Annual Research Report

2018

PNG Oil Palm Research Association Inc.
Dami Research Station, P.O. Box 97, Kimbe, West New Britain Province 621, Papua New Guinea
Tel +675 7999 9494 • enquiries@pngopra.com

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Dami Research Station, P.O. Box 97, Kimbe, West New Britain Province, Papua New Guinea
Telephone +675 79999493

A. REPORT BY THE DIRECTOR OF RESEARCH

Director of Research, Dr Luc Bonneau

August 2019

A.1. CONTEXT

The 2018 crop budget presented for the nucleus estates was higher than 2017 with +8.5% for NBPOL and +10% at HOPL. However it was lowered for the smallholders in NBPOL resulting in aoverall - 5%. But, 2018 has seen some good yields in comparison to 2017 certainly due to the after effect of El Nino of 2017, despite the wet weather. As such the NBPOL Estates exceeded their forecast (+4.8%) while HOPL was 1.5% lower and Smallholder on budget. Nonetheless the industry produced 7.3% more crop year on year (Table 1). 2018 was the best year for the nucleus estates in the last decade while it was below average for the smallholders.

Table 1 FFB production (MT) by the oil palm industry donors to PNGOPRA between 2011 and 2018*

Year	Milling companies	Small holders + Outgrowers	Total	Versus 2011	Versus 2012	Versus 2013	Versus 2014	Versus 2015	Versus 2016	Versus 2017
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%	n/a	
2017	1,973,180	794,041	2,767,221	102%	107%	119%	105%	106%	110%	n/a
2018	2,185,823	785,880	2,971,703	109%	115%	127%	113%	114%	119%	107%

The industry, in comparison to the previous year saw lower CPO price declining throughout the year with a low near 500 USD/T in december highest at 750USD/T in January 2018, unfortunately at the time of writing the price has flattened just around 500USD/T (Figure 1).

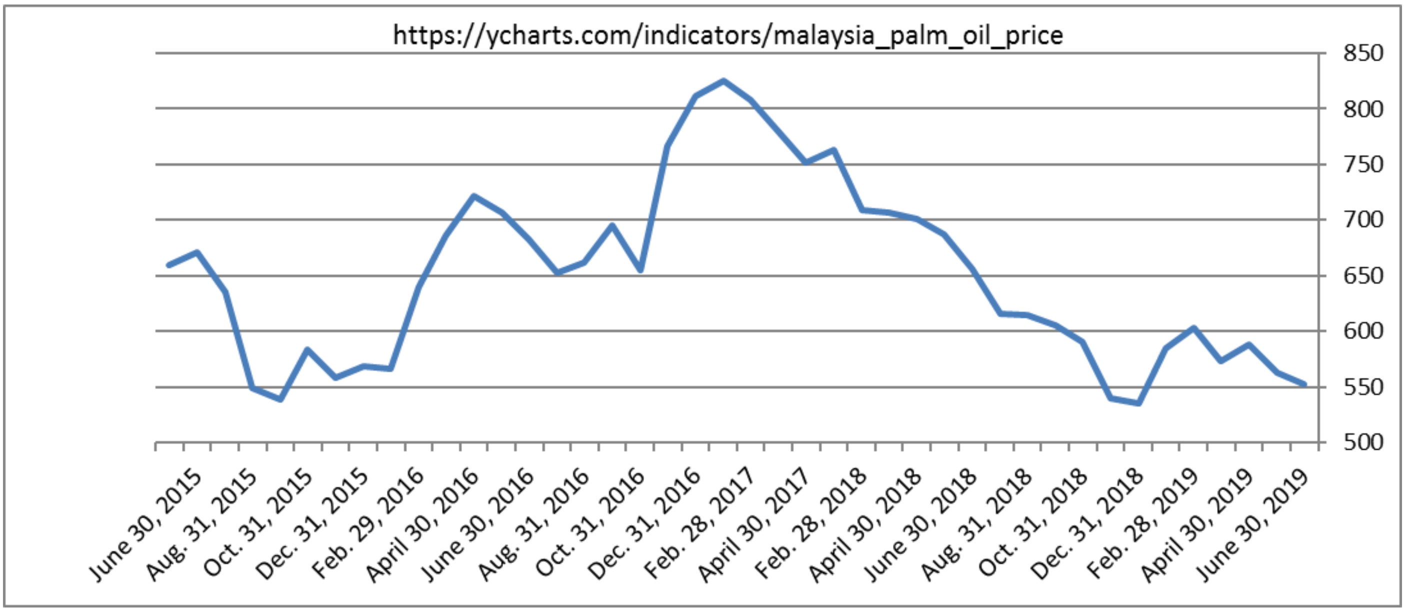

Figure 1 CPO Price from Jan 2017 to May 2018

As for PNGOPRA revenue from FFB was in line with budget but control was enforced throughout the year. Nonetheless, PNGOPRA remained cash positive and has not engaged in large capital investment. On that note the Director of Research thank the Section heads for their understanding when restriction were enforced during 2018 but also the milling company in being flexible with our debts which allow us to retain sufficient free cash throughout the year.

NBPOL Group, had also changed financial calendar in 2016 from calendar to July to June, rendering the budgeting exercise un-timed with the other PNGOPRA Members. As hoped last year, the decision has been reversed for the 2019 financial year following the demerger (PurePlay) exercise of the Sime Darby Bhd, into three distinct entities one of which (Sime Darby Plantation Berhad) focusing on upstream and downstream oil palm operations. At time of writing this has been effected and all associate members are now tuned

Following the production level achieved in 2018 in comparison to 2017 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. Hoqwever, in April 2019, the chairman resigned and Mr Jamie Graham was elected for three year in 2019. Mr Graham king further resigned from the board and Ian Winstanley was appointed non executive Director and representing HOPL interests.

Table 2 FFB production in 2018 and voting right in 2019 per OPRA associate members

MEMBER	*FFB Produced in 2018*		**VOTES Number**	**%**
New Britain Palm Oil Limited	*1,837,442*	*61.8%*	**17**	58.6%
Smallholders (OPIC)	*785,880*	*26.4%*	**8**	27.6%
Hargy Oil Palms Pty Ltd	*348,381*	*11.7%*	**3**	10.3%
Director of Research[1]	*n/a*		**1**	3.4%
TOTAL	*2,971,703*		**29**	100

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

In 2018 the hectares planted have increased by 4,317 ha in comparison to 2017 (Table 3) mainly due to the acquisition of Markham farm as the other project have stagnated. Despite the replant continuing, NBPOL WNB has retain a moderate area (9%) as immature hectares because of a young age profile due to last decade extensions. HOP has seen further decline of its 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 reduced immature from one third to a fifth of its area immature due to replant activities only. As for Bialla, the hectares planted remained equal and the immature proportion has greatly diminished by about 1,673ha as Bialla has not extended this year. Over all the industry has reduced its immature by 2,642ha for a total of 10% of its area, signaling a decline in growth and maturity of the business of PNGOPRA associate members.

Table 3 Planted mature area (ha) in December 2018

Project Area	Plantation	Smallholder+	Outgrowers	Total
Hoskins (*NBPOL, Mosa*)	**35,487**	**25,199**	540	**61,226**
Popondetta (*NBPOL, Kula Group*)	10,066	**10,911**	-	20,977
Milne Bay (*NBPOL, Kula Group*)	9,849	1,116	-	10,965
New Ireland (*NPOL, Kula Group*)	4,639	2,703	-	7,342
Ramu (NBPOL, *RAIL*)	**12,924**	-	577	13,501
Markham Farm Limited	**0**			
Bialla (*Hargy Oil Palms*)	**12,334**	**12,387**		24,721
TOTAL	85,299	52,316	1,117	138,732

Table 4 Planted immature area (ha) in December 2018

Project Area	Plantation	Smallholder+		Total
Hoskins (*NBPOL, Mosa*)	**3,524**	**3,051**		6,575
Popondetta (*NBPOL, Kula Group*)	515			515
Milne Bay (*NBPOL, Kula Group*)	906	444		1,350
New Ireland (*NPOL, Kula Group*)	851	112		963
Ramu (NBPOL, *RAIL*)	1,186		67	1,253
Markham Farm Limited	**4,368**			
Bialla (*Hargy Oil Palms*)	**1,353**	**1,005**		2,358
TOTAL	12,703	4,612	67	17,382

Nonetheless, the total hectares planted by the OPRA members at the end of 2018 reached 156,114 ha with 4,317 additional hectares planted in 2018 by the nucleus mainly due the acquisition of Markham Farm as biggest contributor and minus 592 Ha (mostly in Bialla) in the smallholders which is mainly due to remapping. NBPOL West New Britain remains the biggest site and NBPOL Poliamba the smallest (Table 5). RAIL and POL were the only site seeing a marginal reduction of their surfaces.

Table 5 Total planted area (ha) in December 2018

Project Area	Plantation	Smallholder+		Total
Hoskins (*NBPOL, Mosa*)	**39,011**	**28,250**	540	**67,801**
Popondetta (*NBPOL, Kula Group*)	10,581	**10,911**		21,492
Milne Bay (*NBPOL, Kula Group*)	10,755	1,560		12,315
New Ireland (*NPOL, Kula Group*)	5,490	2,815		8,305
Ramu (NBPOL, *RAIL*)	**14,110**		644	14,754
Bialla (*Hargy Oil Palms*)	**13,687**	**13,392**	**0**	**27,079**
TOTAL	98,002	56,928	1,184	156,114

It is noted that NBPOL POL has the highest proportion of its estate as immature with 15.5% of the total area planted (Table 6) while still NBPOL HOP has the lowest with just above 4.9% of immature. Overall the immature hectares have continued to reduce which signal a shift from the last 4 decade trend that our members as a whole struggle to find new area to continue extension. Only RAIL and HOP are investigating new perimeters in grasslands to expend their operation significantly. Markham farm has been reported as immature although the palms are ready to produce but FFb are not milled due to lack of mill.

Table 6 Proportion of immature palms in December 2017

Project Area	Plantation	Smallholder+		Total
Hoskins (*NBPOL, Mosa*)	**9.0%**	**10.8%**	0.0%	**9.7%**
Popondetta (*NBPOL, Kula Group*)	4.9%	0.0%		2.4%
Milne Bay (*NBPOL, Kula Group*)	8.4%	**28.5%**		11.0%
New Ireland (*NPOL, Kula Group*)	**15.5%**	4.0%		11.6%
Ramu (NBPOL, *RAIL*)	8.4%		10.4%	8.5%
Markham Farm Limited	100.0%			100.0%
Bialla (*Hargy Oil Palms*)	9.9%	7.5%		8.7%
TOTAL	13.0%	8.1%	5.7%	11.1%

Furthermore, in PNG Overall, Dami Seeds reports increase sales to 1.4 million (-7%) seeds sold to non-PNGOPRA members, cumulating 13.9million seeds sold to outsiders since 2000, equating to 69,500 Ha+ worth of planting material. While all new outsider projects have not materialized some have built and are building mills (Table 7 List of operation palm oil mill in Papua New Guinea).

Table 7 List of operation palm oil mill in Papua New Guinea

	Mill	*Site*	*Province*
1	Kapiura Oil Mill	NBPOL WNB	WNB
2	Kumbango Oil Mill [1]	NBPOL WNB	WNB
3	Mosa Oil Mill [1]	NBPOL WNB	WNB
4	Numundo Oil Mill	NBPOL WNB	WNB
5	Waraston Oil Mill	NBPOL WNB	WNB
6	Berema Oil Mill [1]	SIPEF HOPL	WNB
7	Hargy Oil Mill	SIPEF HOPL	WNB
8	Navo Oil Mill	SIPEF HOPL	WNB
9	Gusap Oil Mill	NBPOL RAIL	MP
10	Mamba Oil Mill	NBPOL HOP	ORO
11	Sangara Oil Mill	NBPOL HOP	ORO
12	Sumberipa Oil Mill	NBPOL HOP	ORO
13	Hagita Oil Mill	NBPOL MBE	MBE
14	Poliamba Oil Mill	NBPOL POL	NIR
15	Liguria Oil Mill [2]	Tzen Plantation PNG Limited	ENB
16	Narangit Oil Mill [2]	Tzen Plantation PNG Limited	ENB
17	Mamusi Oil Mill [2]	Memalo Holding (Rimbunan Hijau)	ENB
18	Imbio Oil Mill [2]	Bewani	SANDAUN

[1] *are equipped with CDM*
[2] *are not milling FFB of PNGOPRA member companies*

4 mills were operating from those new projects by the end of 2018, while others are under construction elsewhere. Those additional projects are 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

[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.

encouraged between the two sides of the industry. POPA seems to be the appropriate forum to hold those dicussions.

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 2018 was higher (+22%) than the previous year. The total spending in 2018 cumulated at K6.61 million due to the new extraordinary project on CRB.

The share of the external grants has increase to 18% in 2018 budget due to the CRB-G project financed by the nucleus estates. the Member's levy was maintained at K2/tonne of FFB for all growers and was applicable on first January 2018 and has not changed since but was proposed and endorsed by LPC members to raisie to 2.2PGK/Tonne. 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. Sadly, Sir Brown Bai has passed away in February 2019.

A.2. MAN POWER

In 2018 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 2 and Figure 3. The executive succession plan needs has been addressed for Plant Pathology and Agronomy. However, the succession plan is slow and difficult 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. The financial situation of PNGOPRA is forecasted to be at stress by year end 2019 if levy is not increased in 2020.

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 changed to 37% female (-1%), 63% male (+1%).

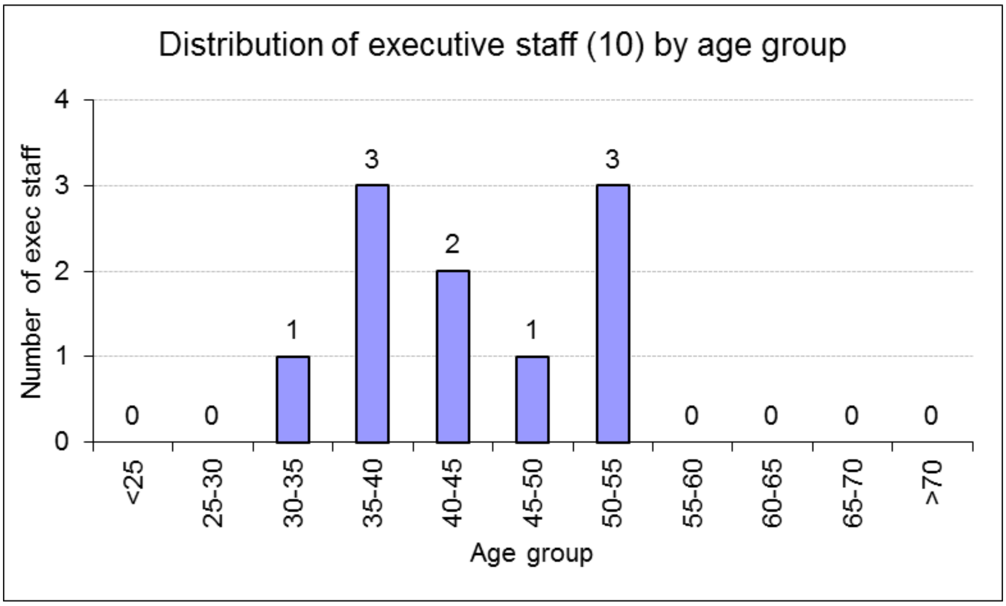

Figure 2 Distribution of the 10 executive staff employed by PNGOPRA per age group

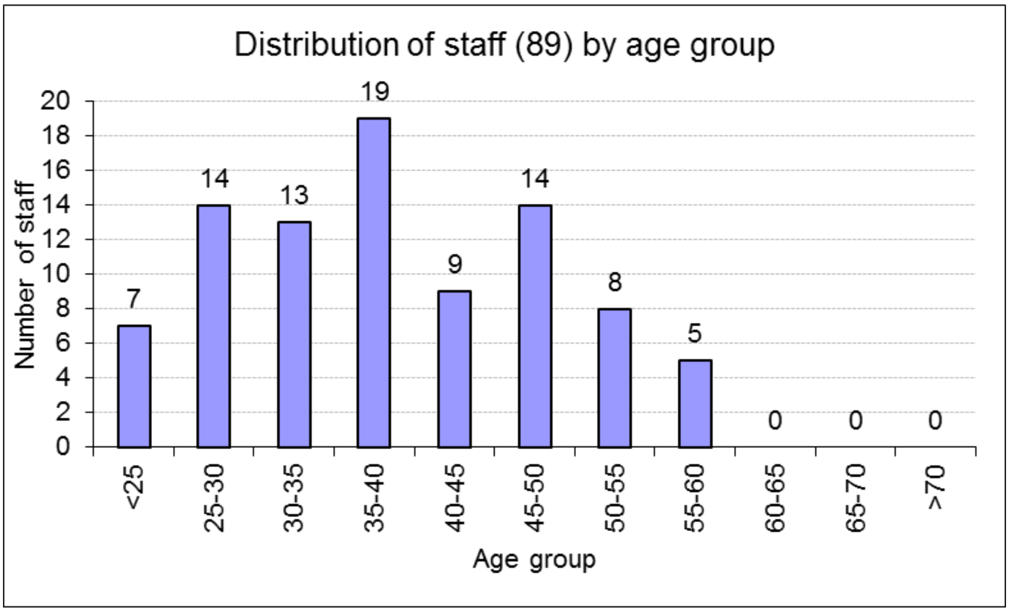

Figure 3 Distribution of the 89 non-executive staff employed by PNGOPRA per age group

- Emmanuel has completed his MPhil degree and has been offered an Executive position as Socioeconomist in HOP.

- In 2018, 2 PNGOPRA workforces were still registered as students, Eva Tokilala and Sharon Agovaua are doing there Master of Philosophy in Plant Pathology and Entomology respectively with Unitech in Lae, PNG.

- In 2018, Dr Carmel Pilotti retired on the 31/12/2019 but was retain as a consultant to the group, until the new Head of Plant Pathology, Dr Emad Jaber (yet to be inducted) feels confident in his job budgeted until June 2020.

A.3. RESEARCH IN 2018

In 2018 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, all new trials have been planted and the first ones are already yielding. 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 second round is already in nurseries.

- The Entomology section denote the CRB-G as 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 2019 with a New Project initiated in January 2018. Meanwhile it is expected that CRB-G will continue its progression in PNG along the south coast of the mainland but it has been slower than anticipated. Note that it has already been reported to be of considerable 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 was organized and at time of writing most of our cultures have been restored with some new programmed to be established in Bialla and NI.

- 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 that regard, the initiative on one hectare replant has been delivering exceptional result of productivity and food security

- 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. But the price of palm oil, hence the farm gate price of FFB plummeted toward the end of 2018 and remains low until the time of writing in July 2019; this has impaired considerably the capacity of the smallholder to purchase the smallholders to purchase fertiliser and other inputs.

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, new trials have been designed for future recommendations. Two new fertiliser trials were planted in 2015 in NBPOL-WNB, and one each at RAIL, HOP, MBE, GPPOL, HOPL and HOP in 2017. Similar progenies were planted into nursery at POL in 2017 and planted into the field in 2018. 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 155 and 160 at Bebere Plantation in 2017 and preliminary measurements done in other trials across different sites in 2018.

Across all sites, there was continued involvement with the industry in training. PNGOPRA was involved in training the plantations on leaf and soil 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 2018, Mr. Joel Ben, a new Assistant Agronomist was recruited at Dami. Thomas Maiap Assistant Agronomist remained at Dami and Mr. Stanley Yane, Assistant Agronomist remained at RAIL. All supervisors remained at respective sites (Peter Mupa and Andy Ullian at Bialla, John Wange at Dami, Andy Samuel at Popondetta, Jethro Woske and Wawada Kanama at Milne Bay and Jaydita Puwe at GPPOL).

B.1.1. 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 effect 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 8.

Table 8 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
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

1. NEW BRITAIN PALM OIL - DAMI

Thomas Maiap, Joel Ben and John Wange

B.1.2. Trial 154: Nitrogen fertiliser response trial on super clonal materials at Bebere Plantation

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.2.1. *Summary*

Full yield potential of selected new clonal materials released into the industry are required to be established. This trial was established with different fertilizer levels imposed on established planted clonal materials. Fertilisers and progenies have significant effects on yield and leaf tissue nutrient contents while physiological growth parameters differed significantly between the progenies. This trial is recommended to continue.

B.1.2.2. *Introduction*

The plantation industry is currently planting new selected clonal materials and this will continue into the future. 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 for the progenies to reach their full yield potential provided nutrition is non-limiting. The information gained from this trial will be used for assisting fertilizer recommendations in WNB. Trial information is presented in Table 9.

Table 9 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	2014	**Topography**	Flat
Age after planting	5 years	**Altitude**	
Recording Start	2016	**Previous Land-use**	Oil palm 3rd generation
Treatment start	2016	**Area under trial soil type (ha)**	
Progeny	Known*	**Assistant Agronomists in charge**	Thomas Maiap and Joel Ben
Planting material	Dami D x P		

B.1.2.3. *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 clone 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 3 levels of fertilizer levels initially however another level was added in 2017. The additional level was labeled as level 1 and received the standard fertilizer rates recommended for the age of palms in the plantations while the other 3 were high rates at increasing amounts (Table 10). The treatments were allocated to each of the 4 progenies and were duplicated except for Progeny T120 at Fert level-1 which was not duplicated because of insufficient progeny numbers. This resulted in 31 plots. The plantation applied the recommended fertilizer rates and PNGOPRA applied the difference to top it up to the treatment rates.

Table 10 Trial 154 Treatment fertilizer levels in 2018

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 samples 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.1.2.4. *Results*

Yield and yield components

Fertiliser levels affected FFB yields only while progenies significantly affected FFB yield and yield components in 2018 and 2016-2018 (Table 11). Fertiliser levels increased FFB yield from 22.9 t/ha to 26.3 t/ha in 2018 (Table 12). A similar trend in yield increase is seen for 2016-2018. FFB yield in progeny T038 was greater than the other three progenies by 3-6 t/ha and this was due mostly to high bunch numbers and single bunch weights.

Table 11 Trial 154 effects (*p values*) of treatments and progenies on FFB yield and its components in 2018 and 2016-2018

Source	2018			2016-2018		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Fert levels	**0.019**	0.402	0.250	**0.005**	0.067	0.072
Progenies	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
Fert x Progeny	0.237	0.472	0.365	0.463	0.536	0.709
CV %	9.6	7.2	4..6	8.4	7.4	6.5

Table 12 Trial 154 main effects of N rate treatments on FFB yield, bunch number and single bunch weight in 2018 and 2016-2018

Treatments	2018			2016-2018		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Fert level - 1	**22.9**	2839	8.2	**17.0**	2670	6.3
Fert level - 2	**26.4**	3035	8.8	**19.6**	2935	6.6
Fert level - 3	**27.0**	3063	8.9	**20.0**	2944	6.7
Fert level - 4	**26.3**	2957	9.0	**20.1**	2907	6.9
l.s.d$_{0.05}$	*2.64*	*296.5*	*0.90*	*1.72*		
Prog - T038	**29.8**	**3195**	**9.3**	**22.6**	**3217**	**7.1**
Prog - T118	**26.3**	**3259**	**8.0**	**18.3**	**2850**	**6.2**
Prog - T120	**22.7**	**3044**	**7.5**	**15.9**	**2606**	**5.9**
Prog - T123	**23.9**	**2396**	**10.1**	**19.9**	**2783**	**7.4**
l.s.d$_{0.05}$	*2.64*	*296.5*	*0.90*	*1.72*	*227.9*	*0.47*
GM	25.7	2973	8.7	19.2	2864	6.6
SE	2.47	276.5	0.84	1.60	212.6	0.43
CV %	9.6	9.3	9.6	8.4	7.4	6.5

Leaflets and rachis nutrient contents

Effects of fertilizer levels and progenies on leaflet and rachis nutrient contents for 2018 are presented in Table 13 and Table 14 respectively. Fertiliser levels affected leaflet Mg, Cl and B contents while in the rachis, Mg and P contents were affected. The different progenies expressed significant differences in their leaf tissue nutrient contents except for leaflet Cl and rachis N, K and Ca contents. The fertilizer levels increased leaflet Cl and B contents but lowered Mg content (Table 15). In the rachis, only Mg content was increased (Table 16). The leaflet N, K, Ca, B and S were higher in progenies T038 and T123 than in the other two progenies.

Table 13 Trial 154 effects (*p values*) of fertilizer levels and progenies on leaflet nutrient contents in 2018

Source	Leaflets nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fert levels	0.131	0.963	0.820	0.905	**0.018**	0.171	**0.003**	**0.001**	0.940
Progenies	**0.047**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**0.001**	0.935	**0.014**	**p<0.001**
Fert x Progeny	0.101	0.702	0.249	0.541	0.112	0.799	0.627	0.468	0.433
CV %	3.0	1.2	2.8	4.6	4.5	5.7	11.6	6.8	3.6

Table 14 Trial 154 effects (*p values*) of fertilizer levels and progenies on rachis nutrient contents in 2018

Source	Ash	N	P	K	Mg	Ca
Fert levels	0.276	0.200	0.170	0.060	**0.042**	0.964
Progenies	0.115	0.059	**0.010**	0.071	**0.011**	0.338
Fert x Progeny	0.708	0.927	0.771	0.822	0.893	0.902
CV %	9.2	7.5	17.7	12.6	11.2	11.6

Table 15 Trial 154 effects of fertilizer levels and progenies on leaflet nutrient contents in 2018

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fert level - 1	12.4	2.61	0.152	0.72	**0.27**	0.95	**0.48**	**13**	0.18
Fert level - 2	12.2	2.61	0.151	0.73	**0.27**	0.93	**0.56**	**15**	0.18
Fert level - 3	12.7	2.62	0.151	0.73	**0.26**	1.00	**0.58**	**16**	0.18
Fert level - 4	12.6	2.62	0.150	0.73	**0.25**	0.97	**0.63**	**15**	0.18
***l.s.d*$_{0.05}$**					*0.013*		*0.070*	*1.09*	
Prog - T038	**12.4**	**2.71**	**0.155**	**0.78**	**0.23**	**1.03**	0.57	**16**	**0.19**
Prog - T118	**12.8**	**2.46**	**0.147**	**0.70**	**0.29**	**0.95**	0.56	**15**	**0.17**
Prog - T120	**12.3**	**2.51**	**0.146**	**0.70**	**0.31**	**0.89**	0.55	**14**	**0.18**
Prog - T123	**12.2**	**2.78**	**0.157**	**0.74**	**0.22**	**0.98**	0.57	**15**	**0.19**
***l.s.d*$_{0.05}$**	*0.404*	*0.059*	*0.0046*	*0.036*	*0.013*	*0.059*	*0.070*	*1.09*	*0.007*
GM	12.4	2.61	0.151	0.73	0.26	0.96	0.56	15	0.18
SE	0.377	0.055	0.0043	0.033	0.012	0.055	0.066	1.02	0.007
CV %	3.0	2.1	2.8	4.6	4.5	5.7	11.6	6.8	3.9

Table 16 Trial 154 effects of fertilizer levels and progenies on rachis nutrient contents in 2018

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Fert level - 1	4.6	0.309	0.069	1.37	0.081	0.52
Fert level - 2	5.0	0.329	0.080	1.61	0.095	0.53
Fert level - 3	5.0	0.325	0.073	1.59	0.090	0.52
Fert level - 4	5.0	0.336	0.084	1.63	0.086	0.53
***l.s.d*$_{0.05}$**					*0.0094*	
Prog - T038	4.7	0.331	**0.067**	1.47	**0.083**	0.55
Prog - T118	4.6	0.306	**0.084**	1.50	**0.081**	0.51
Prog - T120	5.0	0.342	**0.089**	1.52	**0.094**	0.53
Prog - T123	5.2	0.320	**0.067**	1.73	**0.095**	0.51
***l.s.d*$_{0.05}$**			*0.0146*		*0.0094*	
GM	4.9	0.325	0.077	1.55	0.088	0.53
SE	0.472	0.0243	0.0136	0.195	0.0088	0.049
CV %	9.7	7.5	17.7	12.6	10	9.3

Physiological growth measurements

Results of vegetative measurements done in 2018 are presented here.

