In contrast leaf Mg was above the optimum level of 0.20%.Muriate of potash (MOP) must be supplied to smallholders to alleviate the K deficiency issue.

E.6.2.2. *Introduction*

There are three important diagnostic tools to determine palms health status. They are; (i) visible symptoms of nutrient deficiency or excess; (ii) plant (leaf) analysis, and (iii) soil analysis (Asher *et al*, 2002). Leaf analysis was developed primarily to provide information on the nutrient status of the oil palms as a guide to nutrient management (fertiliser management tool) for optimal oil palm growth and production. Leaf analysis is also used to protect the environment from over-fertiliser application (Asher *et al*, 2001). For smallholders, there is a need to come up with site specific recommendations for fertilizer application hence the objective of the project was to conduct leaf sampling in Popondetta to specifically determine foliar nutrient levels of oil palm in smallholders.

E.6.2.3. *Materials and Methods*

Seventy-five (75) blocks were randomly selected from the two divisions (Gurney and Sagarai) in Milne Bay. The selected blocks were within the prime age group. Blocks with immature and over-aged palms were not selected. In each block, both leaflet and rachis samples were taken from marked palms. The sampling points (palms) were identified using sampling intensity of 5x5 depending on the size of the block. A 5x5 sampling intensity would mean that every 5th palm in every 5th row is sampled.

The samples are then brought back to the office for processing. After processing, they are oven-dried at 70^{o}C, ground, packed and dispatched to Hill Laboratory in New Zealand for analysis.

E.6.2.4. *Results and Discussion*

The foliar nutrient concentrations are presented in Figure 101 to Figure 105. Seventy-one blocks (94.6%) were deficient of N, whereas 76 blocks had N levels between <2.2% to <2.4%. Leaf N in both divisions ranged from <2.0% to >2.6% with a mean of 2.19% (Figure 101, Table 84). Similarly, leaf P and K were low in both divisions. Leaf P ranged from 0.113% to 0.155% with 0.136% as the mean. Leaf K ranged from 0.26% to 0.81% with a mean of 0.41%. Only two blocks (3% of total sampled blocks) had K levels above the optimum mark, bulk of the sampled blocks (97%) were K deficient. Only 23 blocks (31% of sampled blocks) fall above the optimum level for B. The remaining 52 blocks were low in leaf B. Rachis K was above optimum level at Sagarai but low in Gurney. Rachis K ranged from 0.27% to 2.34% with a mean of 1.04% which is below the level of adequacy (Figure 105). Potassium (K) deficiency is widespread in the Milne Bay due to the presence of 2:1 clay minerals (smectite and vermiculite) which locks up K ions and impairs uptake. This might be one of the reason why the K levels in both the leaf and rachis were quite low. N is also low because of non-application of N fertilizer in most of the blocks.

Mg levels were in abundance, ranging from <0.25% to >0.60%. Leaf Mg in all block sampled (100%) were above the optimum level (0.20%). This is because the alluvial clay soils of Milne Bay are reasonably high in Mg and Ca ions, resulting in low K levels.

Table 84 Foliar nutrient concentration in smallholder blocks at Gurney and Sagarai divisions

Division	**LN%**	**LP%**	**LK%**	**LMg%**	**LB (ppm)**	**RK (%)**
Gurney	2.21	0.134	0.39	0.46	14.5	0.86
Sagarai	2.17	0.137	0.43	0.43	13.2	1.22
Project Mean	***2.19***	***0.136***	***0.41***	***0.45***	***13.9***	***1.04***
Optimum level (Fairhurst, 1997)	**2.45**	**0.145**	**0.65**	**0.20**	**15.0**	**1.20**

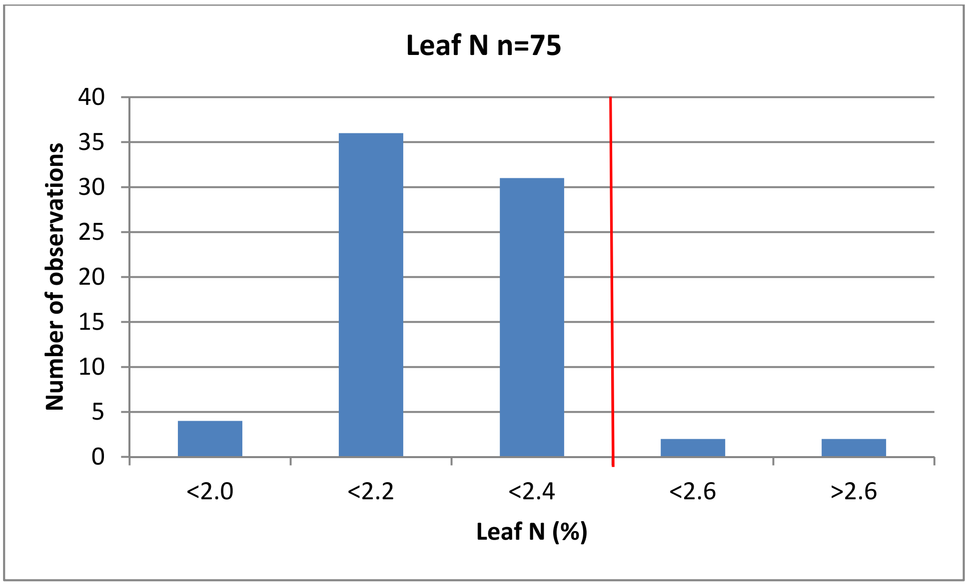

Figure 101 Leaf N concentration for all sampled blocks in Milne Bay

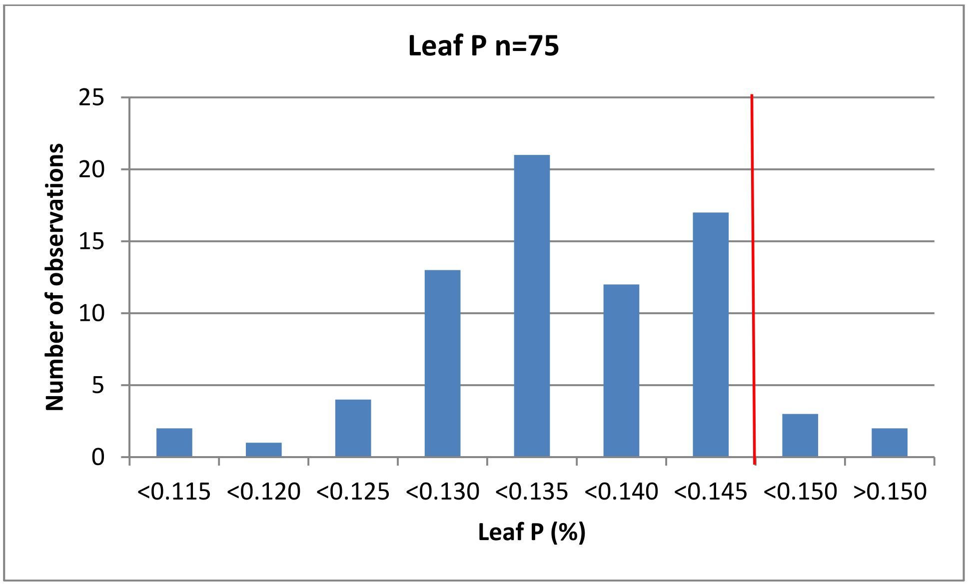

Figure 102 Leaf P concentrations for all sampled blocks in Milne Bay

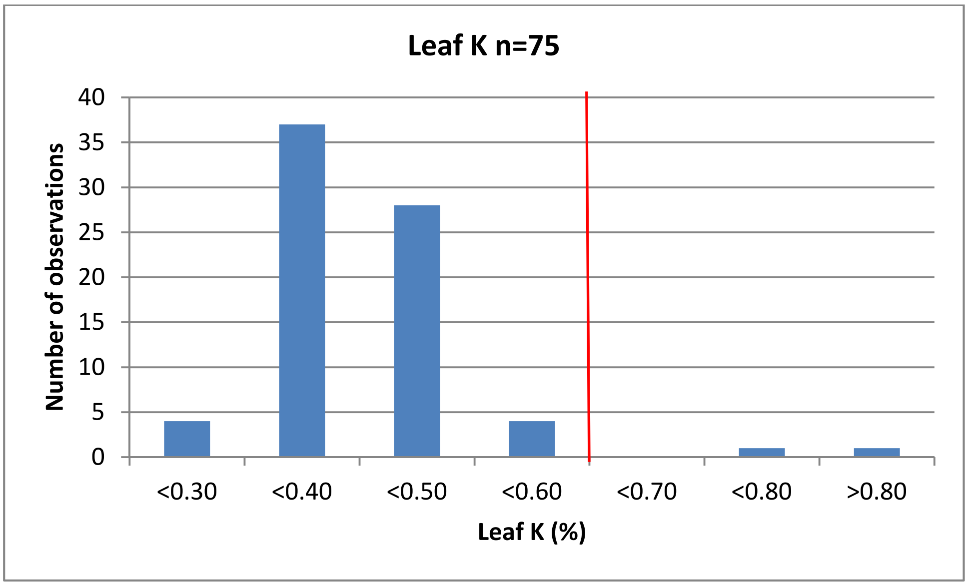

Figure 103 Leaf K concentrations for all sampled blocks in Milne Bay

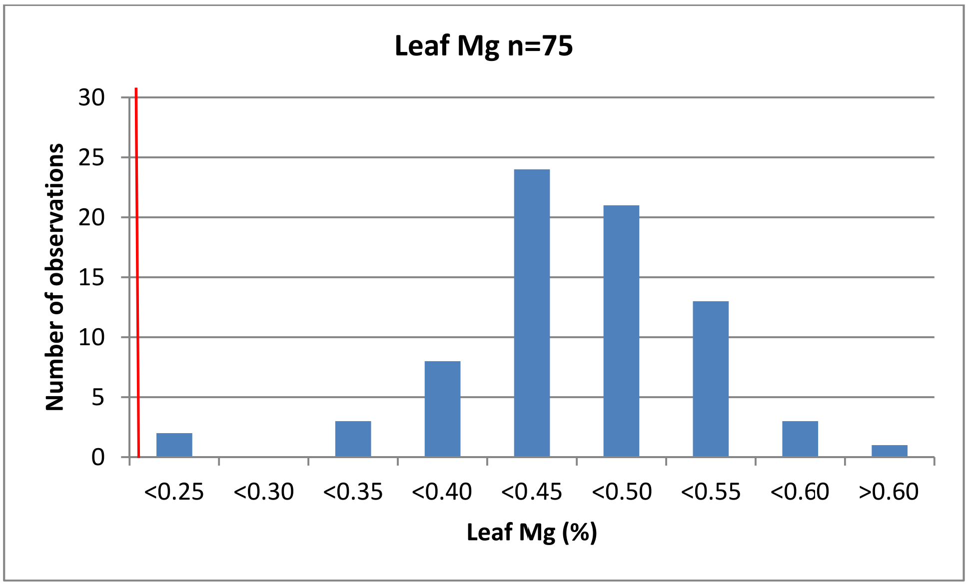

Figure 104 Leaf Mg concentration for all sampled blocks in Milne Bay

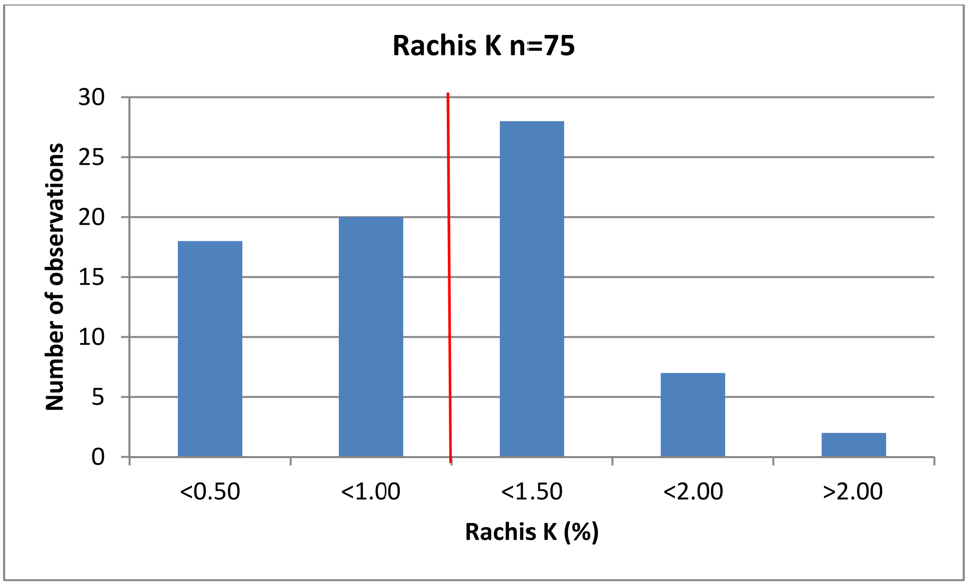

Figure 105 Rachis K concentrations for all sampled blocks in Milne Bay

E.6.2.5. *Conclusion*

All the elements (N, P, K, B), except Mg were found to be deficient and in low quantities in both the leaf and the rachis. Mean values of leaf N, P, K, B and rachis N were 2.19%, 0.136%, 0.41%, 13.9% and 1.04 % respectively. Leaf Mg was in abundance in the leaf, in levels twice more than the optimum level of 0.21%. Low K and high Mg in the leaf and rachis is common in Milne Bay where the soils there contain low K and high Mg/Ca levels. Potassium must be recommended to all smallholders in Milne Bay.

E.7. Technical services