The effect of progenies on vegetative growth parameters were significant ($p<0.001$) for all the parameters measured in 2018 (Table 17). Fertiliser levels only affected frond production rate in 2018.

Progenies T118 and T120 have greater values than the other 2 progenies and were consistent with time for petiole cross section (PCS), frond weight, frond area and LAI (Table 18).

Table 17 Trial 154 effects (*p values*) fertilizers and progenies on physiological growth parameters in 2018

Source	PCS	Frond weight	Frond length	Total frond count	Frond production rate	Frond area	LAI
Fert levels	0.968	0.968	0.086	0.869	**0.020**	0.265	0.112
Progenies	**p<0.001**	**p<0.001**	**p<0.001**	**0.001**	**p<0.001**	**p<0.001**	**p<0.001**
Fert x Progeny	0.995	0.995	0.354	0.327	0.301	0.126	**0.037**
CV %	4.7	2.7	1.8	3.1	2.2	4.2	4.4

Table 18 Trial 154 effects fertilizers and progenies on physiological growth parameters in 2018

Treatments	PCS	Frond weight	Frond length	Total frond count	Frond production rate	Frond area	LAI
	(cm2)	(kg)	(m)		(no./year)	(m2)	
Fert level - 1	32.7	0.59	536	47.0	**26.3**	10.7	6.0
Fert level - 2	32.8	0.60	529	46.4	**27.2**	10.2	5.7
Fert level - 3	32.9	0.60	523	46.6	**27.0**	10.5	5.9
Fert level - 4	33.1	0.60	527	46.7	**27.4**	10.4	5.8
l.s.d$_{0.05}$					*0.640*		
Prog - T038	**24.2**	**0.51**	**552**	**44.9**	**28.2**	**9.6**	**5.2**
Prog - T118	**36.0**	**0.63**	**529**	**46.8**	**26.3**	**11.5**	**6.5**
Prog - T120	**41.9**	**0.69**	**516**	**46.3**	**25.2**	**11.6**	**6.5**
Prog - T123	**29.5**	**0.56**	**517**	**48.7**	**28.2**	**9.1**	**5.3**
l.s.d$_{0.05}$	*1.67*	0.017	*10.0*	*1.53*	*0.64*	*0.47*	*0.27*
GM	32.9	0.60	529	46.7	27.0	10.5	5.8
SE	1.56	0.016	9.3	1.43	0.60	0.44	0.25
CV %	4.7	2.7	1.8	3.1	2.2	4.2	4.4

Progeny T038 had the highest FFB yield compared to the other 3 progenies in 2018 but rank low in FW and LAI (Table 19).

Table 19 Trial 154 effects of progenies on FFB yield, frond weight, frond area and leaf area index in 2018

Progeny	FFB yield (t/ha)	FW (kg)	FA (m^2)	LAI
Prog - T038	**29.8**	**0.51**	**8.9**	**4.8**
Prog - T118	**26.3**	**0.63**	**10.7**	**6.0**
Prog - T120	**22.7**	**0.69**	**10.8**	**6.0**
Prog - T123	**23.9**	**0.56**	**8.5**	**4.9**
l.s.d$_{0.05}$	*2.64*	0.017	*0.43*	*0.26*
GM	25.7	0.60	9.7	5.4

B.1.2.5. *Conclusion*

The fertilizer levels significantly increased FFB. There were significant effects of progenies on yield, leaf tissue nutrient contents and physiological growth parameters. The responses to fertilizer levels and difference in progenies will be monitored with time. The trial is recommended to continue.

B.1.3. Trial 155. Nitrogen and potassium fertiliser trial – Bebere Plantations NBPOL

(RSPO 4.2, 4.3, 4.6, 8.1)

1. Summary

The trial was established to assess full potential of clonal palm materials with nutrition non-limiting. Fertiliser increased yields and affected nutrient contents while significant differences are reported from the progenies in their yield and nutrient contents. The sex ratio of the palms remained at 100% for 22 months. The trial is recommended to continue.

B.1.3.1. *Background*

Fertiliser remains the major field input cost in the oil palm industry. Fertiliser trials are carried out to provide information for fertiliser recommendations to optimise FFB yield and profitability. New progenies with high yield potentials are also released which have high nutrient demands due to high crop yields that are exported from the oil palm system. Responses to fertilisers vary between progenies and the potential yields are needed to be established for the different progenies for different growing environment.

This trial looked at combined N and K fertilisers for four different progenies to see how much yield potential the different selected progenies had when nutrition was unlimiting. Fertiliser treatments were applied from the very start of the trial 3 months after field planting. The flowering pattern from these progenies were also monitored to see differences in fruiting activities between the progenies. Trial information is provided in Table 20.

Table 20 Trial 155 background information

Trial number	**155**	**Company**	**Bebere Plantation - Division 1**
Estate	Bebere Div 1	**Block No.**	Bebere MU 1111-03A
Planting Density	120	**Soil Type**	Volcanic
Pattern	Triangular	**Drainage**	Freely draining
Date planted	Nov 2015	**Topography**	Flat
Age after planting	3 years	**Altitude**	
Recording Start	2016	**Previous Land-use**	Oil palm 3rd generation
Treatment start	2018	**Area under trial soil type (ha)**	
Progeny	Known*	**Assistant Agronomist in charge**	Thomas Maiap and Joel Ben

B.1.3.2. *Methods and materials*

Experimental design and treatments

Four progenies; SF46.01, SF21.11, SF108.07 and SF08.06 were planted for the trial at Bebere Plantation in plots of 36 palms of single progenies in each plot. Of the 36 palms, 16 core palms were recorded palms and were surrounded by 20 guard row palms, all same progeny.

The trial had a single fertiliser treatment of Urea/MOP at four levels with four oil palm progenies replicated four times, totaling 48 plots arranged in a randomised complete block design. Kieserite, TSP and Borate were applied at optimum rates to optimize responses to fertiliser treatments. The fertiliser treatments started 3 months after planting at immature rates and changed to mature rates with time (Table 21).

In addition to the 48 plots, four plots of each of the four progenies were planted for flower monitoring. The monitoring plots received recommended plantation fertiliser rates.

Table 21 Trial 155 Immature and mature treatment application rates

Year	Treatment	Fertilizers and rates (kg/palm/year)				
	levels	Urea	MOP	TSP	Kie	Borate (g)
1	1	0.5	0.3	1.0	0.5	-
	2	1.0	0.5	1.0	0.5	-
	3	1.5	0.8	1.0	0.5	-
	4	2.0	1.0	1.0	0.5	-
2	1	0.75	0.5	1.0	1.0	100
	2	1.50	1.0	1.0	1.0	100
	3	2.25	1.5	1.0	1.0	100
	4	3.00	2.0	1.0	1.0	100
3 plus	1	1.1	1.0	2.0	2.0	100
	2	2.3	1.5	2.0	2.0	100
	3	3.4	2.0	2.0	2.0	100
	4	4.5	2.5	2.0	2.0	100

Data Collection

Yield recording, physiological growth measurements and leaf tissue sampling were done as per the standard trial management (see appendices). In the four flower monitoring plots, male and female flowers at anthesis were recorded every week. Vegetative measurements and leaf tissue samples were also done on the 4 flower monitoring plots. Yield recording started in July 2017 and leaf sampling for nutrient analysis also started in 2017. Flower monitoring started in June 2016 (7 months after field planting) when the first flowers came into anthesis. Vegetative measurements commenced in 2016.

Statistical Analysis

A general ANOVA was done to see the main effects of fertiliser levels and progenies and possible interaction between the fertiliser levels and the progenies using statistical program GenStat.

B.1.3.3. ***Results***

Yield and yield components

Yield and yield components data for 2018 and running 18 months are presented here.

There were significant differences in FFB yield and its components from the effects of progenies while fertilizer affected FFB yield only (Table 22). There were significant differences between the progenies with SF21.11 and SF108.07 having higher FFB yields than the other two progenies (Table 23).

Table 22 Trial 155 effects (*p values*) of fertilizer treatments and progenies on FFB yield and its components in 2018 and July 2017-December 2018

Source	2018			July 2017 - Dec 2018		
	FFB yield	BHA	SBW	FFB yield	BHA	SBW
Fertliser	**0.039**	0.238	0.236	0.053	0.149	0.125
Progeny	**0.017**	**0.025**	**p<0.001**	0.056	**0.001**	**p<0.001**
Fert x Prog	0.520	0.396	0.999	0.622	0.567	0.994
cv %	13.1	7.1	5.3	7.3	6.6	5.3

Table 23 Trial 155 effects of fertilizer treatments and progenies on FFB yield (t/ha) and its components in 2018 and July 2017-December 2018

	2018			July 2017 - Dec 2018		
Source	**FFB yield**	**BHA**	**SBW**	**FFB yield**	**BHA**	**SBW**
	(t/ha)		**(kg)**	**(t/ha)**		**(kg)**
Fert. Level 1	**16.4**	3658	4.5	10.7	2530	4.1
Fert. Level 2	**17.1**	3660	4.7	11.0	2478	4.2
Fert. Level 3	**15.7**	3484	4.5	10.2	2386	4.1
Fert. Level 4	**17.0**	3671	4.6	11.1	2517	4.3
l.s.d$_{0.05}$	*1.041*					
Prog. SF46.01	**15.8**	**3734**	**4.2**	10.4	**2597**	**3.8**
Prog. SF21.11	**17.0**	**3712**	**4.6**	10.8	**2493**	**4.1**
Prog. SF108.07	**17.4**	**3429**	**5.1**	11.3	**2309**	**4.7**
Prog. SF08.06	**16.1**	**3599**	**4.5**	10.6	**2512**	**4.0**
l.s.d$_{0.05}$	*1.041*	*212.8*	*0.20*		*136.4*	*0.18*
GM	16.5	3619	4.6	10.8	2478	4.2
SE	1.25	255.2	0.24	0.79	163.6	0.22
CV	7.5	7.1	5.3	7.3	6.6	5.3

Leaf tissue nutrient contents

2018 was the second year of leaf tissue sampling. NK fertilisers significantly affected leaflet Ash, Mg and Cl contents (Table 24). Fertiliser treatments increased leaflet Cl but lowered Mg and Ash contents (Table 26).

There were significant differences between the progenies for leaflet Ash, K, Ca and B (Table 24) and rachis P and K contents (Table 25). There were differences in the nutrient contents of each of the progenies (Table 26 and Table 27).

Table 24 Trial 155 effects (*p values*) of fertilizer treatments and progenies on leaflet nutrient concentrations in 2018, p values <0.05 shown in bold

Source	Leaflet nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fertliser	**0.002**	0.661	0.966	0.351	**0.004**	0.540	**p<0.001**	0.745	0.693
Progeny	**p<0.001**	0.185	0.186	**p<0.001**	0.067	**0.016**	0.326	**0.008**	0.196
Fert x Prog	0.255	0.288	0.130	0.095	0.966	0.437	0.133	**0.038**	0.689
CV %	3.4	3.0	3.1	6.7	6.9	4.6	9.7	5.3	3.7

Table 25 Trial 155 effects (*p values*) of fertilizer treatments and progenies on rachis nutrient concentrations in 2018, p values <0.05 shown in bold

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Fertliser	0.479	0.525	0.148	0.085	0.753	0.182
Progeny	0.115	0.357	**p<0.001**	**0.013**	0.299	0.320
Fert x Prog	0.311	0.301	0.67	0.139	0.726	0.232
cv %	8.0	6.5	9.6	8.3	10.7	7.8

Table 26 Trial 155 effects of fertilizer treatments and progenies on leaflet nutrient concentrations % DM except for B in 2018, *p values* <0.05 shown in bold

Source	Leaflet nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fert. Level 1	**13.0**	2.86	0.164	0.81	**0.29**	1.09	**0.39**	13	0.21
Fert. Level 2	**12.3**	2.85	0.164	0.78	**0.27**	1.08	**0.46**	13	0.20
Fert. Level 3	**12.4**	2.82	0.163	0.77	**0.27**	1.09	**0.49**	13	0.20
Fert. Level 4	**12.4**	2.86	0.164	0.78	**0.26**	1.11	**0.49**	13	0.21
l.s.d$_{0.05}$	*0.356*				*0.016*		*0.037*		
Prog. SF46.01	**11.8**	2.80	0.161	**0.77**	0.28	**1.06**	0.46	**12**	0.20
Prog. SF21.11	**12.3**	2.87	0.165	**0.86**	0.28	**1.08**	0.47	**13**	0.21
Prog. SF108.07	**13.0**	2.87	0.165	**0.78**	0.26	**1.12**	0.44	**13**	0.21
Prog. SF08.06	**13.0**	2.85	0.163	**0.73**	0.27	**1.11**	0.46	**13**	0.21
l.s.d$_{0.05}$	*0.356*			*0.044*		*0.042*		*0.57*	
GM	12.5	2.85	0.164	0.79	0.27	1.09	0.46	13	0.20
SE	0.427	0.085	0.005	0.05	0.0190	0.050	0.044	0.68	0.008
CV %	3.4	3.0	3.1	6.7	6.9	4.6	9.7	5.3	3.7

Table 27 Trial 155 effects of fertilizer treatments and progenies on rachis nutrient concentrations in 2018, *p* values <0.05 shown in bold

Source	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Fert. Level 1	5.53	0.35	0.088	1.78	0.090	0.49
Fert. Level 2	5.82	0.36	0.094	1.91	0.090	0.52
Fert. Level 3	5.66	0.35	0.090	1.76	0.090	0.51
Fert. Level 4	5.62	0.35	0.086	1.84	0.090	0.52
Prog. SF46.01	5.86	0.36	**0.083**	**1.90**	0.090	0.52
Prog. SF21.11	5.78	0.36	**0.086**	**1.87**	0.090	0.51
Prog. SF108.07	5.55	0.34	**0.089**	**1.82**	0.090	0.52
Prog. SF08.06	5.45	0.35	**0.100**	**1.70**	0.080	0.49
***l.s.d*$_{0.05}$**			0.0072	*0.126*		
GM	5.7	0.35	0.089	1.82	0.09	0.51
SE	0.455	0.023	0.009	0.151	0.009	0.040
CV %	8.0	6.5	9.6	8.3	10.7	7.8

Physiological growth parameters

The effects of fertilisers and progenies on physiological growth parameters are presented here. There were significant differences between the progenies for all the measured growth parameters (Table 28). Fertilisers affected only the frond production rate. SF108.7 had larger fronds, frond area and LAI compared to the other three progenies and correlate well to high FFB yields as well (Table 29).

Table 28 Trial 155 effects (*p values*) of fertilisers and progenies on vegetative growth parameters in 2018

Source	PCS	FW	FL	TFC	FPR	FA	LAI
Fert levels	0.353	0.353	0.129	0.476	**0.032**	0.477	0.142
Progenies	**p<0.001**	**p<0.001**	**0.001**	**0.004**	**p<0.001**	**0.002**	**p<0.001**
Fert x Progeny	0.545	0.545	0.632	**0.040**	0.853	0.135	**0.019**
CV %	6.2	2.3	2.0	2.0	3.1	5.0	4.5

Table 29 Trial 155 effects of fertilisers and progenies on vegetative growth parameters in 2018

Treatments	PCS	FW	FL	TFC	FPR	FA	LAI
	(cm^2)	(kg)	(m)		(no./year)	(cm^2)	
Fert level - 1	15.1	0.41	388.1	48.8	27.6	5.0	2.9
Fert level - 2	15.5	0.42	387.2	49.2	28.2	5.0	2.9
Fert level - 3	15.1	0.41	383.3	48.8	27.1	4.9	2.9
Fert level - 4	15.6	0.42	390.9	49.3	27.6	5.1	3.0
l.s.d$_{0.05}$					*0.70*		
Prog. SF46.01	15.4	0.42	381.1	49.0	28.2	4.9	2.9
Prog. SF21.11	14.2	0.41	383.9	49.0	28.4	5.0	2.9
Prog. SF108.07	16.2	0.42	392.6	49.9	27.4	5.3	3.1
Prog. SF08.06	15.6	0.42	391.9	48.2	26.5	4.9	2.8
l.s.d$_{0.05}$	*0.79*	*0.008*	*6.38*	*0.82*	*0.70*	*0.21*	*0.11*
GM	15.3	0.42	387.4	49.0	27.6	5.0	2.9
SE	0.95	0.10	7.66	0.99	0.84	0.25	0.1
CV %	6.2	2.3	2.0	2.0	3.1	5.0	4.5

Flowering monitoring

Flowering monitoring data from June 2016 to April 2019, a total of 151 weeks data is presented here. Ablation was done from week 33 to week 36.

There were no differences between the number of female (Figure 4) and male (Figure 5) flowers between the four progenies at anthesis. The number of female flowers at anthesis started increasing at week 40 and appeared to plateau after week 53. The number of male flowers at anthesis showed the opposite pattern to female flowers. There was generally very low number of male flowers from week 33 to week 151 (16 months).

The sex ratio (proportion of female flowers at anthesis to total flowers) increased steadily and leveled off at 100 % (Figure 6). It remained at close to 100 % for 22 months (week 60 to week 151) and continued at the time of reporting.

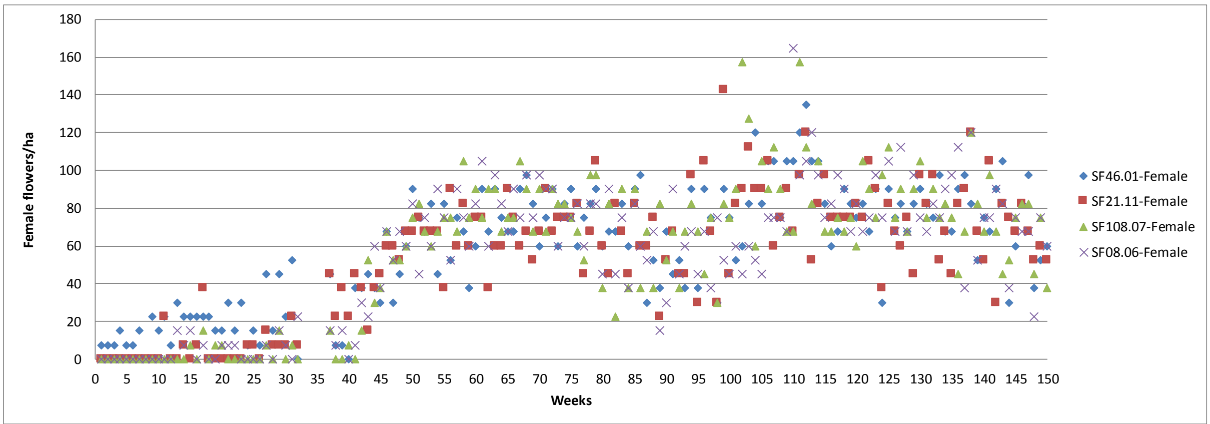

Figure 4 Trial 155 number of female flowers/ha at anthesis from June 2016 to April 2019

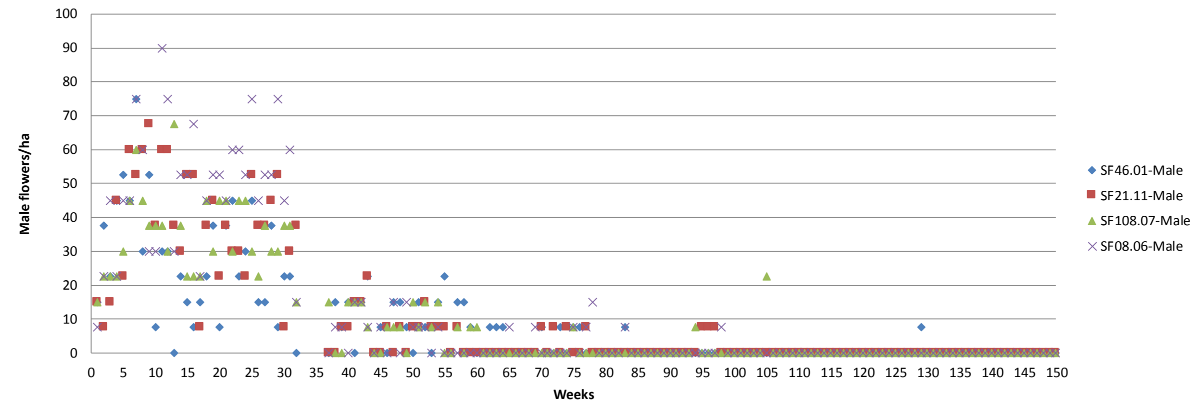

Figure 5 Trial 155 number of male flowers/ha at anthesis from June 2016 to April 2019

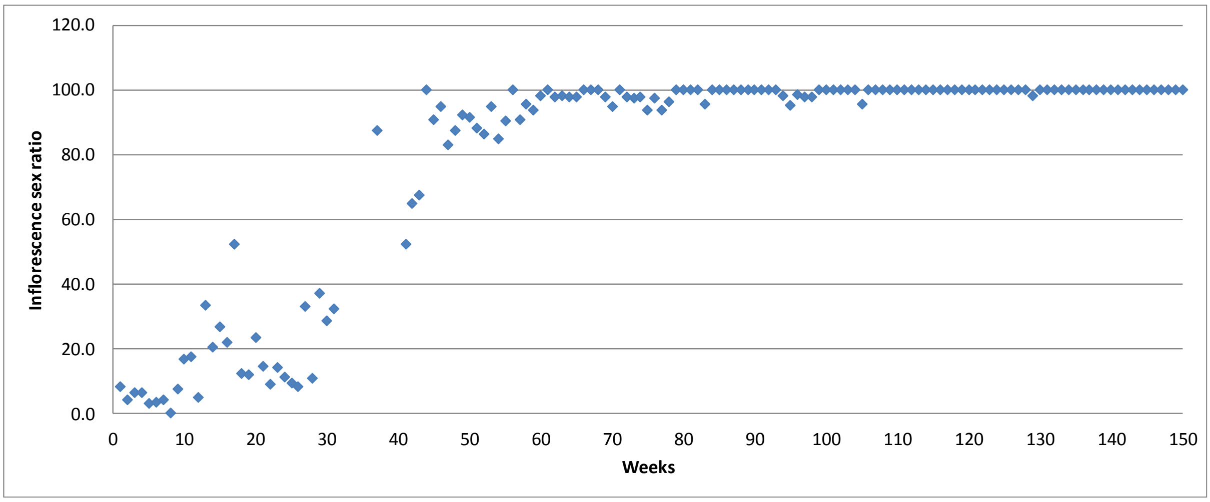

Figure 6 Trial 155 mean sex ratio for the progenies from June 2016 to April 2019

B.1.3.4. *Conclusion*

There are differences in the yield components, leaf tissue nutrient contents and physiological growth parameters for the different progenies. The sex ratio remained at close to 100% for 22 months. The trial is recommended to continue.

B.1.4. Trial 160: NPKMg Fertiliser Trial on Volcanic soils, Bebere Plantations

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.4.1. *Summary*

The NPKMg trial is aimed to provide information for fertilizer recommendations on the volcanic soils in WNB. The results from the trial are inconclusive because fertilizer treatments started in 2017 however fertilisers are already affecting the nutrient contents in the leaf tissues. The trial is recommended to continue.

B.1.4.2. *Introduction*

The soils at Bebere are young being formed from recent volcanic ash and alluvial volcanic materials. The area is generally flat and is dissected by streams running through the plantations. The soils are young and weakly to moderately developed, and therefore are very friable to loose and generally structure less. The surface soils are sandy loam to loamy sand and have buried soils at depth. Pumice gravel layers at depth are a common feature throughout the landscape. The soils have high infiltrability properties and with high annual rainfall of 3400 mm, soluble nutrients are more susceptible to leaching losses. The soils are deep to greater than 200 cm. The palms were third generation replant.

There has been lack of or inconsistent responses to fertilisers in the past trials in this environment however this is third generation planting and progenies with high yield potentials are being planted. This trial is established with the aim to provide information for fertiliser recommendations in NBPOL plantations in WNB to achieve yields greater than 30 t FFB/ha/yr. Trial information is provided in Table 30.

Table 30 Trial 160 background information

Trial number	**160**	**Company**	**Bebere Plantation - Division 1**
Estate	Bebere Div 1	**Block No.**	Bebere MU 1111-03A and 03B
Planting Density	120	**Soil Type**	Volcanic
Pattern	Triangular	**Drainage**	Freely draining
Date planted	Nov 2015	**Topography**	Flat
Age after planting	3 years	**Altitude**	
Recording Start	2016	**Previous Land-use**	Oil palm 3rd generation
Treatment start	2018	**Area under trial soil type (ha)**	
Progeny	Known*	**Assistant Agronomists in charge**	Thomas Maiap and Joel Ben
Planting material	Dami D x P		

B.1.4.3. *Methods*

Experimental design and Treatments

The trial design is 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) resulting in 64 plots (Table 31). The treatments were allocated randomly to the plots. The optimum rates of the other 3 nutrients will be determined against N rates which is likely going to be the major limiting nutrient in the area. Fertiliser treatment applications were started in December 2017

Table 31 Trial 160 Fertiliser treatments and the levels in kg/palm/year

Treatments	Levels (kg/palm/year)			
	1	2	3	4
Urea	0.0	1.5	3.0	4.5
Muriate of potash	0.0	1.0	2.0	3.0
Triple superphosphate	0.0	2.0		
Kieserite	0.0	2.0		

Data collection

Field trial management, data collection and quality standards are referred to in Appendix. Yield recording started in July 2017. Leaf sampling for tissue nutrient analysis and vegetative measurements started in 2016.

Statistical Analysis

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

B.1.4.4. *Results and discussion*

Effects of treatment on FFB yield and its components

There was no main effect of fertilizers on yield in 2018 and July 2017-Dec 2018 except for TSP affecting the number of bunches in 2018. (Table 32 and Table 33). There were significant interactions between MOP & TSP and MOP & Kieserite however the trial only received its first dose of fertilizer and therefore the interactions are most like artifacts rather than real responses.

Table 32 Trial 160 main effects (*p values*) of fertilizer treatments on FFB yield (t/ha) and its components in 2018 and July 2017-December 2018

Source	2018			July 2017-December 2018		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	0.389	0.098	0.714	0.676	0.332	0.660
MOP	0.733	0.270	0.507	0.791	0.430	0.428
TSP	0.063	**0.045**	0.572	0.155	0.063	0.643
Kieserite	0.648	0.550	0.975	0.893	0.797	0.834
Urea x MOP	0.156	0.602	0.072	0.364	0.673	0.116
Urea x TSP	0.426	0.857	0.107	0.264	0.370	0.639
Urea x Kieserite	0.542	0.766	**0.016**	0.231	0.662	0.168
MOP x TSP	0.252	0.279	**0.050**	0.836	0.732	**0.038**
MOP x Kieserite	0.698	0.784	0.839	0.587	0.607	0.811
TSP x Kieserite	0.153	0.042	0.490	0.171	0.038	0.494
CV %	8.2	6.9	5.1	9.1	7.4	5.7

p values <0.05 shown in bold

Table 33 Trial 160 effects of fertilizers on FFB yield and yield components in 2018 and July 2017-December 2018

Treatments	2018			July 2017-December 2018		
	FFB yield (t/ha)	BNO/ha	SBW(kg)	FFB yield (t/ha)	BNO/ha	SBW(kg)
Urea-1	14.7	3436	4.2	9.5	2338	3.9
Urea-2	15.0	3495	4.2	9.7	2370	3.9
Urea-3	14.5	3311	4.3	9.5	2267	4.0
Urea-4	15.2	3507	4.3	9.8	2361	3.9
MOP-1	15.1	3477	4.3	9.8	2354	4.0
MOP-2	14.9	3456	4.2	9.5	2321	3.9
MOP-3	14.9	3482	4.2	9.7	2379	3.9
MOP-4	14.6	3335	4.3	9.5	2283	4.0
TSP-1	15.2	**3499**	4.3	9.8	2375	3.9
TSP-2	14.6	**3375**	4.2	9.5	2293	3.9
l.s.d$_{0.05}$		*0.622*				
Kieserite-1	14.8	3419	4.3	9.6	2329	3.9
Kieserite-2	14.9	3455	4.3	9.6	2340	3.9
GM	14.9	3437	4.3	9.6	2334	3.9
SE	1.22	237.45	0.22	0.87	171.6	0.22
CV%	8.2	6.9	5.1	9.1	7.4	5.7

Effects of treatments on leaf nutrient concentrations

Effects of fertilisers on nutrient contents were observed in 2018 and the results are presented here (Table 34 and Table 35). Urea increased leaflet K, B, and S, and rachis P contents (Table 36 and Table 37). MOP lowered leaflet K while increasing leaflet Mg, Ca and Cl contents. In the rachis, MOP increased all the nutrient contents except Mg. TSP decreased P in the leaflets but increased the contents in rachis. Kieserite did not have any effect on the nutrient contents in the leaf tissues.

K appears to be required in this environment.

Table 34 Trial 160 effects (*p values*) of treatments on leaflet nutrient contents in 2018

Source	Leaflet nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.103	0.054	0.356	**0.033**	0.072	0.520	0.279	**0.009**	**0.025**
MOP	0.096	0.060	0.068	**0.007**	**0.050**	**0.032**	**0.002**	0.276	0.706
TSP	0.460	0.433	**0.046**	**0.002**	0.945	0.065	0.226	0.405	0.120
Kieserite	0.204	0.258	0.409	0.132	0.092	0.552	0.559	0.447	0.262
Urea x MOP	0.444	0.817	0.715	0.116	0.099	0.534	0.104	0.794	0.322
Urea x TSP	0.124	0.068	0.425	0.400	0.180	0.726	0.060	0.595	0.072
Urea x Kieserite	0.034	0.144	0.640	0.370	0.068	0.351	0.418	0.108	0.394
MOP x TSP	0.014	0.038	0.394	0.194	0.307	0.084	0.079	0.260	0.248
MOP x Kieserite	0.878	0.818	0.206	0.173	0.059	0.361	0.818	0.128	0.902
TSP x Kieserite	0.242	0.859	0.300	0.827	0.196	0.518	0.750	0.094	0.821
CV %	3.2	1.8	2.2	5.6	6.4	4.4	14.8	7.5	2.7

Table 35 Trial 160 effects (*p values*) of treatments on rachis nutrient contents in 2018

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Urea	0.195	0.314	**0.007**	0.382	0.666	0.073
MOP	**0.023**	**0.050**	**p<0.001**	**0.007**	0.132	**0.032**
TSP	0.646	0.497	**0.027**	0.362	1.000	0.602
Kieserite	0.841	**0.047**	0.243	0.380	0.241	0.401
Urea x MOP	0.528	0.516	0.240	0.941	0.868	0.529
Urea x TSP	0.664	**0.048**	0.072	0.685	0.132	0.235
Urea x Kieserite	0.850	0.951	0.936	0.937	0.851	0.945
MOP x TSP	0.237	0.123	0.107	0.145	0.666	0.121
MOP x Kieserite	0.467	0.548	0.788	0.157	0.984	0.161
TSP x Kieserite	0.202	0.940	0.371	0.408	0.693	0.778
CV %	7.3	5.0	7.9	8.4	8.3	7.1

Table 36 Trial 160 effects of treatments on leaflet tissue nutrient concentrations in 2018, *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	12.3	2.66	0.154	**0.79**	0.28	1.07	0.31	**15**	**0.20**
Urea-2	12.0	2.67	0.155	**0.80**	0.29	1.09	0.31	**13**	**0.20**
Urea-3	12.1	2.68	0.154	**0.84**	0.27	1.08	0.34	**14**	**0.20**
Urea-4	12.0	2.71	0.156	**0.81**	0.29	1.06	0.31	**14**	**0.20**
***l.s.d*$_{0.05}$**				*0.0326*				*0.74*	*0.004*
MOP-1	12.1	2.71	0.155	**0.83**	**0.27**	**1.05**	**0.31**	14	0.20
MOP-2	11.9	2.68	0.155	**0.81**	**0.29**	**1.07**	**0.28**	14	0.20
MOP-3	12.3	2.68	0.157	**0.78**	**0.29**	**1.10**	**0.32**	13	0.20
MOP-4	12.1	2.66	0.153	**0.82**	**0.28**	**1.08**	**0.35**	14	0.20
***l.s.d*$_{0.05}$**				*0.0326*	*0.0130*	*0.034*	*0.034*		
TSP-1	12.0	2.69	**0.156**	**0.83**	0.28	1.06	0.31	14	0.20
TSP-2	12.1	2.68	**0.154**	**0.79**	0.28	1.09	0.32	14	0.20
***l.s.d*$_{0.05}$**			*0.002*	0.023					
Kieserite-1	12.1	2.67	0.155	0.82	0.28	1.07	0.31	14	0.20
Kieserite-2	12.0	2.69	0.154	0.80	0.29	1.08	0.32	14	0.20
GM	12.1	2.68	0.155	0.81	0.28	1.07	0.32	14	0.2
SE	0.383	0.049	0.0034	0.045	0.018	0.048	0.047	1.02	0.0050
CV%	3.2	1.8	2.2	5.6	6.4	4.4	14.8	7.5	2.7

Table 37 Trial 160 effects of treatments on rachis tissue nutrient concentrations in 2018, *p values* <0.05 shown in bold

Treatment	Rachis nutrient contents (%DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	5.4	0.32	**0.082**	1.70	0.077	0.45
Urea-2	5.2	0.33	**0.080**	1.76	0.075	0.45
Urea-3	5.5	0.33	**0.078**	1.68	0.076	0.43
Urea-4	5.4	0.33	**0.074**	1.69	0.074	0.42
l.s.d $_{0.05}$			*0.0045*			
MOP-1	**5.3**	**0.32**	**0.075**	**1.63**	0.074	**0.43**
MOP-2	**5.3**	**0.32**	**0.075**	**1.66**	0.074	**0.42**
MOP-3	**5.3**	**0.33**	**0.081**	**1.73**	0.076	**0.45**
MOP-4	**5.6**	**0.33**	**0.083**	**1.81**	0.079	**0.45**
l.s.d $_{0.05}$	*0.281*	*0.0120*	*0.0045*	*0.1030*		*0.022*
TSP-1	5.4	0.33	**0.077**	1.69	0.076	0.43
TSP-2	5.4	0.32	**0.080**	1.72	0.076	0.44
l.s.d $_{0.05}$			*0.0032*			
Kieserite-1	5.4	0.33	0.080	1.72	0.075	0.44
Kieserite-2	5.4	0.32	0.078	1.69	0.077	0.43
GM	5.4	0.33	0.079	1.71	0.076	0.44
SE	0.391	0.016	0.0062	0.143	0.0063	0.031
CV%	7.3	5.0	7.9	8.4	8.3	7.1

Physiological growth parameters

The vegetative parameters were measured but there were no effects of fertilisers on the parameters and therefore are not reported here.

B.1.4.5. ***Conclusion***

There was no effect of fertilisers on FFB yield and yield components and physiological growth parameters, however, effects are seen in the leaf tissue nutrient contents. The trial is recommended to continue.

2. HARGY OIL PALMS – BIALLA

Paul Simin, Andy Ullian and Peter Mupa

B.1.5. Trial 211: Systematic N Fertiliser Trial on Volcanic soils, NAVO Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.5.1. ***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. Trial closed at end of 2018.

B.1.5.2. *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 38.

Table 38 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	20 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	**Supervisor in charge**	Paul Simin and Peter Mupa

B.1.5.3. *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 39). 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.
Since 2016, urea was applied in two split doses during the year. All palms within the trial field received an annual basal application of MOP, kieserite and calcium borate at 2.0kg, 1.5kg, 0.5kg and 0.150kg per palm respectively.

Table 39 Trial 211 Nitrogen treatments and rates in kg/palm/year

N fertiliser code	N0	N1	N2	N3	N4	N5	N6	N7	N8
Urea	0.00	0.54	1.09	1.63	2.17	2.72	3.26	3.80	4.35
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 and combined effects of N and P fertilizers.

B.1.5.4. ***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 2018 and the combined 2016-2018 period (Table 40). FFB yield increased with N rate from 25.7 at nil N to a maximum of 34.1 t/ha/year in 2018. Yield also increased with N rate in 2016-2018. Effect of N fertilizer was consistent on FFB yield and its components since 2004 (Figure 7). A separate analysis on the effect of TSP rates and combined effect of N and TSP on FFB yield and yield components indicated FFB yield response to TSP was at $p=0.291$ and $p=0.226$ for 2018 and 2016-2018 respectively compared to N at $p<0.001$. The effects of TSP were insignificant and are not discussed here.

Table 40 Trial 211 main effects (*p values*) of N rate treatments on FFB, yield (t/ha), bunch number (BNO) and single (SBW) (kg/bunch) for 2018 and 2016-2018

N rates	Urea	2018			2016-2018		
(kg/palm/year)		FFB yield	BHA	SBW	FFB yield	BHA	SBW
		(t/ha)		(kg)	(t/ha)		(kg)
0.00	0.00	**25.7**	**1034**	**24.9**	**26.3**	**1086**	**24.3**
0.25	0.54	**29.0**	**1126**	**25.8**	**29.8**	**1174**	**25.4**
0.50	1.09	**30.5**	**1140**	**26.7**	**30.8**	**1164**	**26.5**
0.75	1.63	**32.3**	**1181**	**27.4**	**32.5**	**1194**	**27.3**
1.00	2.17	**33.1**	**1200**	**27.6**	**34.0**	**1232**	**27.6**
1.25	2.72	**33.7**	**1184**	**28.5**	**34.7**	**1223**	**28.4**
1.50	3.26	**33.5**	**1192**	**28.1**	**34.5**	**1239**	**27.9**
1.75	3.80	**34.1**	**1222**	**28.0**	**36.6**	**1305**	**28.1**
2.00	4.35	**32.8**	**1181**	**27.9**	**35.3**	**1265**	**28.0**
L.S.D$_{0.05}$		*2.36*	*85.7*	*0.897*	*1.98*	*75.3*	*0.786*
Significance		**p<0.001**	**0.003**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
GM		31.6	1162	27.2	32.7	1209	27.0
SE		2.36	85.5	0.895	1.98	75.2	0.785
CV %		7.4	7.4	3.3	6.0	6.2	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 (2004-2018) with yield performing above 30 t/ha (Figure 7). 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 lowest N rate and fertilized plots widened with time.

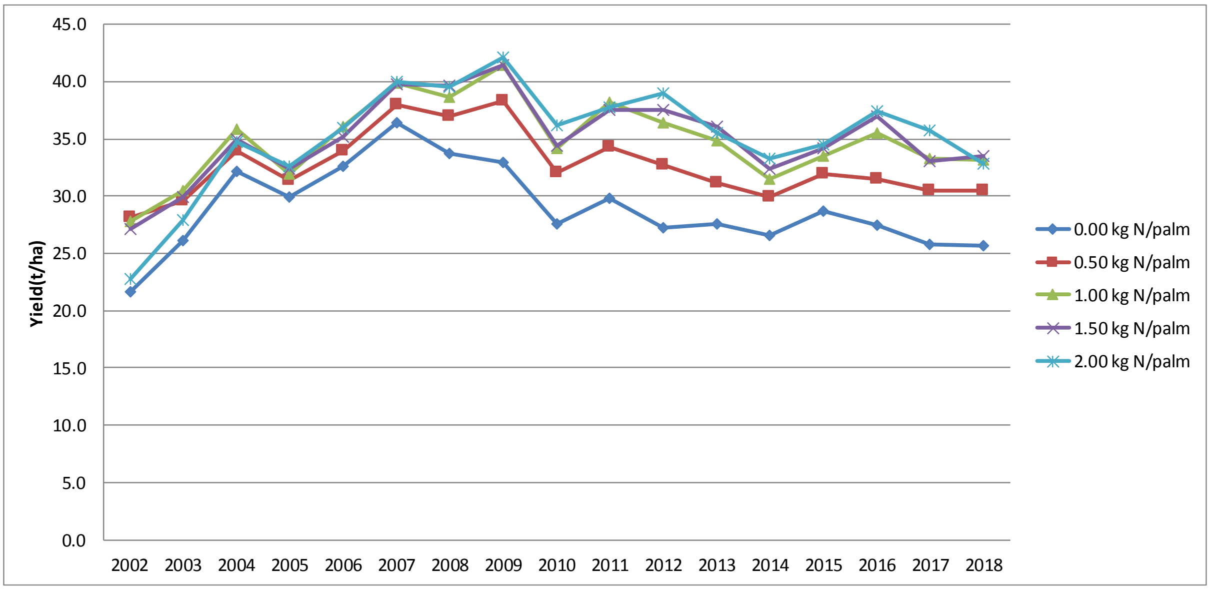

Figure 7 Trial 211 Yield trend from 2002 to 2018 for 5 rates of N (kg/palm). Significant differences were reported since 2005. Note: in 2004 the palms were 6 years old

The relationship between average FFB yield and N rates for the period 2016 to 2018 is presented in Figure 8. There was a very strong quadratic relationship between N rates and FFB yield (R^2=0.9688) in the nature of the graph. 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.

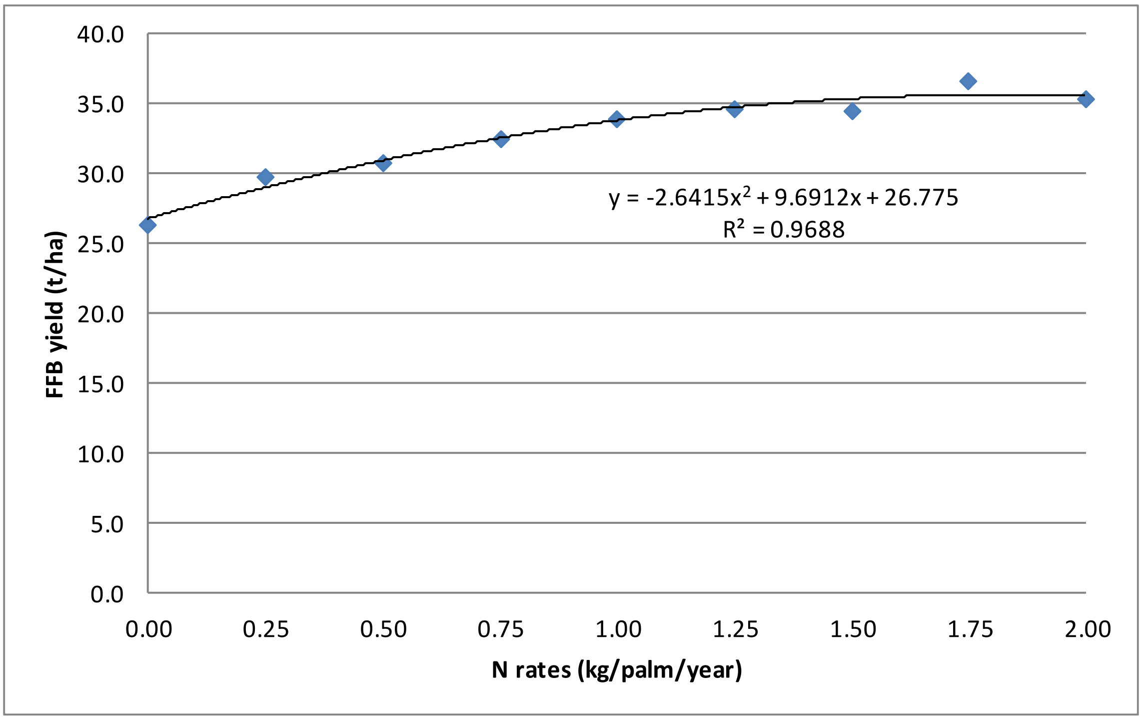

Figure 8 Trial 211 N rates and FFB yield response curve for 2016-2018

Effects of treatments on leaf tissue nutrient concentrations

The effect of N fertilizer on leaf tissue nutrient contents in 2018 is presented in Table 41 and Table 42. N rates did have an effect on leaflet N ($p<0.001$) and also on other nutrient levels. Leaflet and rachis K and Mg were significantly reduced with N rates while rachis Ca was increased. Leaflet Mg contents decreased with N rates to equal to or less than 0.20 % DM, which could be referred to as deficient. Lack of Mg in these volcanic soils could limit responses to high N and P fertilizer rates in these soils.

Table 41 Trial 211 effects of N rate treatments on leaflet nutrients (% DM except B mg/kg) concentrations in 2018

N rates	Equivalent Urea rate	Leaflet nutrient contents (% DM) except B in ppm								
(kg/palm/yr)		Ash	N	P	K	Mg	Ca	Cl	B	S
0.00	0.00	13.9	**2.11**	**0.133**	**0.60**	**0.29**	1.00	**0.49**	**21**	**0.18**
0.25	0.54	14.1	**2.14**	**0.133**	**0.61**	**0.27**	1.05	**0.49**	**22**	**0.18**
0.50	1.09	14.1	**2.25**	**0.136**	**0.60**	**0.23**	1.02	**0.49**	**21**	**0.18**
0.75	1.63	13.8	**2.27**	**0.136**	**0.60**	**0.22**	1.02	**0.50**	**19**	**0.18**
1.00	2.17	14.1	**2.30**	**0.137**	**0.63**	**0.21**	1.01	**0.52**	**19**	**0.19**
1.25	2.72	14.2	**2.36**	**0.137**	**0.63**	**0.21**	1.01	**0.54**	**19**	**0.19**
1.50	3.26	14.2	**2.36**	**0.138**	**0.63**	**0.20**	1.00	**0.53**	**20**	**0.19**
1.75	3.80	14.4	**2.42**	**0.140**	**0.63**	**0.19**	0.96	**0.53**	**18**	**0.19**
2.00	4.35	14.4	**2.39**	**0.138**	**0.64**	**0.19**	0.96	**0.54**	**18**	**0.19**
L.S.D$_{0.05}$			*0.059*	*0.0024*	*0.0267*	*0.024*		*0.0250*	*1.73*	*0.006*
Sig.		**0.327**	**p<0.001**	**p<0.001**	0.012	**p<0.001**	0.176	**p<0.001**	**p<0.001**	**p<0.001**
GM		14.13	2.29	0.136	0.62	0.22	1.00	0.51	20	0.18
SE		0.564	0.059	0.0024	0.0267	0.024	0.065	0.025	1.73	0.006
CV %		4.00	2.6	1.7	4.3	10.6	6.5	4.8	8.8	3.4

p values less than 0.05 are in bold

Table 42 Trial 211 effects of N rate treatments on rachis nutrients (% DM) concentrations in 2018

N rates	Equivalent Urea rate	Rachis nutrient contents (% DM)					
(kg/palm/yr)		Ash	N	P	K	Mg	Ca
0.00	0.00	6.53	**0.30**	**0.173**	**2.02**	**0.09**	**0.42**
0.25	0.54	6.77	**0.32**	**0.150**	**1.98**	**0.09**	**0.44**
0.50	1.09	6.68	**0.32**	**0.126**	**1.98**	**0.09**	**0.49**
0.75	1.63	6.50	**0.35**	**0.103**	**1.86**	**0.08**	**0.50**
1.00	2.17	6.31	**0.33**	**0.097**	**1.78**	**0.08**	**0.50**
1.25	2.72	6.21	**0.36**	**0.087**	**1.73**	**0.07**	**0.52**
1.50	3.26	6.34	**0.38**	**0.091**	**1.81**	**0.07**	**0.53**
1.75	3.80	6.15	**0.36**	**0.090**	**1.74**	**0.07**	**0.51**
2.00	4.35	6.29	**0.40**	**0.088**	**1.75**	**0.08**	**0.54**
L.S.D $_{0.05}$		*0.393*	*0.028*	*0.0213*	*0.133*	*0.009*	*0.0440*
Significance		0.030	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
GM		6.42	0.35	0.112	1.85	0.08	0.50
SE		0.392	0.028	0.0213	0.133	0.009	0.044
CV %		6.1	8.2	19.1	7.2	10.8	8.8

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 Figure 9. The N content was averaged for 2016 to 2018 to minimize year to year variations. There was a strong quadratic relationship between N rates (kg/palm/yr) and leaflet N contents (R^2=0.9805). 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 1.0 kg N but even better at rates greater than 1.25 kg N/palm/yr. The N content leveled off after 1 kg N/palm/year. The deficient Mg contents at high N rates could be limiting further increase in leaflet N contents with N fertilizer rates.

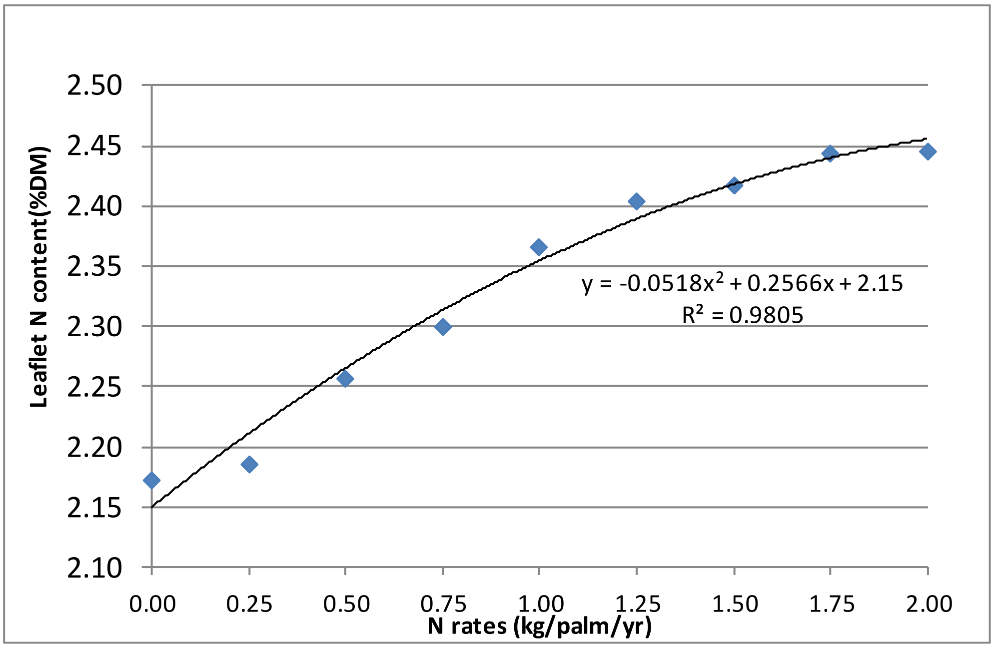

Figure 9 Trial 211 Relationship between N rates and leaflet N content averaged for 2016 to 2018

Effects of TSP fertilizer on leaf tissue P contents

A separate analysis of effects of TSP on leaf P contents showed no statistically significant effect on leaflet and but affected rachis P contents. TSP increased rachis P contents (p=0.022) from 0.089 % DM at 0 kg P/palm/year to above 0.136 % DM at 4kg P/palm/year. The lack of responses to TSP levels were probably limited by falling and deficient Mg contents in the leaflets.

B.1.5.5. ***Conclusion***

Nitrogen rates had significant effects on FFB yield, its components (BHA and SBW) and leaf N contents consecutively since 2004. The optimum N rate for FFB production at Navo is between 0.75 and 1.0 kg N/palm/year which 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 are probably affected by low Mg contents in the leaflets.

B.1.6. Trial 217: NPK trial on Volcanic soils at Navo Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.6.1. ***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 to develop fertiliser recommendations for the new replant on similar soils at Navo. Trial information is presented in Table 43. Formal recording commenced in Dec 2014 and treatment application started in 2015 (4 years after planting).

Table 43 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	7 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	Supervisors in charge	Paul Simin and Peter Mupa
Planting material	Dami D x P		

B.1.6.2. *Materials and method*

Design and Treatment

The trial was planted in December 2011 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 design.

B.1.6.3. *Results and discussion*

2018 was the fourth year of treatment application and data collection and data analysis indicated no significant yield responses to the fertilizer treatments in 2018 (p=0.469) and combined yield for 2016-2018 (p=0.707). The estimated yield parameters for 2018 are presented in Table 44. The estimated yield at nil fertilizers in 2018 was 38.2 t/ha/year. The FFB yield range was 34.0-39.5 t/ha/year and 28.8-34.9 t/ha/year in 2018 and 2016-2018 respectively.

Table 44 Trial 217 estimated yield parameters from regression analysis for 2018

Parameter	estimate	s.e.	t(14)	t pr.
Constant	38.32	4.24	9.04	p<0.001
AC	-1.3	1.42	-0.92	0.375
TSP	2.89	3.4	0.85	0.41
MOP	-1.38	1.36	-1.01	0.33
AC squared	-0.008	0.134	-0.06	0.951
TSP squared	-2.62	1.21	-2.17	0.048
MOP squared	0.146	0.193	0.75	0.464
AC x MOP	0.338	0.274	1.23	0.238
AC x TSP	1.171	0.686	1.71	0.11
AC x TSP X MOP	-0.218	0.155	-1.41	0.18

B.1.6.4. *Conclusion*

The trial to continue.

B.1.7. Trial 220: NPKMg Fertiliser Trial on Volcanic soils, Pandi Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.7.1. *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. 2018 was the fourth year of fertilizer treatments applications and responses to the fertilizers continued to be recorded. This trial is recommended to continue.

B.1.7.2. *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 45.

Table 45 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	8 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	**Supervisor charge**	Paul Simin and Peter Mupa

B.1.7.3. *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 46.

Table 46 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	0.0	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.1.7.4. *Results and discussion*

Effects of treatment on FFB yield and its components

Urea, MOP, TSP and kieserite did not affect yield and yield components in 2018 and 2016-2018 (Table 47). The mean FFB yield FFB yield fell from 34.8 t/ha in 2017 to 25.6 t/ha/year in 2018.