Extension services in terms of trainings and radio broadcast in 2016 are presented in Table 85. While all project sites staged grower trainings in 2016, none was conducted in Popondetta. In Hoskins, 24 field days were conducted out of the 24 proposed for the project, a 100% achievement. Stakeholder involvement has improved considerably with officers from respective OPIC divisions, NBPOL smallholder affairs department, NBPOL Sustainability department and PNG Oil Palm Research Association. Each were allocated a station and allowed 30 minutes of presentation on pressing issues related to smallholder growers. Part from the regular presenters, invitations were also given out Plant Breeding section of OPRS (NBPOL), Transport department of NBPOL, Provincial Health Authority (PHA), Financial Institutions and Police.At the end of the field day, lucky draw prizes are awarded to participants and sponsored by PNGOPRA, OPIC and Sustainability department of NBPOL. Actual presentations, both oral and display have improved significantly overtime. As a result of these improvements, the number of growers attending field days has increased in 2016 to an average of 100 participants.

Total of 50 block demonstrations were also conducted in 2016 in Hoskins project (Table 85). Unlike field days, small group of growers are targeted per session and actual practical demonstrations on common practices like fertilizer application, pruning, cover crop planting, frond boxing and proper harvesting standards are shown to the farmers. This is mode of educating smallholder growers is much effective than the field day presentations.

In 2017, the section intends to work in partnership with stakeholders/institutions in other project sites to stage more grower field trainings.

Table 85 Smallholder trainings and radio extension programs conducted in 2016

	Activities			
Project Sites	**Field days**	**Block Demos**	**Radio Broadcasts**	**Other trainings**
Hoskins (Dami)	24	50	2	1
Bialla	5	6	0	0
Popondetta	0	0	0	0
New Ireland	3	3	3	5
Milne Bay	3	0	0	0

F. ROUND TABLE FOR SUSTAINABLE OIL PALM RSPO

RSPO Principles are regularly updated and those are available on Web Site:

http://www.rspo.org/certification/national-interpretations#

Please go to the website above and download the national interpretation for Papua New Guinea.
The last accessed date was 10/07/2017.