Table 47 Trial 220 main effects of fertilizer treatments on FFB yield (t/ha) and its components in 2018 and 2016-2018

Treatments	2018			2016-2018		
	FFB yield (t/ha)	BNO/ha	SBW(kg)	FFB yield (t/ha)	BNO/ha	SBW(kg)
Urea-1	25.7	1817	14.1	29.9	2460	12.5
Urea-2	25.8	1800	14.3	30.3	2445	12.7
Urea-3	25.2	1812	13.8	29.3	2428	12.4
Urea-4	25.6	1741	14.4	29.6	2405	12.7
MOP-1	26.2	1806	14.2	29.1	2403	12.4
MOP-2	24.5	1762	13.9	29.0	2417	12.3
MOP-3	25.2	1757	14.3	30.0	2411	12.8
MOP-4	26.5	1845	14.3	31.0	2508	12.7
TSP-1	24.8	1764	14.0	29.4	2430	12.4
TSP-2	26.3	1822	14.3	30.2	2439	12.7
Kieserite-1	25.3	1768	14.3	29.8	2416	12.7
Kieserite-2	25.8	1818	14.1	29.8	2453	12.5
GM	25.6	1793	14.2	29.8	2435	12.6
SE	2.53	161.3	0.66	2.72	195.5	0.52
CV%	9.9	9.0	4.6	8.9	8.0	4.1

p values <0.05 shown in bold

Effects of treatments on leaf nutrient concentrations

The effects (*p values*) of the fertilizers on leaflet and rachis nutrient contents in 2018 are presented in Table 48 and Table 49 respectively. Urea affected leaflets Cl and rachis P contents only. MOP affected leaflet Mg (p=0.041), Ca (p=0.001) and Cl (p<0.001) and rachis Ash (p=0.001), N (p=0.006), P (p=0.002), K (p<0.001), Mg (p=0.050) and Ca (p=0.011) contents. TSP affected leaflet P (p<0.001), rachis P (p<0.001) and rachis Mg (p<0.001) nutrient contents. Kieserite affected leaflet Mg (p=0.034) and rachis N (p=0.002). 2018 was the fourth year of fertilizer treatments applications and effects of fertilizer treatments on the leaf nutrient contents were observed.

Urea increased leaflet Cl and rachis P contents (Table 50 and Table 51). MOP increased leaflet Cl and Ca, and rachis Ash, P, K, Mg and Ca nutrient contents. TSP increased leaflet P, and rachis P and Mg contents. Kieserite increased leaflet Mg but decreased rachis N contents.

The effects of fertilizer treatments noticed on leaf tissue nutrient contents are yet to be translated to yield responses. Early indications are that palms grown on this particular soil type will be responsive to fertilizers in the future.

Table 48 Trial 220 effects (*p values*) of treatments on leaflet nutrient contents in 2018

Source	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.826	0.611	0.187	0.235	0.083	0.644	0.010	0.945	0.625
MOP	0.185	0.074	0.435	0.092	0.041	0.001	p<0.001	0.195	0.099
TSP	0.255	0.089	p<0.001	0.156	0.328	0.461	0.631	0.791	0.521
Kieserite	0.594	0.244	0.263	0.788	0.034	0.082	0.501	0.615	0.093
Urea x MOP	0.795	0.269	0.704	0.486	0.776	0.075	0.568	0.786	0.494
Urea x TSP	0.225	0.134	0.866	0.687	0.446	0.043	0.932	0.108	0.726
Urea x Kieserite	0.671	0.100	0.324	0.998	0.581	0.836	0.799	0.822	0.544
MOP x TSP	0.722	0.891	0.200	0.269	0.230	0.616	0.875	0.244	0.726
MOP x Kieserite	0.959	0.564	0.943	0.717	0.915	0.731	0.900	0.731	0.292
TSP x Kieserite	0.537	0.511	0.278	0.876	0.453	0.915	0.430	0.731	0.356
CV %	4.9	2.1	2.7	5.8	7.8	5.8	12.6	9.2	3.2

Table 49 Trial 220 effects (*p values*) of treatments on rachis nutrient contents in 2018

Source	Ash	N	P	K	Mg	Ca
Urea	0.177	0.130	0.046	0.327	0.368	0.402
MOP	p<0.001	0.006	0.002	p<0.001	0.050	0.011
TSP	0.446	0.108	p<0.001	0.116	p<0.001	0.324
Kieserite	0.128	0.002	0.186	0.260	0.530	0.174
Urea x MOP	0.934	0.424	0.685	0.578	0.175	0.915
Urea x TSP	0.841	0.806	0.974	0.512	0.521	0.436
Urea x Kieserite	0.237	0.196	0.585	0.401	0.237	0.502
MOP x TSP	0.340	0.107	0.115	0.657	0.075	0.449
MOP x Kieserite	0.676	0.175	0.841	0.975	0.231	0.792
TSP x Kieserite	0.938	0.062	0.455	0.334	0.683	0.970
CV %	10.3	7.2	18.3	11.0	12.2	12.0

Table 50 Trial 220 effects of treatments on leaflet tissue nutrient concentrations in 2018, p values <0.05 shown in bold

Treatments	Leaflet nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	13.5	2.55	0.140	0.76	0.19	1.11	**0.47**	17	0.20
Urea-2	13.4	2.57	0.141	0.75	0.18	1.11	**0.49**	17	0.20
Urea-3	13.6	2.58	0.140	0.75	0.18	1.09	**0.52**	17	0.20
Urea-4	13.7	2.57	0.143	0.74	0.18	1.12	**0.55**	17	0.20
l.s.d$_{0.05}$							*0.046*		
MOP-1	13.7	2.59	0.141	0.78	**0.18**	**1.05**	**0.44**	17	0.20
MOP-2	13.7	2.58	0.142	0.75	**0.19**	**1.13**	**0.50**	17	0.20
MOP-3	13.2	2.56	0.141	0.74	**0.18**	**1.11**	**0.52**	16	0.20
MOP-4	13.6	2.54	0.141	0.73	**0.18**	**1.15**	**0.57**	17	0.19
l.s.d$_{0.05}$					*0.010*	*0.046*	*0.046*		
TSP-1	13.6	2.55	**0.139**	0.75	0.18	1.12	0.50	17	0.20
TSP-2	13.5	2.58	**0.143**	0.74	0.19	1.11	0.51	17	0.20
l.s.d$_{0.05}$			*0.0019*		*0.007*				
Kieserite-1	13.6	2.56	0.141	0.75	**0.18**	1.12	0.50	17	0.20
Kieserite-2	13.5	2.58	0.141	0.75	**0.19**	1.10	0.51	17	0.20
GM	13.5	2.57	0.141	0.75	0.18	1.11	0.51	17	0.20
SE	0.666	0.053	0.0038	0.0435	0.014	0.064	0.064	1.55	0.0060
CV%	4.9	2.1	2.7	5.8	7.8	5.8	12.6	9.2	3.2

Table 51 Trial 220 effects of treatments on rachis tissue nutrient concentrations in 2018, p values <0.05 shown in bold

Treatments	Rachis nutrient contents (%DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	5.21	**0.300**	**0.063**	1.60	0.057	0.61
Urea-2	5.46	**0.311**	**0.070**	1.72	0.059	0.63
Urea-3	5.12	**0.292**	**0.062**	1.64	0.061	0.62
Urea-4	5.42	**0.300**	**0.074**	1.63	0.058	0.64
l.s.d $_{0.05}$		*0.0156*	*0.0088*			
MOP-1	**4.67**	0.284	**0.057**	**1.43**	**0.055**	**0.57**
MOP-2	**5.49**	0.307	**0.068**	**1.68**	**0.061**	**0.65**
MOP-3	**5.31**	0.302	**0.069**	**1.71**	**0.057**	**0.62**
MOP-4	**5.75**	0.311	**0.074**	**1.77**	**0.062**	**0.67**
l.s.d $_{0.05}$	*0.395*		*0.0088*	*0.131*	*0.0052*	*0.054*
TSP-1	5.37	0.296	**0.059**	1.69	**0.055**	0.62
TSP-2	5.23	0.305	**0.075**	1.61	**0.062**	0.63
l.s.d $_{0.05}$		*0.0110*	*0.0062*		*0.0036*	
Kieserite-1	5.43	**0.310**	0.069	1.68	0.058	0.64
Kieserite-2	5.18	**0.292**	0.065	1.62	0.059	0.61
GM	5.30	0.301	0.067	1.65	0.059	0.630
SE	0.548	0.0216	0.0122	0.181	0.0072	0.075
CV%	10.3	7.2	18.3	11.0	12.2	12.0

B.1.7.5. *Conclusion*

Responses to fertilizer treatments continued in third 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.

3. NBPOL, HIGATURU OIL PALM

Andy Samuel and Richard Dikrey

B.1.8. Trial 334: Nitrogen x Phosphorus Trial (Mature Phase) on Volcanic Ash Soils, Sangara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.8.1. *Summary*

There was little leaf P contents responses to P fertilizers in past trials on Higaturu Volcanic Ash soils however the leaf P contents had been falling with time to below critical levels. This trial was set up on the matured oil palm plantings to determine the optimum P and N supply rate and to determine critical P (or N/P ratio) deficiency level in leaflets and rachis of palms with differing N status in the matured palms. In 2016-2018, Urea significantly increased yield. 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. The trial closed at end of 2018.

B.1.8.2. *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 52.

Table 52 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	19	**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**	Andy Samuel and Richard Dikrey

B.1.8.3. *Methods*

Urea treatment was applied three times per year while TSP was applied twice a year (Table 53). Fertiliser applications started in 2007. Every palm within the trial field received basal applications of 1 kg Kieserite, 2 kg MOP and 100 g Borate. Yield recording, leaf tissue sampling and vegetative measurements are described in Appendix 1.

Table 53 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.1.8.4. *Results and discussion*

Effects of treatment on FFB yield and its components

Urea significantly (p=0.005) affected and increased FFB yield from 34.3 t/ha to 37.5 t/ha in 2016-2018 (Table 54 and Table 55). Urea also increased yield in 2018 but was not statistically significant. There was no effect of TSP on yield and yield components in both 2018 and 2016-2018. The mean FFB yield slightly increased from 34.2 t/ha in 2017 to 35.8 t/ha in 2018.

Table 54 Trial 334 effects (*p values*) of treatments on FFB yield and its components in 2018 and 2016-2018

Source	2018			2016-2018		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	0.059	0.200	0.528	**0.005**	0.093	0.222
TSP	0.243	0.123	0.322	0.280	0.059	0.398
Urea.x TSP	0.202	0.505	0.425	0.151	0.289	0.835
CV %	8.9	9.5	5.8	7.0	7.5	5.0

Table 55 Trial 334 main effects of treatments on FFB yield (t/ha) in 2018 and combined harvest for 2016-2018

Treatments	2018			2016-2018		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea-1	34.3	1217	28.2	**34.3**	1272	27.0
Urea-2	36.0	1273	28.4	**36.5**	1331	27.6
Urea-3	37.2	1295	28.9	**37.5**	1348	27.9
l.s.d$_{0.05}$				*1.89*		
TSP-1	35.9	1229	29.2	35.9	1287	28.0
TSP-2	36.4	1308	27.6	36.1	1340	26.9
TSP-3	34.4	1209	28.8	35.6	1295	27.7
TSP-4	37.7	1336	28.2	37.7	1396	27.1
TSP-5	34.9	1227	28.6	35.2	1266	27.9
GM	35.8	1262	28.5	36.1	1318	27.5
SE	3.18	119.3	1.66	2.52	96.6	1.38
CV %	8.9	9.5	5.8	7.0	7.5	5.0

p values <0.05 are shown in bold.

Effects of interaction between treatments on FFB yield

There was no significant interaction between Urea x TSP on FFB yield in 2018 (p=0.202) and 2016-2018 (p=0.151) (Table 54). However, two way table for the running average FFB yield for 2016-2018 is presented in Table 56. The highest yield of 39.9 t/ha was obtained at Urea-3 and TSP-1.

Table 56 Trial 334 effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2016-2018. The interaction was not significant (p=0.151)

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	34.3	34.1	32.4	36.2	34.3
Urea-2	33.6	37.5	36.0	39.6	35.9
Urea-3	39.9	36.6	38.5	37.4	35.3
Grand mean	36.1		sed=	2.06	

Effects of Urea and TSP treatments on leaf nutrient concentrations

Urea had significant effects on leaflet N, Ca and S and rachis P contents (Table 57 and Table 58). Urea increased leaflet N and S contents however lowered leaflet Ca and rachis P contents (Table 59 and Table

60). TSP increased rachis P contents only (Table 60). All leaflet and rachis nutrient concentrations were above their respective critical levels.

Table 57 Trial 334 effects (*p values*) of treatments on frond 17 leaflets nutrient concentrations 2018. *p values* <0.05 are indicated in bold

Source	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.662	**0.001**	0.758	0.077	0.235	**0.023**	0.577	0.384	**0.036**
TSP	0.212	0.857	**0.050**	0.834	0.136	0.568	0.790	0.792	0.694
Urea.TSP	0.447	0.325	0.368	0.405	0.195	1.00	0.630	0.770	0.335
CV%	4.6	3.5	2.8	7.2	10.4	9.3	7.8	17.8	3.4

Table 58 Trial 334 effects (*p values*) of treatments on frond 17 rachis nutrient concentrations 2018. *p values* <0.05 are indicated in bold

Source	Ash	N	P	K	Mg	Ca
Urea	0.663	0.180	**p<0.001**	0.416	0.545	0.201
TSP	0.296	0.312	0.179	0.101	0.320	0.768
Urea.TSP	0.629	0.917	0.450	0.474	0.126	0.477
CV%	7.3	10.5	16.9	9.5	15.5	12.1

Table 59 Trial 334 main effects of treatments on leaflet tissue nutrient concentrations in 2018

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	14.6	**2.27**	0.142	0.66	0.22	**0.89**	0.54	18	**0.17**
Urea-2	14.8	**2.29**	0.143	0.67	0.23	**0.87**	0.55	17	**0.17**
Urea-3	14.8	**2.38**	0.143	0.70	0.23	**0.81**	0.53	16	**0.18**
l.s.d $_{0.05}$		*0.061*				*0.060*			*0.004*
TSP-1	14.9	2.32	0.140	0.68	0.21	0.86	0.54	18	0.17
TSP-2	15.0	2.30	0.141	0.66	0.24	0.84	0.53	17	0.17
TSP-3	14.3	2.30	0.143	0.68	0.23	0.83	0.54	17	0.17
TSP-4	14.7	2.33	0.144	0.67	0.23	0.89	0.54	16	0.17
TSP-5	14.9	2.33	0.145	0.69	0.22	0.87	0.55	16	0.17
l.s.d $_{0.05}$			*0.0039*						
GM	14.8	2.31	0.143	0.67	0.23	0.86	0.54	17	0.17
SE	0.676	0.081	0.004	0.048	0.023	0.080	0.042	3.00	0.006
CV %	4.6	3.5	2.8	7.2	10.4	9.3	7.8	17.8	3.4

Effects with p<0.05 are shown in bold.

Table 60 Trial 334 main effects of treatments on rachis tissue nutrient concentrations in 2018

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	4.83	0.300	**0.200**	1.58	0.070	0.40
Urea-2	4.81	0.310	**0.191**	1.51	0.080	0.39
Urea-3	4.72	0.330	**0.139**	1.56	0.070	0.37
l.s.d$_{0.05}$			*0.022*			
TSP-1	4.68	0.300	0.160	1.48	0.070	0.38
TSP-2	4.77	0.320	0.168	1.57	0.080	0.38
TSP-3	4.87	0.300	0.183	1.61	0.080	0.39
TSP-4	4.66	0.320	0.179	1.48	0.080	0.38
TSP-5	4.97	0.330	0.194	1.63	0.080	0.40
l.s.d$_{0.05}$						
GM	4.79	0.310	0.177	1.55	0.070	0.39
SE	0.349	0.033	0.0299	0.147	0.0120	0.047
CV %	7.3	10.5	16.9	9.5	15.5	12.1

Effects with $p<0.05$ are shown in bold

B.1.8.5. *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 30 t/ha/year. There was no clear response to TSP and it was recommended P requirements have to be calculated to replace exported P. The trial closed at the end of 2018.

B.1.9. Trial 335. Nitrogen x TSP Trial on Outwash Plains Soils, Ambogo Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.9.1. *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 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 2018, 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.1.9.2. *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 61.

Table 61 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	11	**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**	Andy Samuel and Richard Dikrey

B.1.9.3. *Methods*

The Urea.TSP trial was set up as a 3 x 5 factorial arrangement, resulting in 15 treatments (Table 62). 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 62 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

B.1.9.4. *Results and discussion*

Yield and yield components

The effects of fertiliser on yield and its components are presented in Table 63 and Table 64. Urea had significant effect on FFB yield, the number of bunches and SBW in 2018 and 2016-2018. In 2018, FFB yield increased by 1.75 t/ha for every kg increase in Urea (Table 64). The average FFB yield increased from 31.5 t/ha in 2017 to 36.7 t/ha in 2018.

Table 63 Trial 335 effects (*p values*) of treatments on FFB yield and its components in 2018 and 2016-2018

Source	2018			2016-2018		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	**p<0.001**	**p<0.001**	**0.018**	**p<0.001**	**p<0.001**	**p<0.001**
TSP	0.890	0.933	0.973	0.154	0.563	0.933
Urea.x TSP	0.579	0.721	0.644	0.266	0.072	0.934
CV %	7.6	8.5	5.4	4.9	5.4	4.3

Table 64 Trial 335 main effects of treatments on FFB yield (t/ha) in 2018 and 2016-2018

Treatments	2018			2016-2018		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea-1	**33.4**	**1642**	**20.4**	**32.6**	**1716**	**19.2**
Urea-2	**36.6**	**1720**	**21.4**	**34.7**	**1744**	**20.0**
Urea-3	**40.2**	**1898**	**21.2**	**38.2**	**1860**	**20.7**
l.s.d$_{0.05}$	*1.78*	*95.2*	*0.72*	*1.107*	*61.0*	*0.551*
TSP-1	36.0	1722	21.0	34.3	1742	19.8
TSP-2	36.8	1772	20.9	34.8	1766	19.9
TSP-3	36.9	1747	21.2	35.2	1766	20.0
TSP-4	37.2	1766	21.1	36.0	1804	20.1
TSP-5	36.7	1759	20.9	35.5	1790	20.0
GM	36.7	1753	21.0	35.2	1773	19.95
SE	2.79	149.1	1.13	1.735	95.5	0.863
CV %	7.6	8.5	5.4	4.9	5.4	4.3

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of Urea x TSP on FFB yield components in 2018 and 2016-2018 (Table 63), however a 2-way yield results for 2016-2018 is presented here. FFB yields greater than 38 t/ha at high N rates were achieved TSP-2 and above (Table 65).

Table 65 Trial 335 effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2016-2018

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	32.8	33.1	31.8	32.5	32.8
Urea-2	34.0	33.1	35.1	36.1	35.2
Urea-3	36.0	38.4	38.7	39.5	38.5
Grand mean	35.2		s.e.d=	1.227	

Effects of Urea and TSP treatments on leaf nutrient concentrations

Urea had significant effect on leaflet Ash, N, Ca and S, and rachis N, P and Mg contents as presented in Table 66 and Table 67 for leaflets and rachis respectively. TSP had significant effect on rachis N and P. Urea increased leaflet Ash, N, P, Ca and S contents (Table 68). In the rachis, urea increased N contents however lowered the P contents (Table 69). TSP increased rachis N and P contents. Mean nutrient contents were above the critical nutrient contents.

Table 66 Trial 335 effects (*p values*) of treatments on frond 17 leaflet nutrient concentrations in 2018. *p values* <0.05 are indicated in bold

Source	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	**0.031**	**p<0.001**	0.229	0.082	0.301	**p<0.001**	0.124	0.561	**p<0.001**
TSP	0.065	0.217	0.243	0.616	0.503	0.134	0.745	0.491	0.321
Urea.TSP	0.311	0.421	0.794	0.969	0.324	0.366	0.699	0.189	0.234
CV%	5.9	2.6	2.3	6.0	7.4	5.3	6.2	10.9	2.6

Table 67 Trial 335 effects (*p values*) of treatments on frond 17 rachis nutrient concentrations in 2018. *p* values <0.05 are indicated in bold

Source	Ash	N	P	K	Mg	Ca
Urea	0.184	**p<0.001**	**p<0.001**	0.316	0.071	0.178
TSP	0.369	**0.022**	**0.043**	0.526	0.505	0.559
Urea.TSP	0.966	0.265	0.408	0.928	0.367	0.912
CV%	7.5	7.9	21.2	8.6	9.2	9.1

Table 68 Trial 335 main effects of treatments on F17 leaflet nutrient concentrations in 2018

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	**13.1**	**2.31**	**0.146**	0.78	0.25	**0.79**	0.51	21	**0.18**
Urea-2	**12.7**	**2.35**	**0.147**	0.79	0.25	**0.77**	0.49	20	**0.18**
Urea-3	**13.4**	**2.44**	**0.148**	0.75	0.24	**0.74**	0.49	21	**0.18**
l.s.d $_{0.05}$	*0.494*	*0.039*	*0.0021*			*0.026*			*0.003*
TSP-1	12.6	2.34	0.145	0.77	0.25	0.79	0.49	21	0.18
TSP-2	12.9	2.35	0.147	0.79	0.24	0.77	0.49	21	0.18
TSP-3	13.0	2.38	0.146	0.78	0.24	0.75	0.49	20	0.18
TSP-4	13.3	2.39	0.147	0.77	0.26	0.78	0.50	21	0.18
TSP-5	13.5	2.38	0.148	0.76	0.25	0.75	0.49	20	0.18
GM	13.1	2.37	0.147	0.77	0.25	0.77	0.49	21	0.18
SE	0.774	0.062	0.0034	0.046	0.018	0.04	0.0310	2.27	0.0050
CV %	5.9	2.6	2.3	6.0	7.4	5.3	6.2	10.9	2.6

Table 69 Trial 335 main effects of treatments on F17 rachis nutrient concentrations in 2018

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	4.76	**0.27**	**0.212**	1.60	0.070	0.33
Urea-2	4.58	**0.26**	**0.192**	1.54	0.070	0.31
Urea-3	4.77	**0.31**	**0.160**	1.58	0.070	0.32
l.s.d $_{0.05}$		*0.014*	*0.0255*			
TSP-1	4.69	**0.28**	**0.165**	1.60	0.070	0.32
TSP-2	4.58	**0.28**	**0.177**	1.55	0.070	0.31
TSP-3	4.86	**0.28**	**0.185**	1.59	0.070	0.33
TSP-4	4.76	**0.30**	**0.196**	1.60	0.070	0.32
TSP-5	4.64	**0.27**	**0.215**	1.52	0.070	0.32
l.s.d $_{0.05}$		*0.018*	*0.0329*			
GM	4.7	0.28	0.188	1.57	0.07	0.32
SE	0.354	0.022	0.0399	0.135	0.007	0.029
CV %	7.5	7.9	21.2	8.6	9.2	9.1

B.1.9.5. *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 30 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.

4. NBPOL, MILNE BAY ESTATES

Wawada Kanama and Jethro Woske

B.1.10. Trial 516: New NxK trial at Maiwara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.10.1. *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.1.10.2. *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 70.

Table 70 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	17	**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 and Jethro Woske

Basal fertiliser applied in 2018: 0.5 kg TSP

B.1.10.3. *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.1.10.4. *Results*

Yield data (2018 and 2016-2018) and leaf tissue nutrient contents for 2018 were analysed using multiple linear regression function in Genstat. The results are presented in Table 71. The regression significantly explained FFB yield response in 2018 and 2016-2018 and including bunch numbers in the later. With FFB yield in 2018 and three years mean FFB yield for 2016-2018 , 57.2 % and 81.6% of the variances were explained by the regression respectively. In the rachis, the regression significantly explained the response in rachis N (p=0.037) and rachis K (p<0.001) nutrient contents. The regression did not statistically explain differences in leaflet and rachis N and K nutrient contents. The regression also explained 59.3% and 94% of the rachis N and rachis K variances respectively.

Table 71 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 2018	5	**0.044**	57.2	2.66
BNO/ha 2018	5	0.054	54.3	74.9
SBW 2018	5	0.158	34.6	1.61
FFB yield 2016-2018	5	**0.003**	81.6	1.81
BNO/ha 2016-2018	5	**0.011**	72.2	70.0
SBW 2016-2018	5	0.107	42.8	1.29
Leaflet N contents	5	0.595	Residual variance> response variate	0.0695
Leaflet K contents	5	0.747	Residual variance> response variate	0.0787
Rachis N contents	5	**0.037**	59.3	0.0112
Rachis K contents	5	**p<0.001**	94.0	0.0790

FFB yield for the period 2016-2018 was chosen to develop a response surface. In 2016-2018, Urea appeared to explain significant (p=0.029) increase in FFB yield (Table 72).Yield was at 13.1 t/ha/year at nil fertilizer rates. Maximum yield of 30-35 t/ha was obtained at 3.7 kg to 5 kg Urea Urea/palm and at 3-8 kg MOP/palm (Figure 10).

Table 72 Trial 516 estimated coefficients for FFB yield in 2016-2018

Parameter	estimate	s.e.	t(7)	t pr.
Constant	14.55	2.7	5.38	0.001
Urea	3.74	1.37	2.73	0.029
MOP	1.424	0.973	1.46	0.187
Urea squared	-0.24	0.22	-1.09	0.311
MOP squared	-0.104	0.111	-0.93	0.383
Urea x MOP	0.003	0.208	0.01	0.989

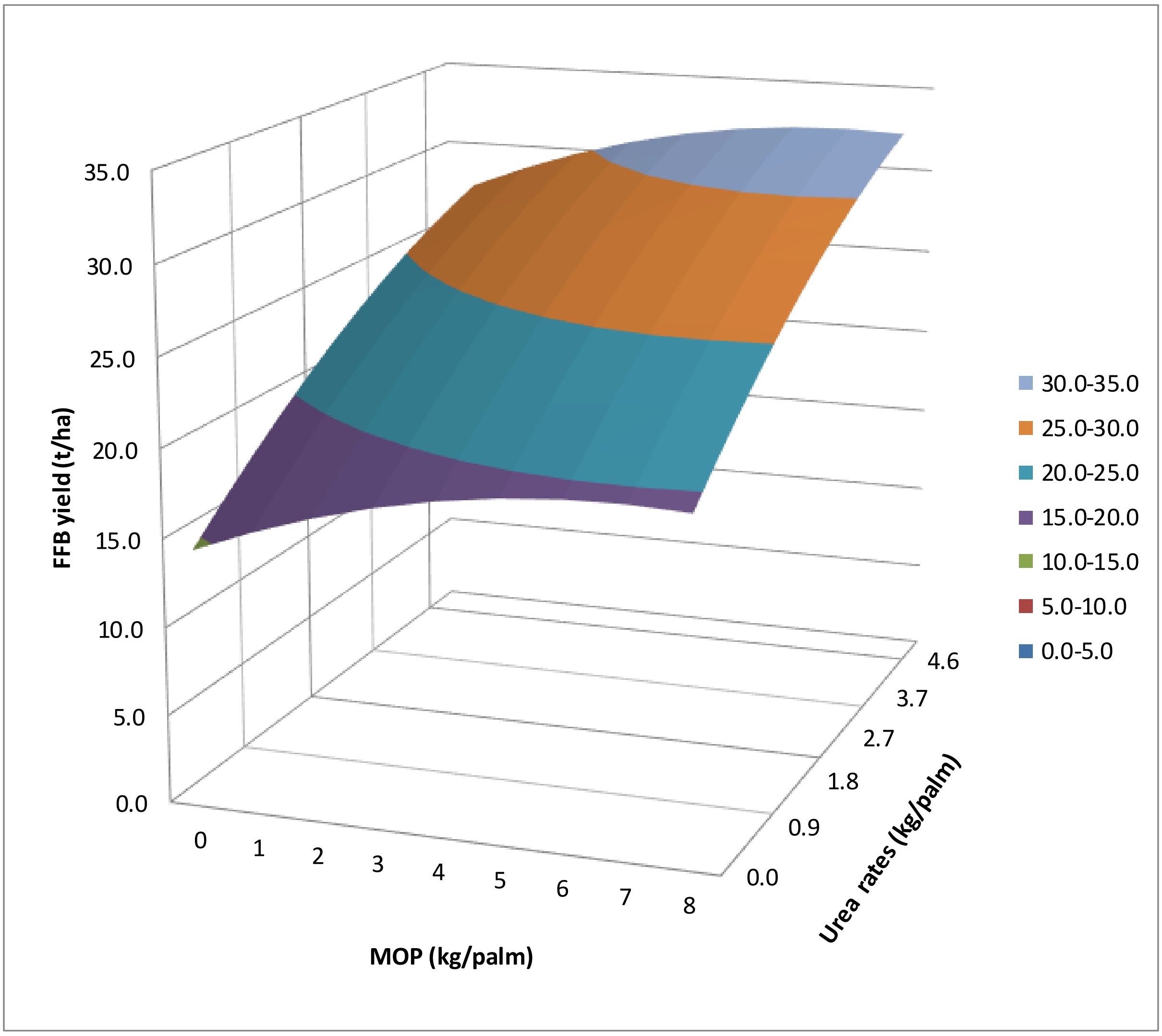

Figure 10 Trial 516 2016-2018 FFB yield surface for Urea and MOP combination

B.1.10.5. *Conclusion*

In 2018, Urea was more influential in determining yield response in the trial. Maximum yield of 30-35 t/ha/year was obtained at 3.7-5.0 kg Urea/palm/year and 3-8 kg MOP/palm/year. It was recommended the trial continued.

5. NBPOL RAMU AGRI INDUSTRIES LIMITED

Stanley YANE

B.1.11. Trial 605: NPKCl fertiliser response trial on super clonal materials at Gusap Estate Division 3-RAIL

(RSPO 4.2, 4.3, 4.6, 8.1)

1. Summary

Oil palm fertiliser management in RAIL is different to other sites in PNG because of the distinct monthly rainfall weather pattern. The trial was established with the aim to provide information for fertiliser recommendation in RAIL and neighbouring areas with similar climatic and soil conditions. Pretreatment vegetative data showed large CV% suggesting large differences between palms and progenies. There was delay in flowering until 18 months after field planting when first flowers at anthesis were recorded. The trial to continue.

B.1.11.1. *Introduction*

The plantation industry is currently planting new selected semi clonal materials at all sites in PNG and Solomon Islands. Four selected materials were planted and replicated in all the sites for fertiliser trials which were to be used to generate information for fertiliser recommendations. The materials are high yielding and therefore high in nutrient demand to meet crop growth and FFB production demand. RAIL differs from the other oil palm growing areas with 6 months of monthly rainfall amounts less than 150 mm. Because of the dry growing environment, fertiliser management practices are different from the other oil palm growing areas. This trial is aimed to provide information for fertiliser recommendations in RAIL and other neighbouring areas with similar soil and climatic conditions. Trial information is presented in Table 73.

Table 73 Trial 605 background information

Trial number	**605**	**Company**	**RAIL Gusap Estate- Impu Div. 3**
Estate	Gusap	Block no.	Impu 1211-1211
Planting density	136 palms/ha	Soil type	Alluvial
Pattern	Triangular	Drainage	Freely Draining
Date planted	Feb-17	Topography	Flat
Age after planting	2 year	Altitude	
Recording start	2017	Previous Land- Use	Sugar Cane
Treatment start	Not yet	Area under trial soil type (ha)	27.2
Progeny	Known	Assistant Agronomist in charge	Stanley Yane
Planting material	Dami DxP		

B.1.11.2. *Method*

Experimental design and treatments

The trial was planted with four progenies; SF46.01, SF21.11, SF108.07 and SF08.06 in plots of 36 palms. Each plot consisted of nine of each of the four progenies however only the 16 core palms in the plots (four of each of the progenies) were to be recorded while the surrounding 20 palms remained as guard row palms. A total of 76 plots were planted.

In addition to the 76 plots, four plots of single progenies were planted, bringing the total number of plots to 80 plots. The four additional plots were to be used for flower monitoring. Weekly recording of male and female flowers at anthesis started in July 2018, 18 months after field planting. The palms received the immature plantation fertiliser types and application rates. The palms were immature and no particular trial design was in place for the trial as yet.

Data collection

Vegetative growth parameters including frond length (FL), petiole cross section (PCS) and leaflet dimensions were measured on frond 3 in June 2018 and January 2019. The leaflet dimensions were measured to determine frond area (FA) and leaf area index (LAI).

B.1.11.3. *Results*

The results of measured vegetative parameters for the four different progenies across all plots are presented in Table 74 and Table 75 for June 2018 and January 2019 respectively. Means of all measured parameters increased from June 2018 to January 2019 except for total frond production. There appears to be little difference between the means of the measured parameters however large CV values for both June 2018 and January 2019 suggests large variation within and between the progenies.

Table 74 Trial 605 vegetative growth parameters for the different progenies across all plots in June 2018

	Physiological growth parameters				
Progenies	FL (cm)	PCS (cm^2)	TFC	FA (m^2)	LAI
SF46.01	136.6	3.19	19.1	0.87	0.22
SF21.11	134.6	3.24	18.4	0.90	0.22
SF108.07	135.5	3.19	18.9	0.87	0.23
SF08.06	136.2	3.18	18.4	0.90	0.23
Mean	135.7	3.21	18.7	0.87	0.22
Min	52.6	1.05	11.0	0.31	0.08
Max	188.0	7.80	25.0	1.68	0.50
std dev	16.60	0.822	2.68	0.212	0.067
CV%	12	26	14	25	30
n	1077	1274	1279	1063	1062

Table 75 Trial 605 vegetative growth parameters for the different progenies across all plots in Jan 2019

	Physiological growth parameters				
Progenies	FL (cm)	PCS (cm^2)	TFC	FA (m^2)	LAI
SF46.01	142.2	4.11	19.0	0.93	0.24
SF21.11	141.3	4.16	18.6	0.97	0.25
SF108.07	141.5	4.12	18.8	0.97	0.25
SF08.06	144.9	4.08	18.4	0.97	0.25
Mean	142.5	4.12	18.7	0.96	0.25
Min	72.8	0.84	11.0	0.29	0.05
Max	200.5	9.25	25.0	1.97	0.61
std dev	24.23	1.367	2.64	0.275	0.092
CV%	17	33	14	29	37
n	1223	1265	1277	1181	1181

Flower census

Flowering monitoring data from July 2018 (18 months after field planting) to May 2019, a total of 43 weeks data is presented here.

There was a delay in flowering until after 18 months from month of planting (Figure 11 and Figure 12). There was a further delay in female flowers coming to anthesis for 21 weeks (Figure 11). Progeny SF108.07 appears to have the least number of female flowers at anthesis from week 26 to 43. Progeny SF46.01 has high female flowers at anthesis from week 34 to 43 compared to the other 3 progenies. There appears to be no differences between the number of male flowers at anthesis between the four progenies (Figure 12).

The sex ratio (proportion of female flowers at anthesis to total flowers) started increasing after week 23 (Figure 13). The ratio ranged from 0 to 50 % with an increasing trend after week 23.

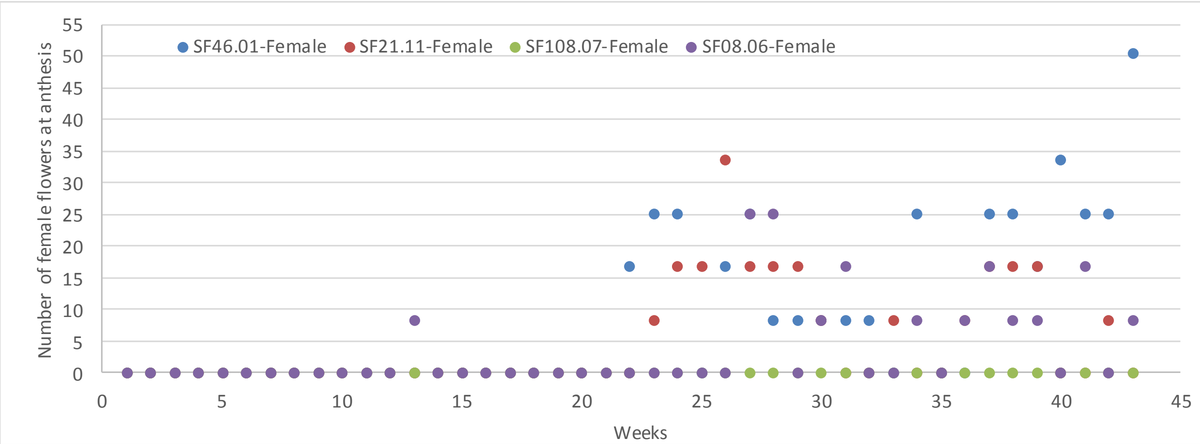

Figure 11 Trial 605 number of female flowers/ha at anthesis from July 2018 to May 2019

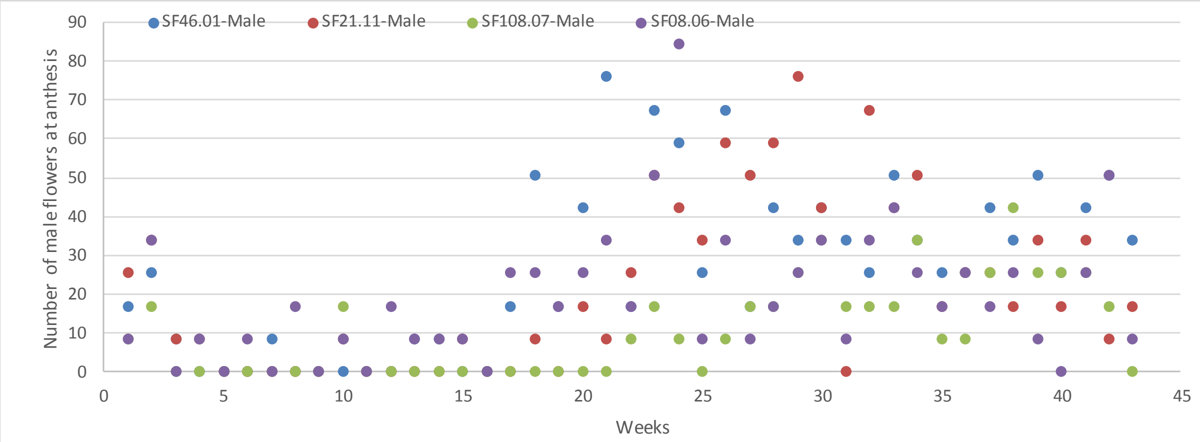

Figure 12 Trial 605 number of male flowers/ha at anthesis from July 2018 to May 2019

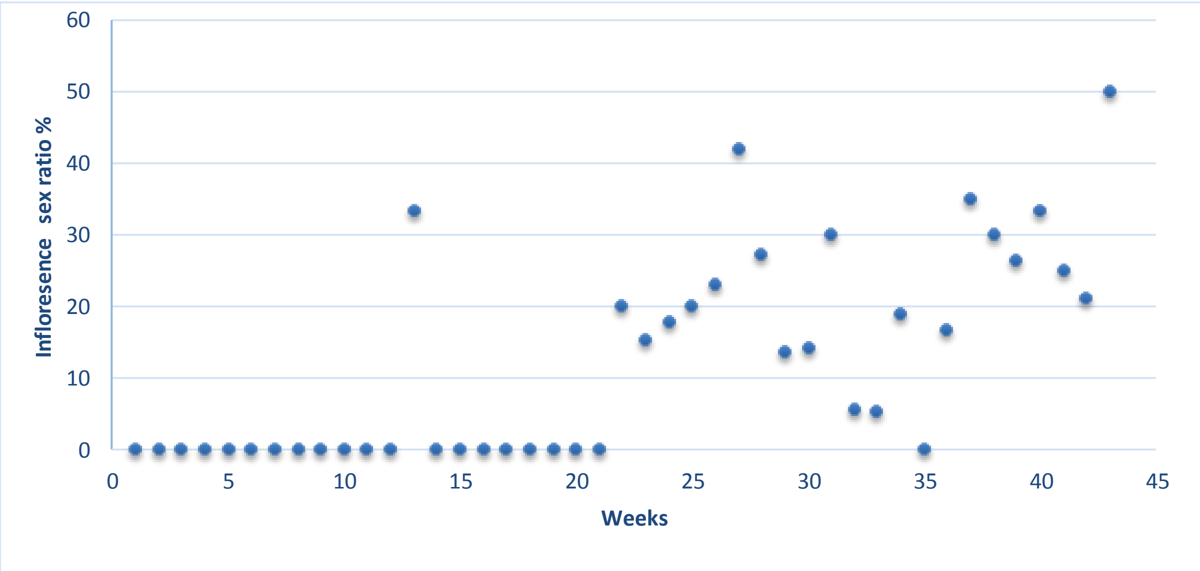

Figure 13 Trial 605 mean inflorescence sex ratio from July 2017 to May 2019

B.1.11.4. *Conclusion*

The measured physiological growth parameters were highly variable. The palms came into flowering 18 months after field planting. The trial to continue.

6. NBPOL, GUADALCANAL PLAINS PALM OIL LIMITED

JAYDITA PUE

B.1.12. Trial 703: NPKCl fertiliser response trial on super clonal materials at Tetere Plantation - GPPOL

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.12.1. *Summary*

Selected oil palm progenies were planted throughout the oil palm industry for fertilizer trials to generate information for fertilizer recommendations. The petiole cross section measurements indicate differences between progenies and also trend in difference in soil conditions. The sex ratio increased towards 90% after 65 week of recording. The trial to continue.

B.1.12.2. *Introduction*

The plantation industry is currently planting new selected semi clonal materials at all sites in PNG and Solomon Islands. Four selected materials were planted and replicated in all the sites for fertiliser trials which were to be used to generate information for fertiliser recommendations. The materials are high yielding and therefore high in nutrient demand to meet crop growth and FFB production demand. GPPOL is on alluvial four generally major soil types commonly flood plain soils. This trial is aimed to provide information for fertiliser recommendations in GPPOL and other neighbouring areas with similar soil and climatic conditions. Trial information is presented in Table 73.

Table 76 Trial 605 background information

Trial number	**605**	**Company**	**GPPOL**
Plantation	Tetere	Block no.	
Planting density	128 palms/ha	Soil type	Alluvial flood plain
Pattern	Triangular	Drainage	Freely Draining
Date planted	March-April 17	Topography	Flat
Age after planting	1 year	Altitude	
Recording start	2017	Previous Land- Use	Oil Palm
Treatment start	Not yet	Area under trial soil type (ha)	
Progeny	Known	Supervisor in charge	Jaydita Pue
Planting material	Dami DxP		

B.1.12.3. *Method*

Experimental design and treatments

The trial was planted with four progenies; SF46.01, SF21.11, SF108.07 and SF08.06 in plots of 36 palms. Each plot consisted of nine of each of the four progenies however only the 16 core palms in the plots (four of each of the progenies) were to be recorded while the surrounding 20 palms remained as guard row palms. A total of 75 plots were planted.

In addition to the 75 plots, three plots of single progenies were planted, bringing the total number of plots to 78 plots. The three additional plots were to be used for flower monitoring for three of the progenies. For the fourth progeny, monitoring is done on 9 of the palms in a neighbouring plots. A fourth . Weekly recording of male and female flowers at anthesis started in January 2018, 10 months after field planting. The palms received the immature plantation fertiliser types and application rates. The palms were immature and no particular trial design was in place for the trial as yet.

Data collection

Rachis thickness and width were measured to determine petiole cross section (PCS) on frond 17 in June 2018 and November 2018.

B.1.12.4. *Results and discussion*

Petiole cross section measurements

The petiole cross section data is summarized in Table 77. There was no differences between the progenies however SF08.06 had the lowest petiole cross section area. The large CV values suggest large variation between palms and between the progenies.

Table 77 Trial 703 petiole cross section measurements (cm^2) for months of June 2018 and November 2018

Progenies	Jun-18	Nov-18
SF46.01	7.3	8.0
SF21.11	7.2	8.2
SF108.07	7.2	8.1
SF08.06	7.0	7.7
Mean	7.2	8.0
Min	1.8	2.5
Max	17.1	20.4
Std	1.37	1.85
CV %	19	23

The mean petiole cross section of all the plots are presented in Figure 14. There appears to be differences from plot 1 to plot 78 suggesting differences in the soil conditions which will be taken into consideration in the trial design.

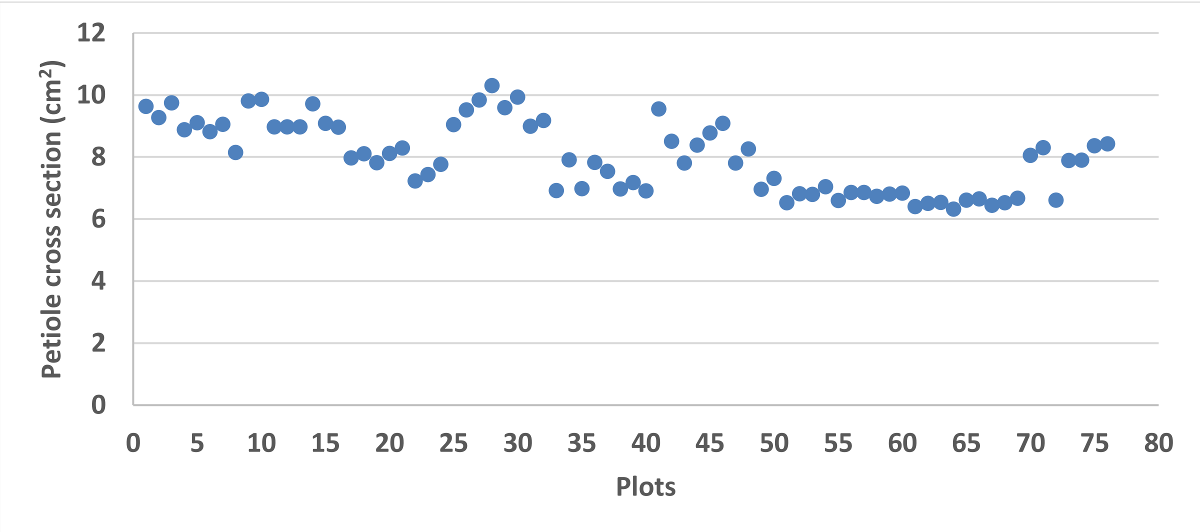

Figure 14 Trial 703 mean petiole cross section across all plots in November 2018.

Flower census

There was no difference between the female flowers at anthesis however the number of flowers increase with time Figure 15.

There was also no difference between male flowers of the different progenies however there was a downward trend after week 40 (Figure 16).

The mean sex ratio of the palms started increasing after week 40 towards 90% in week 65 (Figure 17).

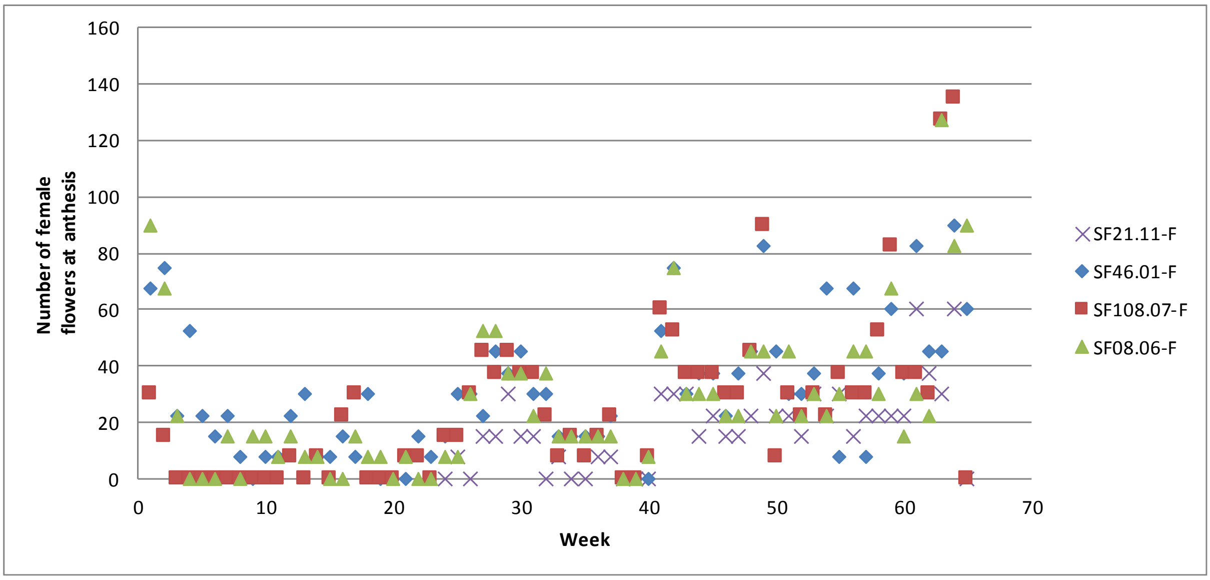

Figure 15 Trial 703 number of female flowers/ha at anthesis from January 2018 to March 2019

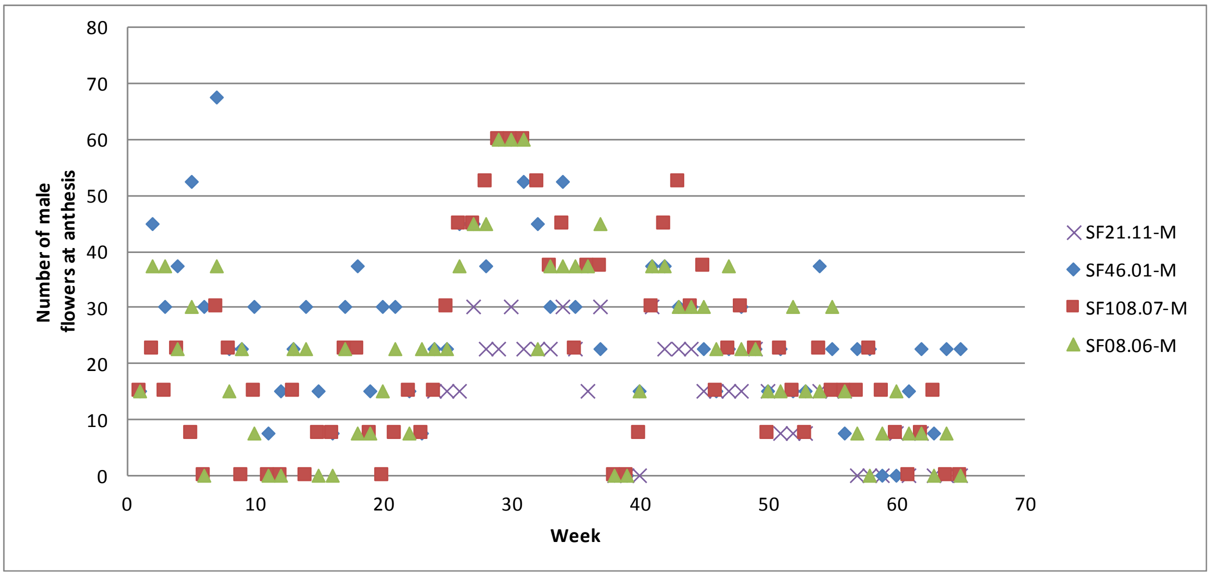

Figure 16 Trial 703 number of male flowers/ha at anthesis from January 2018 to March 2019

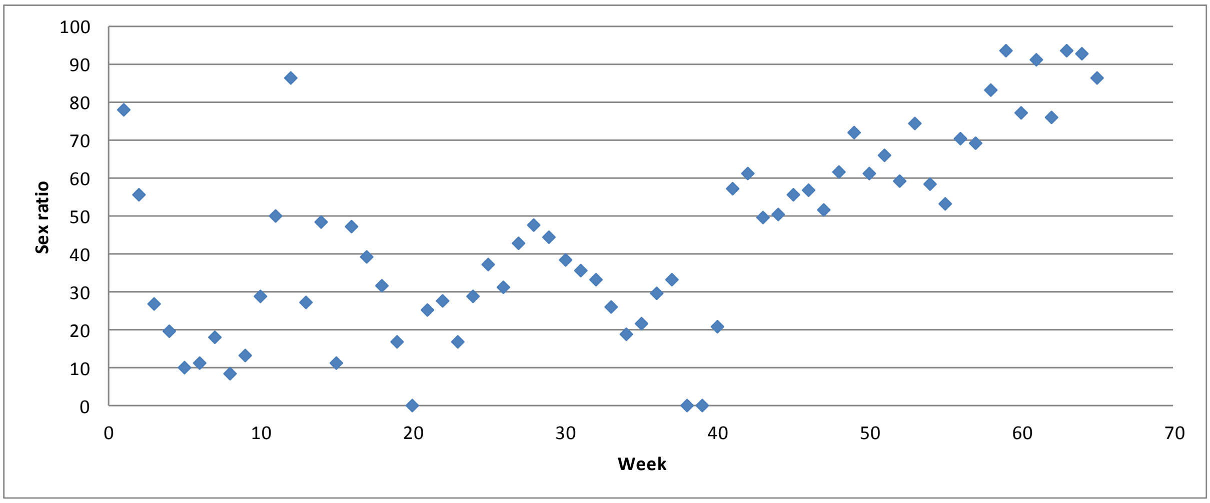

Figure 17 Trial 703 mean inflorescence sex ratio from January 2018 to March 2019

B.1.12.5. *Conclusion*

Progeny SF08.06 is different from the other three progenies. There is variation in the growth of the palms reflecting differences in the field conditions. The sex ratio is increasing with time towards 90%. The trial to continue.

B.2. APPENDIX

Appendix 1 Field trials operations

Fresh fruit bunch yield recording

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

Leaf tissue sampling for nutrient analysis

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

Vegetative measurements

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

Trial maintenance and upkeep

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

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

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

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

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

d) Scales are checked against a known weight once a week.

e) Other tools are inspected to ensure there are no defects before using them.

f) Field data is checked by supervisors and agronomists before passing them to data entry clerks for data entry. Data base entry checks are done prior to commencement of data analysis and report writing for each year to ensure that no wrong entries of dates, unusual figures, and all data are captured in the system.

g) All samples sent for analysis have standard samples sent along with to ensure data results are within the accepted range.

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 member milling companies and smallholder oil palm growers in the country.

The key pests reported frequently during the year that required regular management intervention remained to be the 3 species of Sexavae (*S. decoratus*, *S. defoliaria*, *S. gracilis*) and 1 species of stick insect (*E. calcarata*). *Segestes decoratus* and *Segestidea defoliaria* occur in WNB whilst *S. gracilis* occurs in New Ireland. *Eurycantha calcarata* occurs in both WNB and New Ireland.

With methamidophos now been gradually phased out, only Dimehypo was used for most of the TTI during the year. Slightly less insecticide was applied (through TTI) in 2018 (7,034L) than those applied in 2017 (8,483L). This is 1,449L less. Between the Smallholders and the Plantations, the Smallholders used slightly more insecticide (3,900L) than the Plantations (3,135L). Higher volume of insecticide used in plantation was in Milne Bay (1,511L) for Coconut Flat Moth (CFM) control. Around 73% (5,138L) of the insecticides was used in WNB to control both Sexavae and Stick Insects. The main reason for further decline in the volume of insecticide applied continued to be the maintenance of effective monitoring and reporting system, where infestations were reported earlier and treated in smaller areas with further spread contained. The penalty system introduced for smallholder growers with poorly sanitised blocks also helped minimise the rate of re-infestation.

The biological control agent release programme in WNB was affected by the collapse of most lab cultures towards the back end of 2017 due to mite infestation. Only *D. leefmansi* was re-established with routine field releases done. Approximately 6.4 million *D. leefmansi* were field released. Efforts will be put into reviving the other biocontrol agents in the new year.

The field parasitism and predation rate of sexavae eggs and the infection of adult *S. novaeguineae* by an Internal Abdominal Parasite (IAP) in the field in WNB and Popondetta respectively was high. This potentially contributed towards the suppression of the pest population in the field.

As was the case in 2017, *Oryctes rhinoceros* (CRB-S[3]) 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. These efforts were augmented by natural Oryctes *NudiVirus* infection. The incursion of the Guam biotype (CRB-G) *O. rhinoceros* at Guadalcanal Plains Palm Oil Ltd (GPPOL) in the Solomon Islands continued to prove to be a major challenge. Various control options including pheromone trapping, and mechanical and chemical control options were explored for its management. Incursion in PNG is still confined to NCD and the Central Province. It has not got into oil palm areas but is thought to gradually spread along both the east and west coastlines. If nothing is done to prevent the spread, it will only be a matter of time before the population enters the oil palm catchment areas. Research into the search for effective biocontrol agents continued.

Pheromone trap monitoring for CRBin Milne Bay and Northern Provinces continued throughout the year. No *O. rhinoceros* were caught in any of the traps. The activity will continue into the new year.

[3] S for *Samoan* biotype which is the homonym of the *Pacific* biotype

RAIL maintained the pheromone traps within the Markham Valley. With the confirmation of biotype to be CRB-S, seven males dosed with Oryctes *NudiVirus* were released adjacent to Markham Farms where infestation was also detected. Establishment of the virus will be monitored over time and more infected beetles can be released if deemed necessary..

Weed control continued with *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 continued. At Wandoro, 141 immature stands were treated/uprooted. This is 997 less than those treated/uprooted in 2017. For Numondo, the number treated/uprooted increased from 721 to 1,372 (651 more). The increase is due to improved surveillance further extending the area of survey downstream of the creek where the infestation is concentrated. The activity will continue until the weed is eradicated from the sites. In Northern Province 51,015 biocontrol agents (*Acanthoscelides* spp.) were released. Post release monitoring for 4 selected sites were done. The agents were establishing but in low numbers. The main reason for slow establishment was destruction to the weeds particularly from bush fires in the grassland and flooding along the rivers. The release programme was terminated at the end of year but the post release monitoring will continue into the new year (2019).

For the research projects, the results of only the completed and partially completed research projects have been presented in this report. These include the results of the CRB management study in WNB and a small Laurel/Trumpet vine management study that was conducted at Mamba Estate, Higaturu Oil Palms (HOP).

Legume cover crops fully established over the fallen palm trunks within 4 months after planting. The fallen palm trunk decomposition process is slow taking more than one year. Pheromone trapping of CRB-P at the density of 1 per 2ha was found to be effective with the population effectively suppressed within the first 4 months after trap set up. Natural field infection by the *NudiVirus* was high and this contributed towards the control of the infestation.

Both Glyphosate and Imzapyr effectively killed the Laurel/Trumpet vine through the slash and spray application method, despite the difference in the rate of action where Glyphosate killed faster than Imazapyr. Additinally, glyphosate is cheaper at around K7.00/L than Imazapyr at K13.00/L.

Sharon Agovaua enrolled for an MPhil programme at PNG University of Technology. She is expected to complete the studies at the end of 2019.

C.2. ROUTINE PEST REPORT AND THEIR MANAGEMENT

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

As is often the case, the most commonly reported pests were S. defoliaria (33%), E. calcarata (33%) and S. decoratus (22%). Sporadic pests recorded during the year, apart from the common pests included O. rhinoceros, Agonoxena sp., S. novaeguinea, Valanga sp., O. latitarsus, S. australis, M. corbetti, E. variegata and Dermolepida sp. The reports of each of these pests constituted less than 5% (Figure 18). GPPOL continued to battle the incursion of the Guam biotype Coconut Rhinoceros Beetle (CRB-G), whilst the common population (CRB-S) was occasionally encountered in replants at Poliamba Estates (NI) and Numondo Plantation (WNB). Coconut Leaf Miner (CFM), *Agonoxena* sp. infestation was intermittently encountered at Milne Bay Estates sometimes requiring TTI for its management when infestation levels were moderate to severe. The Root Chafer Beetle (*Dermolepida* sp.) recurred at Embi Estate (Higaturu Oil Palms) in Popondetta. Infestation level was moderate and TTI was recommended. Only one new pest was recorded this year from Kerakera Division, Hargy Plantation (Hargy Oil Palms Ltd). It was *Oryctoderus latitarsis* (Coleoptera: Scarabaeidae) observed causing concentrated damage to fruit bunches in Field 11. The damage was scattered throughout the field but sporadic on a few palms.

The control of the beetle was through manual removal of damaged fruit bunches and killing of the beetles. The beetle, although common has never been recorded as a pest of oil palm. It was first detected in October and dropped off by the end of the year (December).

The proportion (%) of pest infestations reported per month fluctuated throughout the year (Figure 19). Highest proportion of reports was received in May (17%) followed by March (13%), August (11%), October (11%), April (10%) and January (8%). The least number of reports were received in December (2%).

Across the sites, most of the report was from WNB constituting 88% of the reports (Figure 20). Poliamba and MBE had 6% and 5% of the reports respectively, whilst only 1% of the reports was from Higaturu. WNB reports covered those from both NBPOL and Hargy Oil Palms Ltd. The highest proportion of pest infestation reports coming from WNB was expected as all of the regular pests occur within the province with recurrent infestation encountered over time.

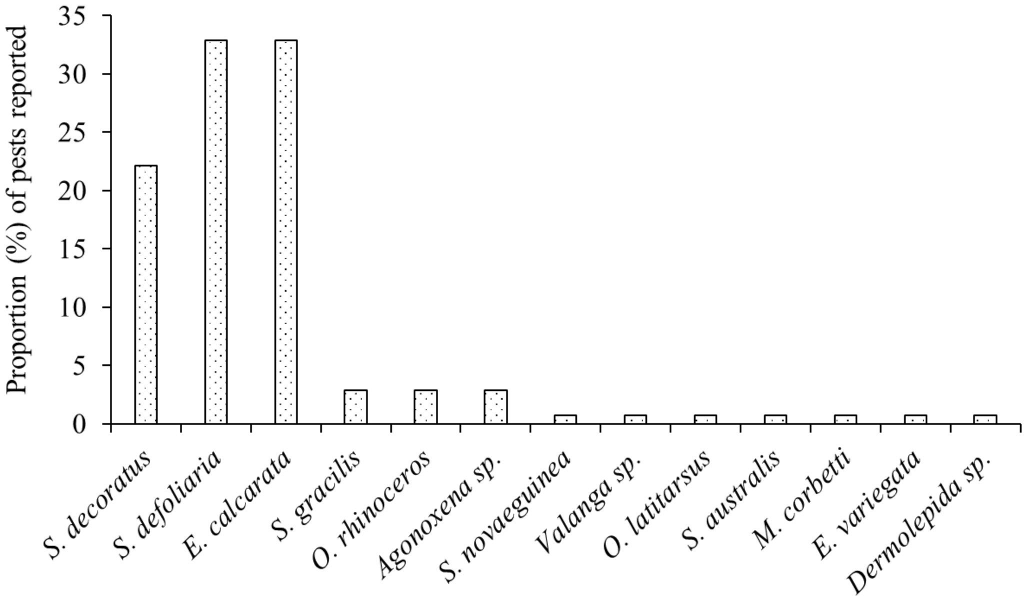

Figure 18. Proportion (%) of different pests reported during the year.

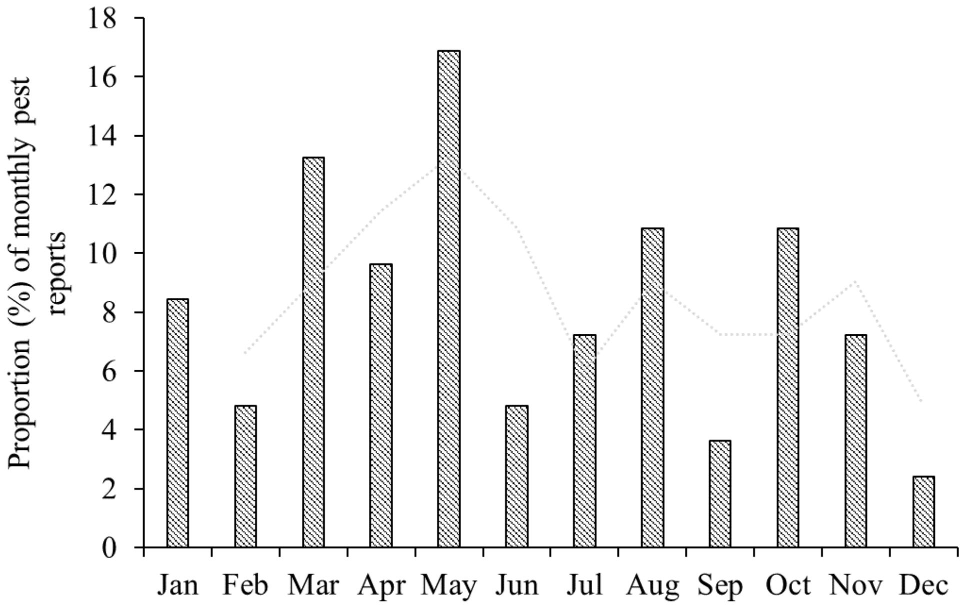

Figure 19. Proportion (%) of infestation reports received per month throughout the year.

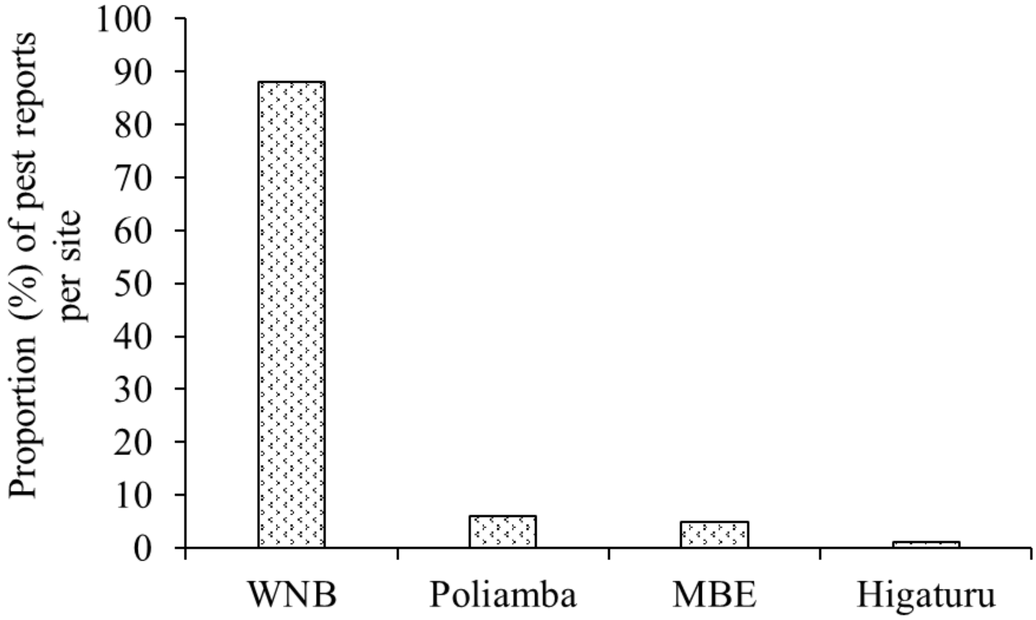

Figure 20. Proportion (%) of infestation reports received from different sites during the year.

C.2.2. Pest damage levels, management recommendations and targeted trunk injection (TTI) in 2018

The most common pest species that were treated using insecticide in 2018 included *S. decoratus* (Sexavae), *S. defoliaria* (Sexavae), *S. gracilis* (Sexavae) and *E. calcarata* (Stick Insect). These pests were mainly treated from WNB and NI. The West New Britain records cover both Hoskins (NBPOL) and Bialla (Hargy Oil Palms Ltd) Projects. Apart from these, *Agonoxena* spp. (Coconut Flat Moth) was treated in Milne Bay. Ramu (RAIL) maintained its own treatment records, thus the report from there is not captured.

Treatment through Targeted Trunk Injection (TTI) was only done in blocks with 'moderate' to 'severe' levels of infestation. Areas with 'light' infestation levels were recommended for monitoring. Dimehypo™ was mostly used for the treatment as Methamidophos has been gradually phased out. SAN certification prohibits the use of Methamidophos in all its certified plantations and smallholder blocks.

Slightly lower volume of insecticide was used in 2018 (7,034L) than 2017 (8,483L). This was 1,449L less than the volume used in 2017. As has been the case earlier, smallholders used more volumes of insecticide (765L more) than the plantations. Smallholders used 3,900L whilst the plantations used 3,135L. For smallholders, all chemical application was done in WNB. Lesser volume of insecticide was applied in plantations for both WNB (1,238L) and NI (385L). Higher volume of insecticide used in plantation was in Milne Bay (1,511L) for Coconut Flat Moth (CFM) control, and this constituted all of the insecticides used on the mainland. The main reason for further decline in the volume of insecticide applied continued to be the maintenance of effective monitoring and reporting system, where infestations were reported earlier and treated in smaller areas with further spread contained. The penalty system introduced for smallholder growers with poorly sanitised blocks also helped minimise the rate of re-infestation.

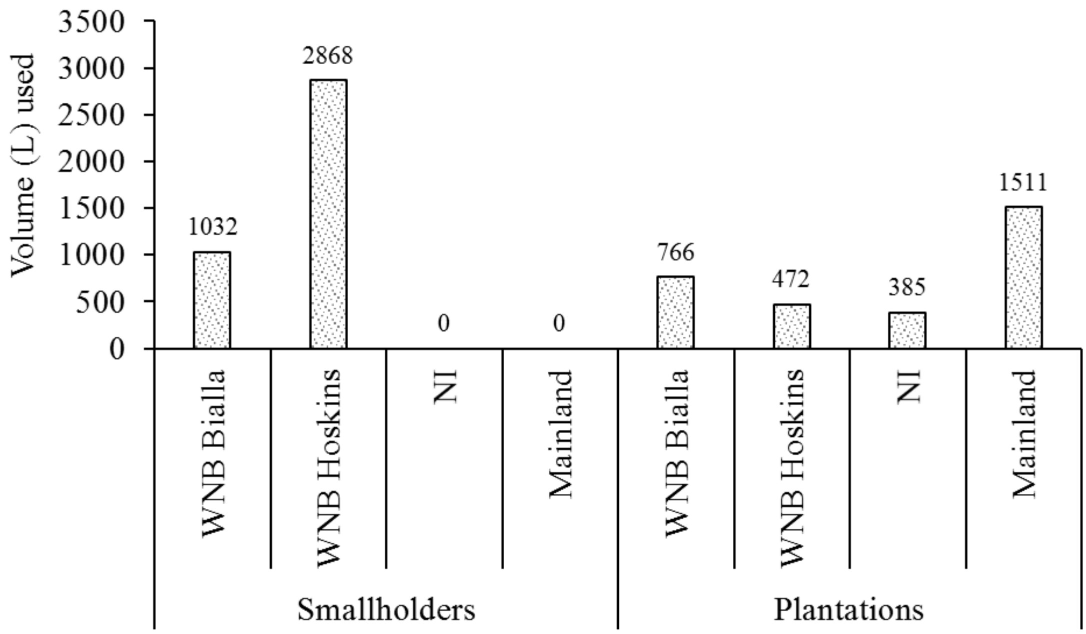

Figure 21. Volumes (L) of Dimehypo™ used in Plantations and Smallholder blocks in 2018.

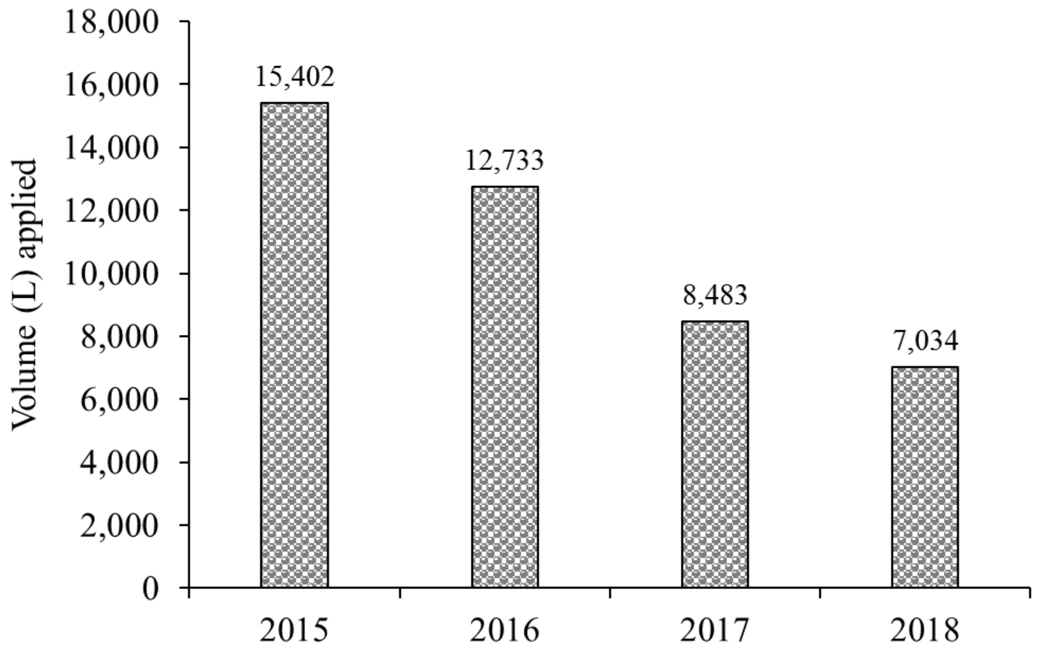

Figure 22. Volume (L) of Dimehypo™ used between 2015 and 2018.

C.2.3. Biological control agent releases

There are 4 biological control agents (*Stichotrema dallatorreanum* for adult and nymph *S. defoliaria* (Sexavae), *Anastatus eurycanthae* for the eggs of *E. calcarata* [stick insect], *Doirania leefmansi* and *Leefmansia bicolor* for all Sexavae eggs) that is normally maintained in the laboratory at Dami for mass rearing and augmentative field releases in WNB.

Unfortunately, only *Doirania leefmansi* was consistently maintained and released. The cultures of the other two egg parasitoids (*A. eurycanthae* and *Leefmansia bicolor*) collapsed at the end of the previous year and no releases were done. Attempts to re-establish the cultures with collections from the field continued throughout the year but without success. The efforts will continue into the new year including baiting of the parasitoids using eggs reared in the lab. Only two releases of *S. dallatoreanum* was done due to the collapse of the field population (where stock is normally sourced for stocking and release), due to the improvements in the routine monitoring and timely treatment programmes. There is also a need to increase the rearing facility to maintain the ongoing cultures of the biological control agents. Capex has been approved for the extension to the extension to the rearing lab for the new year and this should help improve the rearing and release programme.

A total of approximately 6.4 million *D. leefmansi* were released during the year. This agent also collapsed towards the end of 2017, and active field release programme started in March and continued throughout the year (Figure 23) after the agent culture was re-established from field collected eggs. The rearing and release programme for this agent will continue into the year whilst attempts will be made to re-establish the other agents.

Field releases of the laboratory reared biological control agents are necessary to augment the wild natural enemy populations to sustainably suppress the target pest populations in the field.

Apart from the biocontrol agent releases, Sexavae eggs were sampled weekly from all OPIC Divisions (Buvussi, Kavui, Nahavio, Salelubu, Siki) within Hoskins Project to determine parasitism and predation levels. Active sampling for all divisions started about 2013 and this data is captured here.

Generally, the levels (%) of parasitism and predation remained high for all divisions across the years sampled. The proportion of unhatched eggs remained low throughout most of the years except for Salelubu Division in 2013 and Siki Division in 2016 where the proportion of unhatched eggs were higher (close to 50%) than the proportions of parasitized and predated eggs (Figure 24).

Between the proportion of eggs parasitised and predated, the proportions fluctuated between the two over the years. In 2018, the proportion of parasitised eggs was generally higher than the proportion of predated eggs for all divisions as was the case in 2017 (Figure 24).

Since Sexavae (*Segestidea novaeguineae*) infestation in Popondetta always remains low over many years, monthly sampling was continued in smallholder blocks in 2018 to determine the potential impact of the natural enemies to the pest population. The sampling data showed that an average of 59% infection was attained by the internal abdominal parasites- IAP (*Stichotrema dallatoreanum* and Tachnid fly) (Table 78). The high level of parasitism has been potentially contributing towards the suppression of the pest population in the field.

Both the Hoskins Project egg sampling and Popondetta project adult sampling data show that there were high levels of natural enemy activities in the field potentially contributing towards the natural suppression of the pest populations. The natural enemies need to be continued to be promoted as part of the IPM programs for the sustainable management of the pests. The beneficial weeds play a critical role in the sustenance of parasitoid populations, and will also need to be promoted as part of the oil palm cropping system.

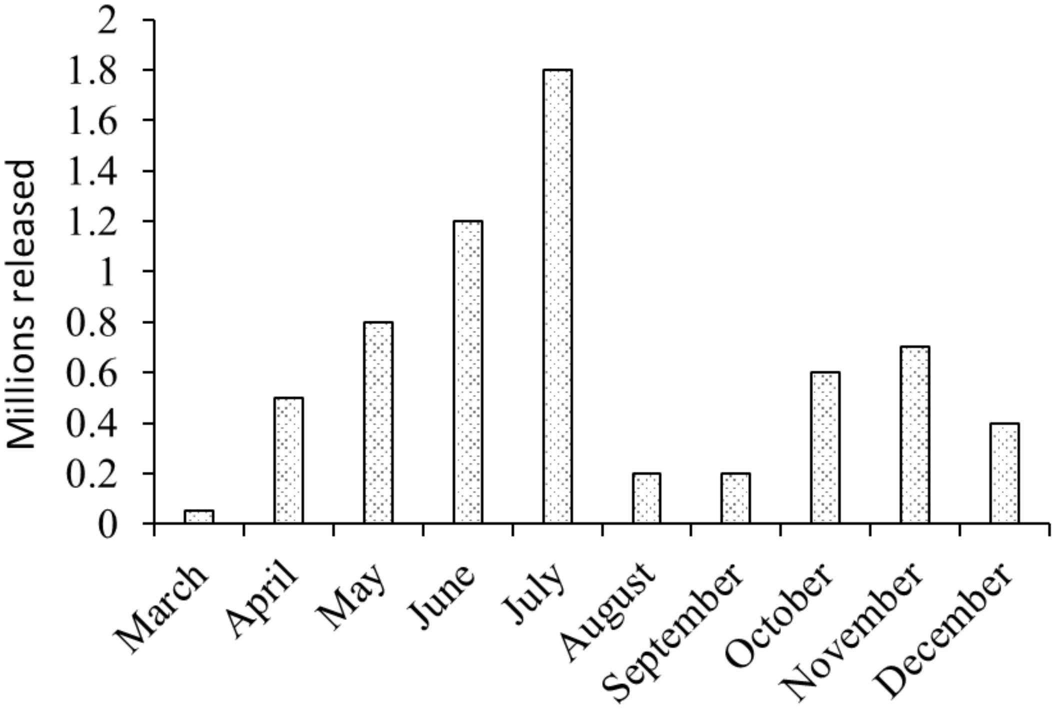

Figure 23. Estimated number (in millions) of *D. leefmansi* field released in WNB during the year for the control of Sexavae through egg parasitism.

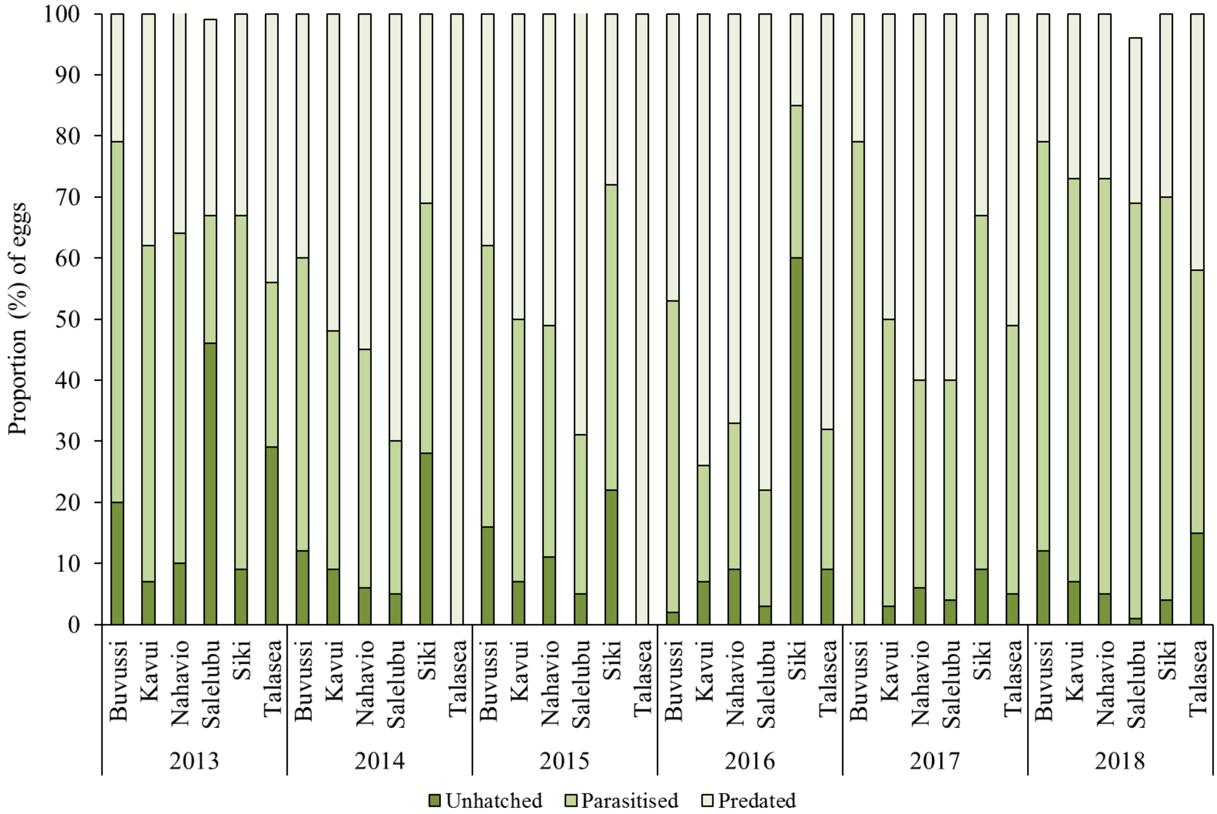

Figure 24. Proportion (%) of different categories of Sexavae eggs sampled in Hoskins OPIC Project Divisions (Buvussi, Kavui, Nahavio, Salelubu; Siki and Talasea) during weekly monitoring (2013 – 2016).

Table 78. *Segestidea novaeguineae* infection by Internal Abdominal Parasites (IAP) in Smallholder blocks in Popondetta. ***No surveys were done in October and November.***

Month	Total collected	Number infected	Total % infection
Jan-18	5	3	**60**
Feb-18	2	1	**50**
Mar-18	1	1	**100**
Apr-18	3	1	**33**
May-18	1	1	**100**
Jun-18	3	2	**67**
Jul-18	1	0	**0**
Aug-18	2	1	**50**
Oct-18	0		
Nov-18	0		
Dec-18	3	2	**67**

C.2.4. Management of *Oryctes rhinoceros* L. (Coleoptera: Scarabaeidae) at Poliamba Estates (NBPOL)

Oryctes rhinoceros' infestation in replant plantations at Poliamba Estates continued. As was the case for the previous years, infestation was managed through pheromone trapping and *Metarhizium* infection and release complemented by the natural infection by Oryctes virus (*NudiVirus*).

Pheromone trapping at Maramakas and Lakurumau continued from 2017, whilst trapping in Fissoa replant started in December 2017 and continued throughout the year. The number of beetles caught per month from Maramakas and Lakurumau both remained very low (below 100 beetles/month) throughout the year. The number of beetles trapped from Fissoa replant was high for the first 4 months of trapping but dropped off considerably there after (Figure 25). Pheromone trapping at Maramakas and Lakurumau will be terminated in the new year whilst trapping at Fissoa will continue until no more beetles are trapped and damaged palms have fully recovered. Trapping at Lamasong started in May and continued throughout the year. The number of beetles caught from this field remained high with an average of around 2,200 beetles caught per month with a cumulative total of close to 18,000 beetles trapped (Figure 26). Trapping for the replant will continue into the new year.

To complement pheromone trapping efforts, sub-samples of male beetles trapped from Maramakas, Lakurumau and Fissoa replants were drawn, submerged in *Metarhizium* solution and released mainly at Fissoa replant. The numbers released dropped off significantly towards the back end of the year (Figure 27) because of drop in the number of beetles caught from sites close by to Poliamba (Maramakas, Lakurumau, Fissoa) where the beetles were drawn from for infection and release. The activity was not extended to Lamasong because it involved long distance as motor was mainly used for the travels.

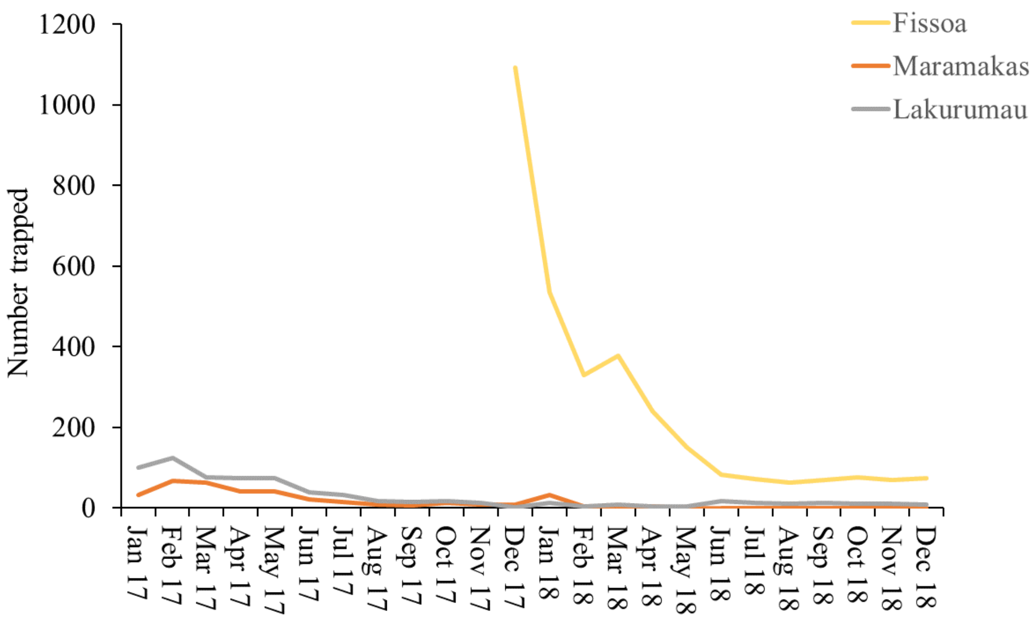

Figure 25. Monthly beetle trap catches from Maramakas, Lakurumau and Fissoa replants.

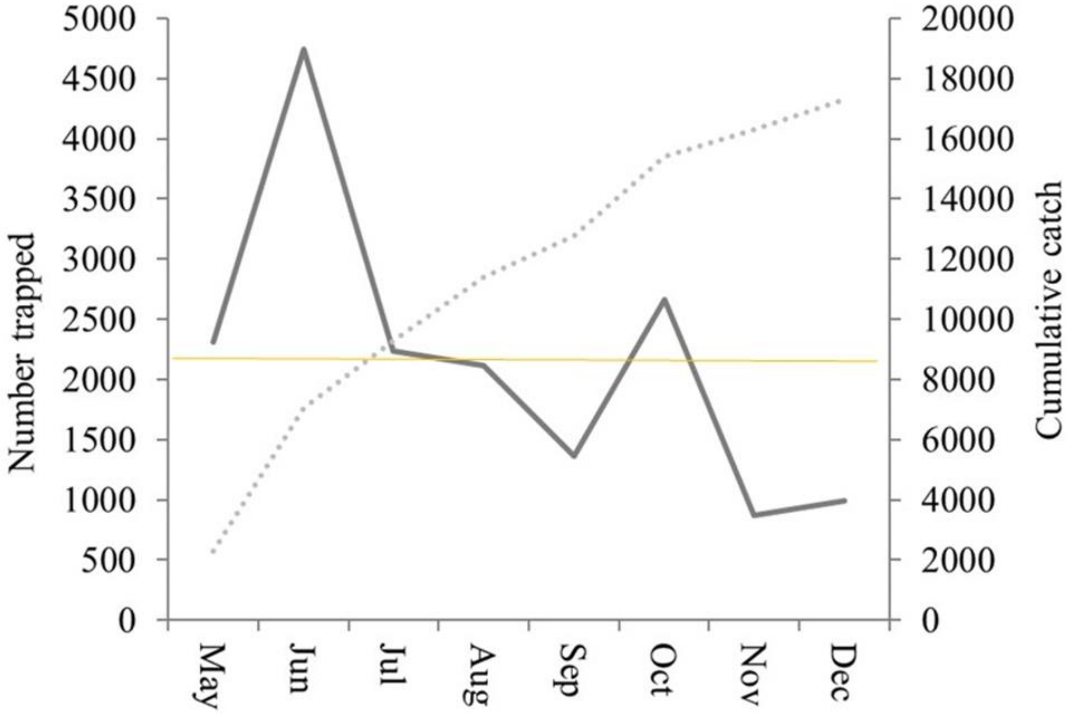

Figure 26. Number of beetles trapped from Lamasong replant.

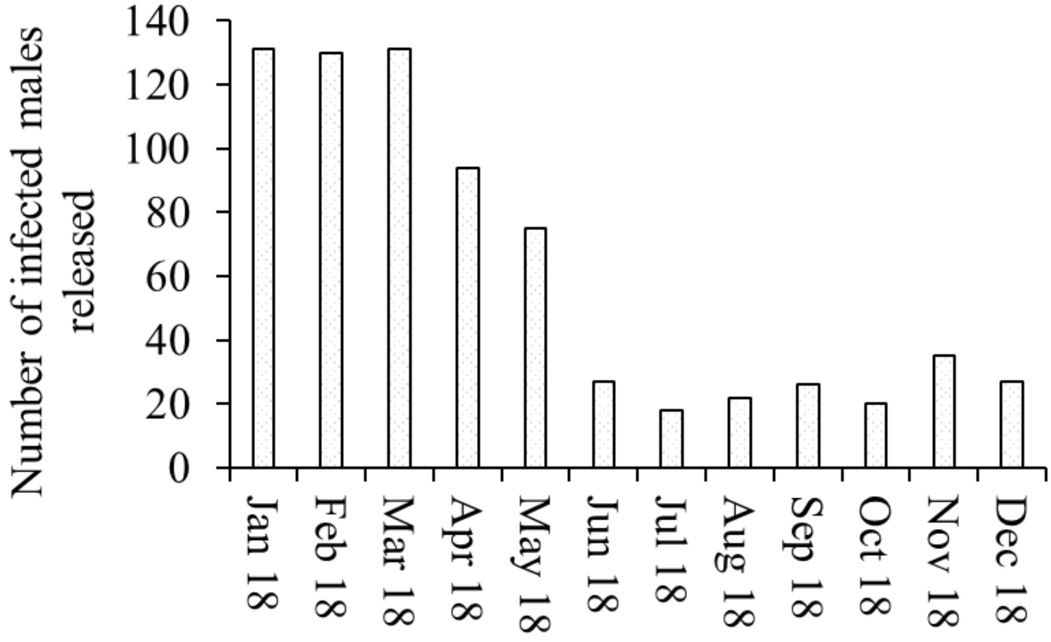

Figure 27. Number of adult *O. rhinoceros* males submerged in *Metarhizium* mix solution for infection and released in the field.

Apart from the pheromone trapping, and *Metarhizium* infection and release, sub-samples of beetles (approximately 20 depending on the number caught) were randomly taken per month and dissected to determine egg load and natural infection by the Oryctes *NudiVirus*. Large portion of eggs counted were mature with an average of 720 eggs per month disrupted from being oviposited (Figure 28). Thus, pheromone trapping not only trapped the adult beetles but also disrupted the breeding cycle by preventing the large number of eggs being laid. This beetles were also checked for symptoms of Oryctes *NudiVirus* infection. The proportion of symptomatic beetles remained high with an average of more than 50% of the beetles showing the symptoms of infection (Figure 29). High infection rate demonstrates that natural *NudiVirus* transmission and infection effectively complimented the pheromone trapping efforts in suppressing the beetle population.

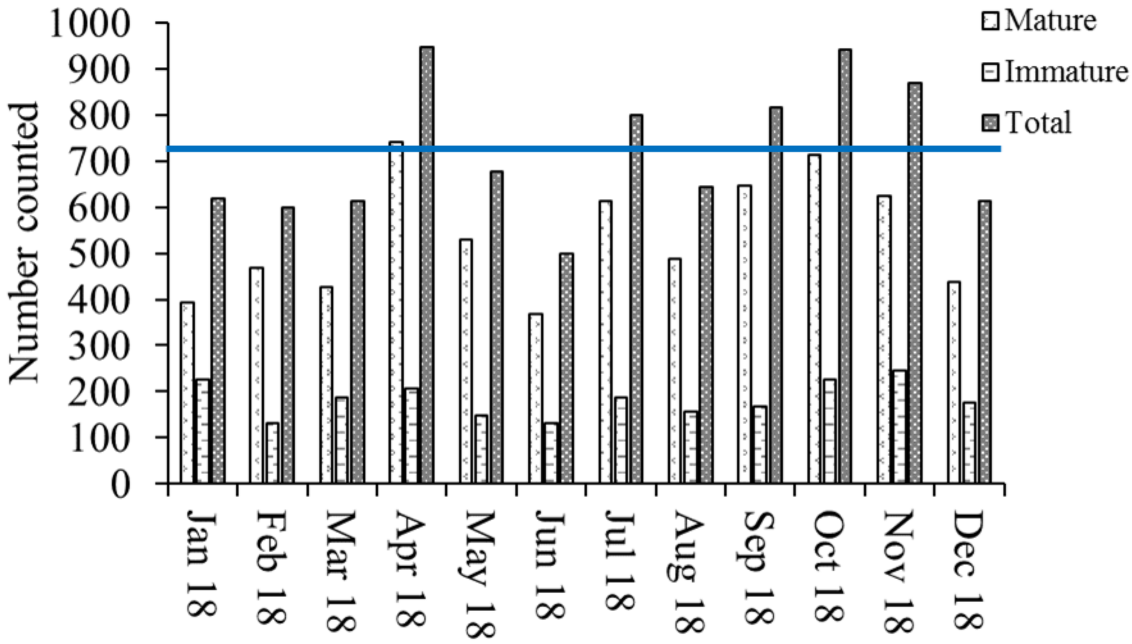

Figure 28. Egg load counted in sub-sample of female beetles dissected (data combined from Fissoa, Maramaka, Lakurumau).

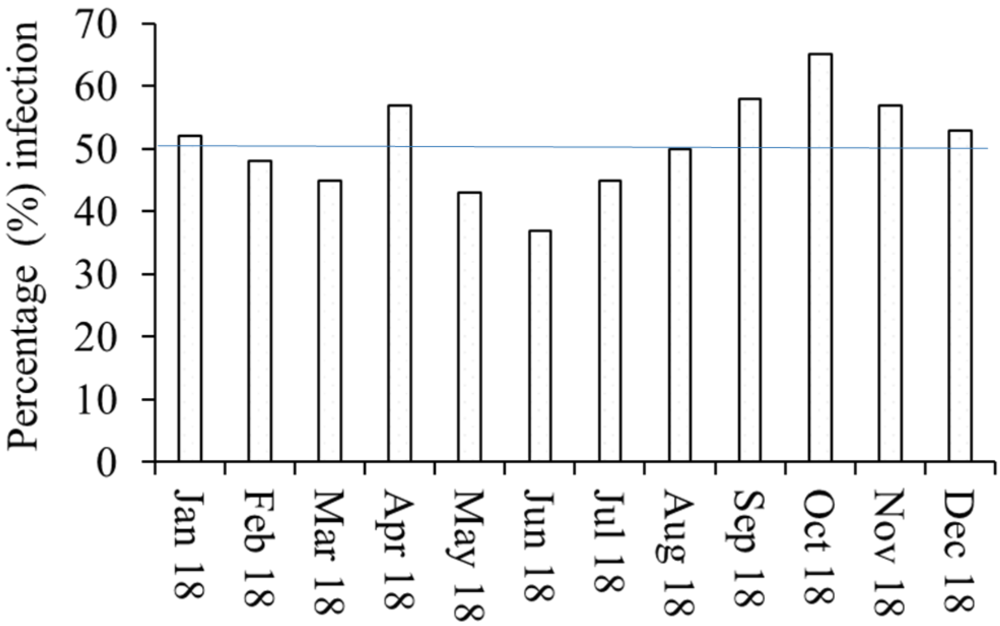

Figure 29. Average percentage (%) virus infection of *O. rhinoceros* at Poliamba Estates (data combined from Fissoa, Maramaka, Lakurumau).

Apart from CRB management at Poliamba, pheromone trap monitoring for CRB-G (Guam biotype) in Milne Bay and Northern Provinces continued throughout the year. No *O. rhinoceros* were caught in any of the traps. The activity will continue into the new year. RAIL has set up pheromone traps for the beetle infestation in the Markham Valley and trapped some. Fortunately, it was confirmed in 2017 by AgResearch through DNA analysis to be CRB-S (Samona biotype) but without *NudiVirus* infection. In October 2018, seven male *O. rhinoceros* dosed with Oryctes *NudiVirus* from WNB were released close to Markham Farms. Establishment of the virus will be monitored over time with further releases done.

CRB-G infestation in replant plantations at GPPOL continued to cause severe economic damage to the palms. Control programmes were tightened up with the inclusion of chemical and mechanical control options. The control programmes will be continued into the new year and their effectiveness monitored over time.

C.2.5. Management of targeted invasive weeds in Papua New Guinea

The section continued with the management of some of the invasive weeds. As was the case in 2017, the main focus in 2018 was the eradication of *Mimosa pigra* in WNB (Numundo and Wandoro- Pusuki Estate) using Ally 20 (Metsulfuron methyl as an active ingredient) as well as manual uprooting during wet weather and the rearing and release of its seed feeding biological control agent (*Acanthoscelides* spp.) in Northern Province.

The treatment at Wandoro (Pusuki Estate) started in August 2014 with fortnightly herbicide application/manual uprooting done. Since then 92 rounds of treatment have been done with 8,206 plants treated/uprooted. A total of 141 weeds were treated/uprooted from this site in 2018. This is 997 weeds less than those treated/uprooted (1,138 weeds) in 2017. The declining trend in the number of weeds treated/uprooted shows that the control programme implemented for this site is having an impact.

The treatment programme for Numondo site started a year later in Feb 2015. A total of 4,919 weeds have been treated after 81 rounds of treatment/uprooting. There was an increase in the number of weeds treated/rooted with 1,372 weeds treated/uprooted compared to 721 treated/uprooted in 2017. High numbers still continue to persist because of the late start of the programme, as well as the cattle ranging and water way of the creek within the area of infestation that have widely spread the seeds before the eradication programme started. The increase was also due to increase in surveillance extending the area of survey further downstream.

The exercise will continue until no new germinations are detected for up to 12 months before it is considered to be eradicated. The persistence of new germinations is expected to continue for some more years before eradication is achieved due to the very long dormancy period of seeds (up to around 25 years).

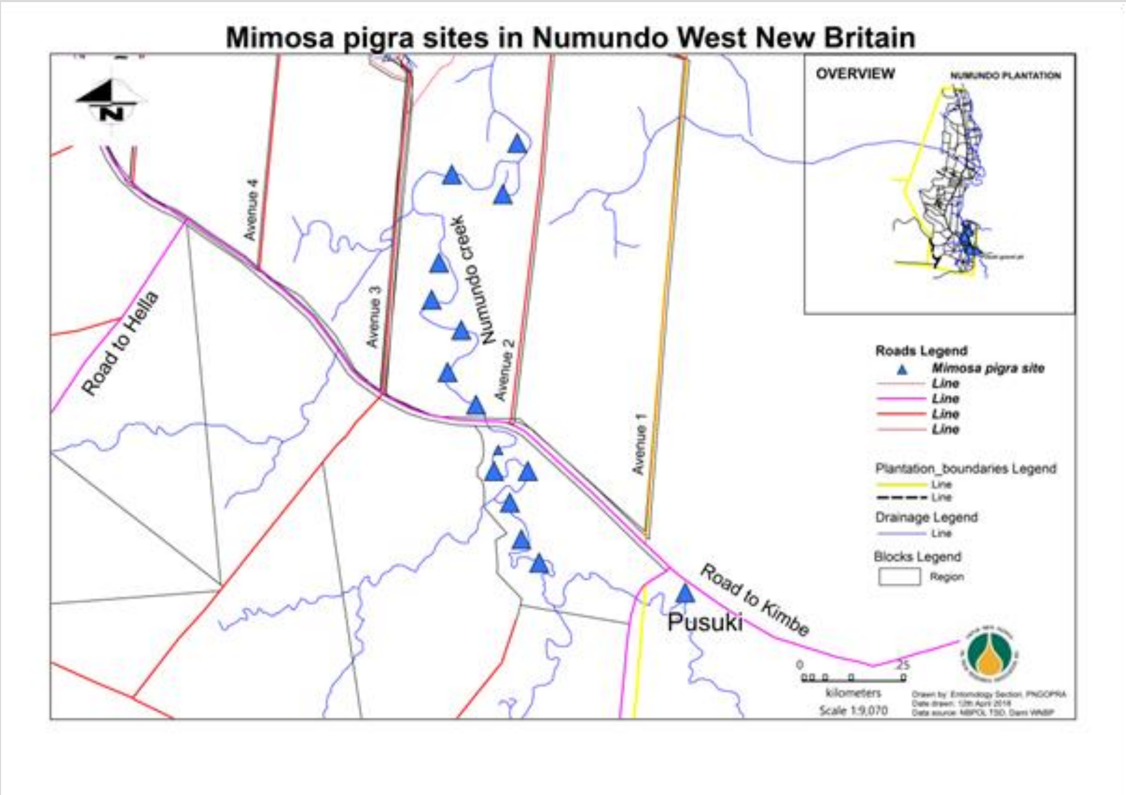

Figure 30. Map of Numondo-Wandoro area showing the locations of *M. pigra* infestation.

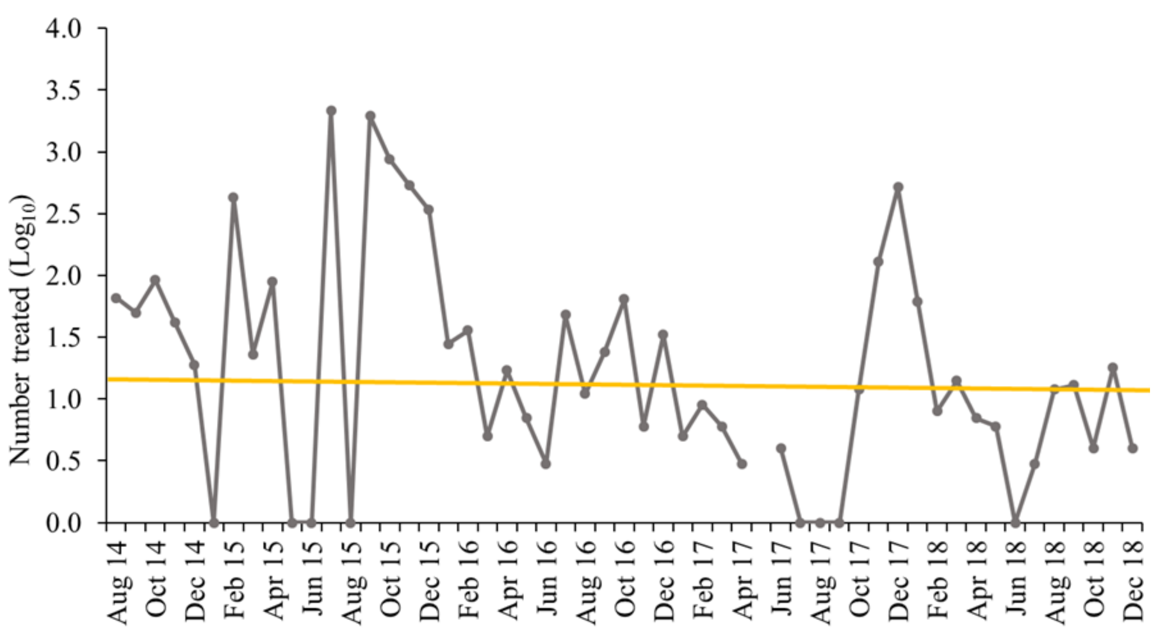

Figure 31. The number of new germination of *M. pigra* (Log_{10} transformed data) treated/uprooted at Wandoro (Pusuki Estate) from August 2014 to December 2018.

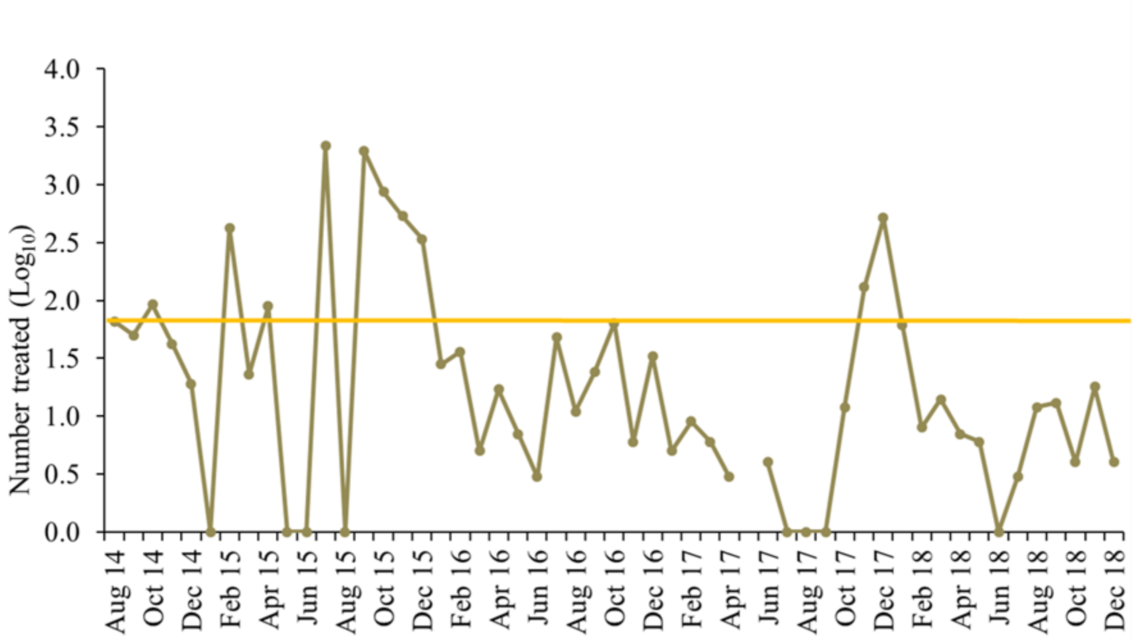

Figure 32. The number of new germination of *M. pigra* treated/uprooted (Log_{10} transformed data) at Numondo from February 2015 to December 2018.

Rearing of the seed feeding biological control agent (*Acanthoscelides* spp.) started at Higaturu in February 2015, and continued in 2018. A total of 113,340 beetles have been released since the start of the programme. A total of 51,015 beetles were released across different sites in 2018 (Figure 33). With the high number of beetles released, the release programme was terminated at the end of 2018. Only post monitoring programme will continue in the new year to monitor establishment.

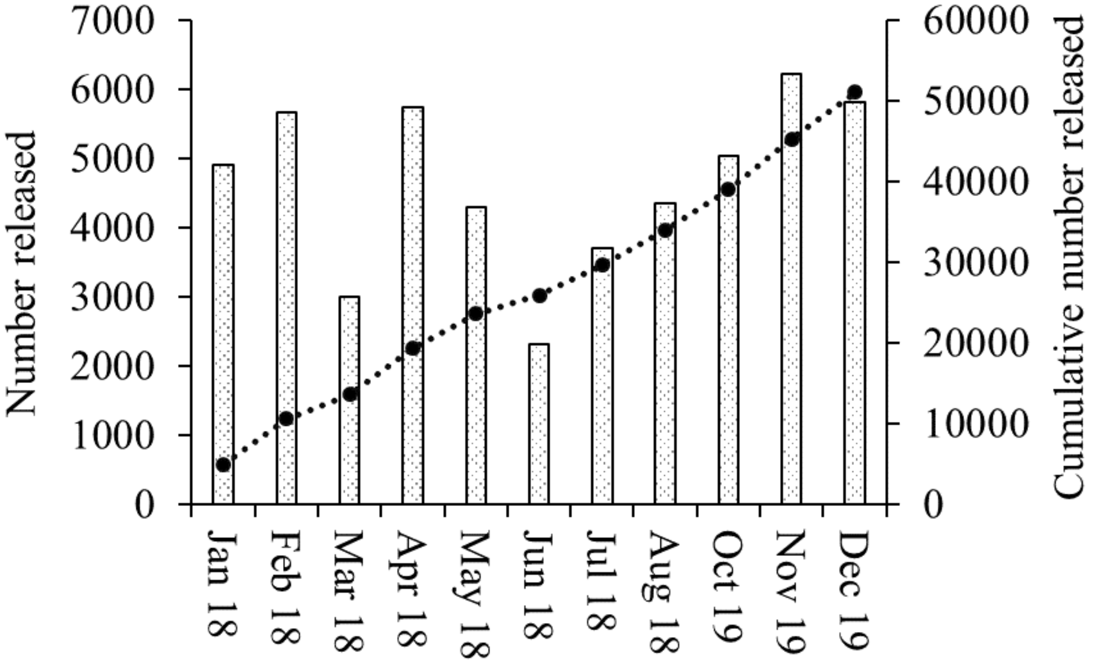

Figure 33. Number of *M. pigra* biocontrol agent (*Acanthoscelides* spp.) released monthly in parts of Northern Province in 2018.

Eradication was targeted for WNB because the distribution of the weed is concentrated at the two mentioned sites within close proximity from each other, but biological agent release has been instigated for Northern Province as the weed has spread widely throughout the province.

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

C.3. APPLIED RESEARCH REPORTS

Only projects which have been either fully completed or majority of the activities achieved during the year are presented here. Most of the Scientific Advisory Committee (SAC) approved research projects are still in progress and will be reported in the next annual report once all activities are completed.

Integrated management approach of the Coconut Rhinoceros Beetle (CRB), *Oryctes rhinoceros* Linneaus (Coleoptera: Scarabaeidae) in West New Britain Province

Introduction

The Coconut Rhinoceros Beetle (CRB), *Oryctes rhinoceros* Linneaus (Coleoptera: Scarabaeidae) is one of the key pests of oil palm in some parts of the country (PNG), particularly during replant (Ero, et al., 2016). The adult beetles attack young replant palms by mainly tunneling through the palm bases and feeding on sap from the apical meristem. They can also feed on frond bases causing whole fronds to collapse.

In WNB, major incursion that required management intervention was detected during the year at NBPOL Numondo replant field. Light infestation was observed at Bebere replant and monitored but the infestation subsided and palms fully recovered. No infestation was observed in other milling company replants except for scattered light damage in some smallholder replant blocks.

Separate trials were established in replant blocks at Kumbango and Numondo Plantations. The trial at Kumbango was to monitor legume cover crop (LCC) establishment, palm trunk decay rate and time of CRB incursion (determined by damage assessment surveys) in relation to LCC establishment and palm trunk decay. The LCC establishment monitoring was to confirm claims that LCC establishment prevents CRB breeding in fallen palm trunks. The palm trunk decay rate monitoring is to determine the decay stages at which the beetle starts breeding (thus starts causing damage) and stops breeding (thus stop causing damage). The trial at Numondo replant monitored the beetle population and damage levels in relation to the control options implemented.

This report presents the progress results of the trials.

Materials and Methods

Kumbango replant trial

Monitoring of LCC establishment
The monitoring started a month after planting of LCCs. Since LCCs were planted using the T-planting design, the cross part of the planting was used to monitor their establishment over time. The fallen trunk pile was divided into 4 portions/strata and marked out with spray paint. The ground portion was referred to as the first quarter, the second portion as the second quarter, the third portion as the third and final portion as the final quarter. The establishment was measured in relation to the LCCs growing over those portions of the trunk pile over time (spatial establishment over time- temporal). Ten positions each were marked out (next to every 2nd palm) in each row for 10 rows and the assessment done on a monthly basis until full coverage of the fallen palm trunks was attained. Schematic illustration below (fig here) demonstrates the setup of the trial.

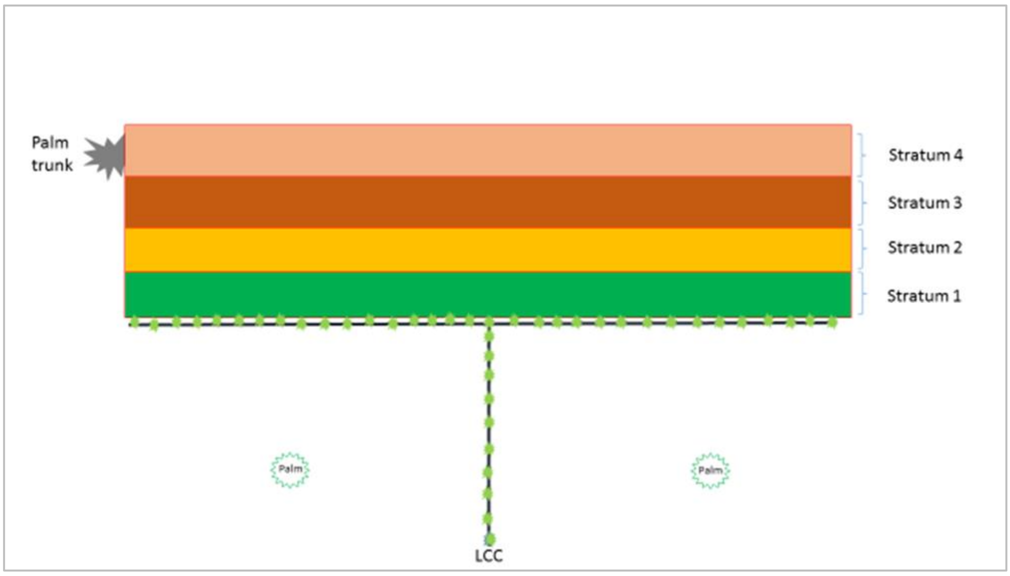

Figure 34. Schematic illustration of the LCC establishment measurement trial set up.

Monitoring of fallen palm trunk decay rate
The assessment of decomposition rate of the fell palm trunk was done concurrently with the monitoring of LCC establishment. Five (5) fallen palm trunks each were marked and numbered in each of the 10 rows where cover crop establishment assessment was done. Each row was used as a replicate. The full length of each of the marked palm trunks were measured using a 100m tap measure and recorded according to palm and replicate numbers. For each of these palm trunks, monthly measurement of undecomposed portion was done and recorded according to palm number and replicate. The assessment is continuing and will stop once all marked palm trunks have fully decomposed.

Rhinoceros beetle palm damage assessment

The damage assessment surveys were done in the same field used for monitoring LCC establishment and fell palm trunk decomposition rates. For the assessment, every 2nd palm in every 2nd row covering 10 palms per row for 10 rows (n = 100 palms) was done. During each month from the start of the trial, each of the selected palms was checked for beetle damage (on both the palm and frond bases). It was recorded as with beetle damage (B) or without (H) beetle damage. If there was beetle damage, it was checked closely to see if damage was fresh or old or both (if both). The number of fronds with and without damage were then recorded accordingly. This was used to determine the damage level.

Calculation of the damage levels were done as per below:

$$\% \text{ fresh damage} = \frac{\text{no. of palms with fresh damage}}{\text{Total number of palms surveyed}} \times 100$$

$$\% \text{ old damage} = \frac{\text{no. of palms with old damage}}{\text{Total number of palms surveyed}} \times 100$$

$$\text{Total } \% \text{ damage} = \frac{\text{no. of palms with old \& new damage}}{\text{Total number of palms surveyed}} \times 100$$

Severity level

Calculate per palm and get the average

$$\frac{\text{Number of fronds with damage}}{\text{Total number of fronds}} \times 100$$

Severity levels

0 %**: No damage**

0.1 to 10% overall damage: **Light**

11% to 30% overall damage: **Moderate**

> 30 % overall damage: **Severe**

Numondo replant trial

Five activities were conducted for the trial at Numondo replant. They included pheromone trapping, *Metarhizium* application in artificial breeding sites (ABS), beetle dissection for egg load count and *NudiVirus* infection, and damage assessment surveys.

Pheromone trapping

Pheromone traps were set at a density of 1 per 2ha within the blocks with infestation and checked on a weekly basis. Any beetles trapped were recorded according to gender. Once the number required for dissection were drawn, the rest of the beetles were destroyed.

Metarhizium application in artificial breeding sites

Artificial breeding sites (ABS) were constructed using different breeding substrates. The substrates included palm trunk (PT) pieces, empty fruit bunches (EFB) and palm kernel extract (PKE). Two traps each were set up for each substrate with different treatment regimes. One was treated on fortnightly basis whilst the other was monthly basis. Pheromone traps without collection buckets were placed over each ABS to attract adult beetles to breed. The manufacturer recommended concentration of *Metarhizium* (Ory-X) of 25g was applied. The mixing process was done in a following manner. Around

15L of rain water was prepared. Water volume half the volume of a 5L mixing jar was drawn into the jar. A 15ml of wetting agent was added to the water in the jar and mixed thoroughly. Once mixed, 25g of *Metarhizium* powder was weighed and added to the mixture. The mixture was stirred thoroughly. Any lump/froth that formed during the mixing was removed using a scoop. Once thoroughly mixed and fully saturated, the mixer was transferred to the knapsack sprayer with the rest of the water through the strainer. The solution was mixed thoroughly again in the knapsack and applied to the respective ABS. The application was done in the afternoons starting at 1600hrs to avoid denaturing of the fungus by heat.

Beetle dissection for *NudiVirus* infection and egg load count
Twelve (6 males and females each) were randomly drawn per month and dissected for *NudiVirus* infection. Infection was confirmed through visual observation of symptom. The females were also checked for egg load (mature vs immature).

Rhinoceros beetle palm damage assessment
Same procedure as that for Kumbango was used for the damage assessment survey within the blocks with CRB infestation where the pheromone traps and ABS were set up.

Results

The LCC fully established over the fallen palm trunks within 4 months from planting. It initially took time (about 2 months) to establish, but once established, it quickly grew over the second and third strata (Figure 35). The palm trunks were still fresh throughout the year because of the prolong wet weather. The final result will be presented in next year’s annual report. There was no damage by the beetle observed in the trial field.

Unfortunately, the results from this trial are inconclusive with fallen palm trunks still remaining fresh and no CRB incursion detected. Although, LCCs took at least 4 months to fully establish over the fallen palm trunks, the notion of their establishment preventing beetle breeding within the trunks still remains to be confirmed due to the lack of their (beetle) incursion. The lack of incursion cannot be attributed to prevention by the LCC establishment as this (lack of incursion) was the case for the entire replanted field. Breeding by the beetles within the palm trunks normally adds to the decomposition process, hence the lack of decomposition affirms lack of incursion.

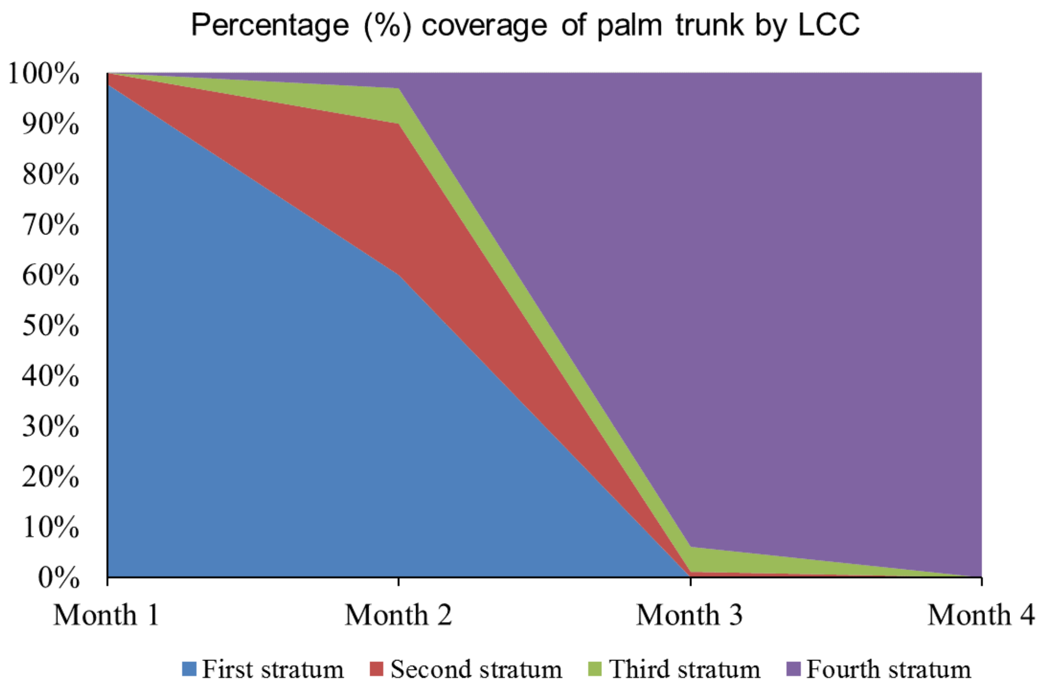

Figure 35. Establishment of LCC on fell palm trunks over time (Kumbango trial).

Highest number of beetles were caught within 3 months of trapping, starting from the second month after trap set up to the fourth month. Thereafter, the number of beetles caught remained below 100 beetles throughout the year (Figure 36).

15,222 beetles were trapped during the year (Figure 37). The increase in the number of beetles caught per month has been steady, thus trapping will continue into the new year.

Pheromone trapping results show that it can be used as an effective component of CRB management approaches. Trapping effectively suppressed the beetle population with peak catch attained within the first 3-4 months of trapping and well over 15,000 beetles trapped during the year consistent with the results obtained from Poliamba Estate trapping. The key to effective trapping is routine servicing of the traps. Trap checks need to be done on weekly basis with any fallen or leaning PVC pipes put back upright and organic matter within collection buckets replenished. The organic matter will allow the beetles to burrow into buckets and be prevented from flying back out. The collection buckets should be tall enough to prevent the beetles from flying back out.

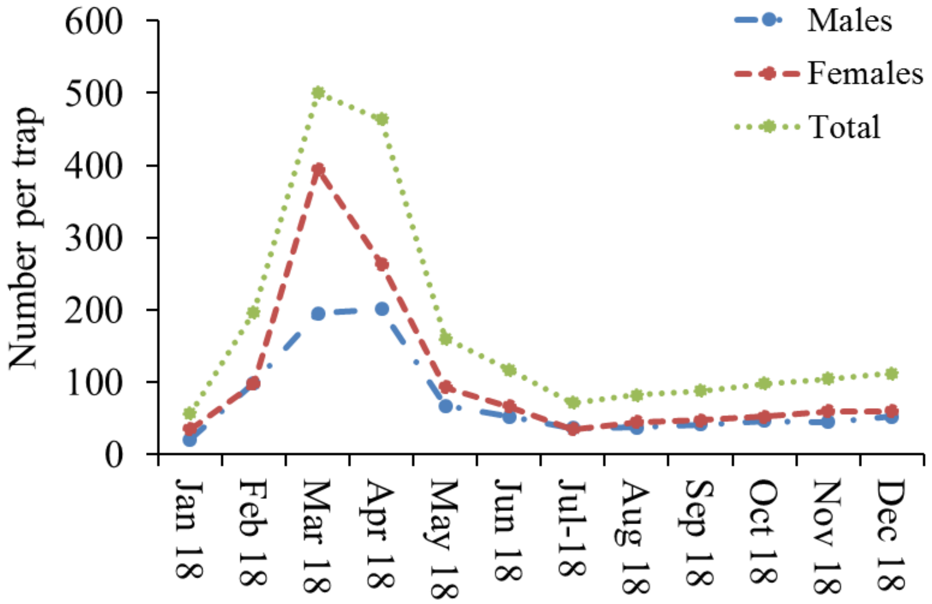

Figure 36. Number of CRB-S caught per trap during the year at Numondo replant.

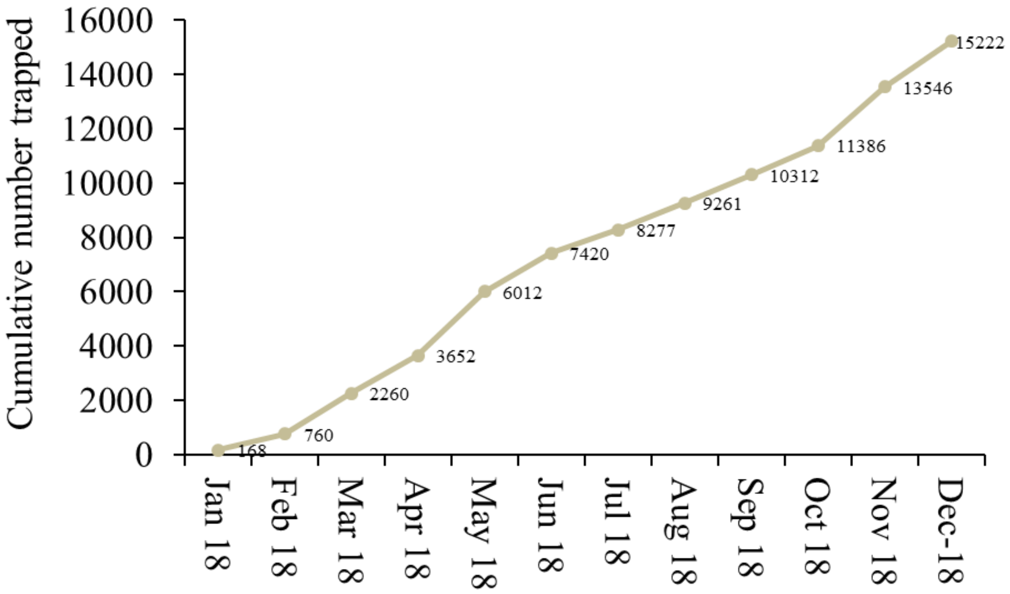

Figure 37. Cumulative number of beetles caught during the year (2018) at Numondo replant.

With respect to the egg load, more immature eggs were found than mature eggs (Figure 38). Below 50 mature eggs were found per month throughout the year.

The overall *NudiVirus* infection rate remained 50-70% throughout the year (Figure 39). Approximately, equal proportions of males and females were infected. Interesting to note was that the rate infection continued to increase over time.

Pheromone trapping also potentially disrupted the breeding cycle of the beetle by drawing large number of immature eggs. The drawing of large number of immature eggs implied that most of the female beetles were trapped early in their breeding cycle before they started laying eggs. Hence, the timing of trap set up is critical. They needed to be set up early in the breeding cycle to prevent the populations from reaching the economic threshold levels. If the population pressure is too high, they can even kill the young palms.

The trapping of large number of beetles showing symptoms of *NudiVirus* infection indicates that the virus was effectively contributing to the suppression of the beetle population through natural transmission and infection. The increase in the rate of infection over time shows that the virus proliferated as the beetle population increased, subsequently suppressing it. Such trend is normally common among natural enemy populations. The availability of more hosts usually enables the natural enemies to breed and increase in population subsequently keeping the host (pest) population under check.

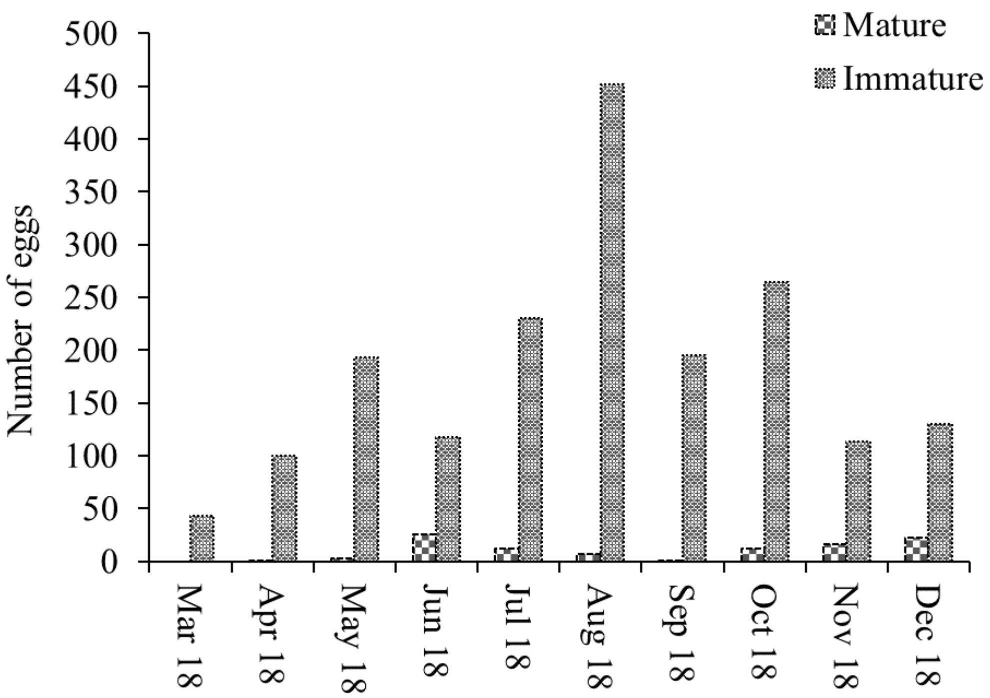

Figure 38. Number of mature and immature CRB eggs counted from Numondo replant traps.

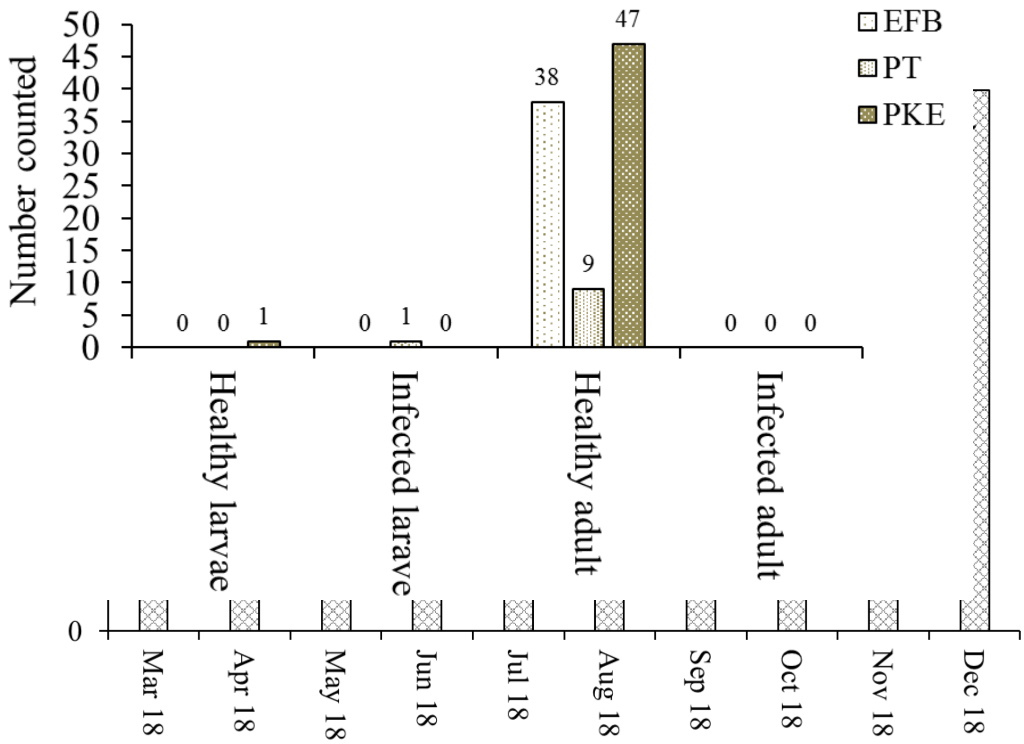

Figure 39. Proportion (%) of beetles infected by Oryctes *NudiVirus* at Numondo replant.

The rate of breeding by the beetle in the artificial breeding sites (ABS) was low although large number of adults were attracted to the sites through the pheromone traps. This trend was similar for both the fortnightly and monthly application regimes. This could imply that the beetles preferred the readily available fallen palm trunks more than the ABS for breeding. The infection rate by *Metarhizium* on adult beetles was very low. The rate of infection on larvae could not be confirmed because of the lack of breeding. The results showed that this method of control is not as effective as pheromone trapping and natural *NudiVirus* infection. Further investigation into the application methods is needed before its recommendation for use as part of CRB integrated pest management (IPM) programme.

Figure 40. Number of larvae and adult beetles (infected and healthy) in different ABS with fortnightly *Metarhizium* application.

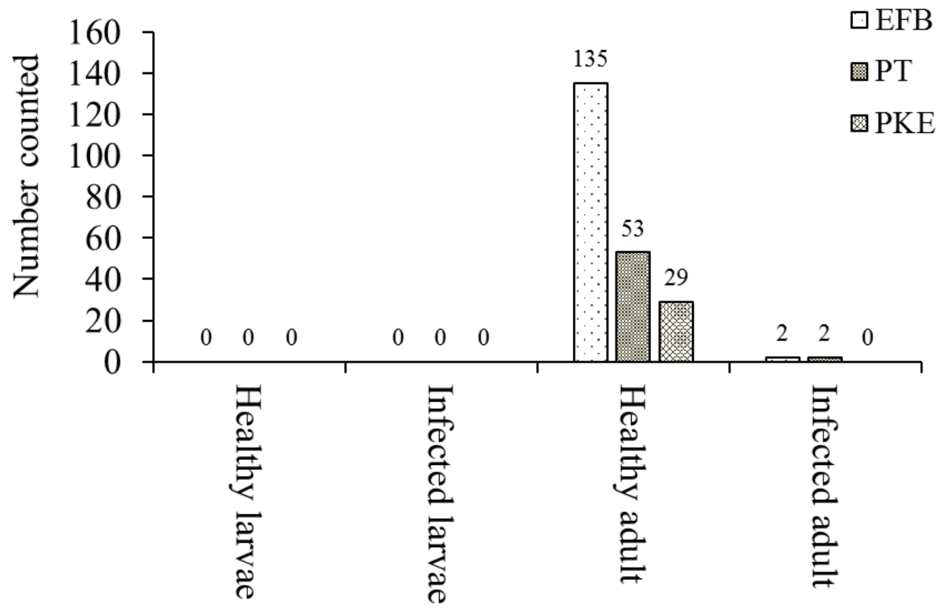

Figure 41. Number of larvae and adult beetles (infected and healthy) in different ABS with monthly *Metarhizium* application.

The damage level remained low throughout most part of the year. It increased to moderate level in November but dropped off again to light level in December (Figure 42). This result generally shows that the pheromone trapping complimented by *NudiVirus* infection was effectively suppressing the beetle population thus minimizing the level of damage.

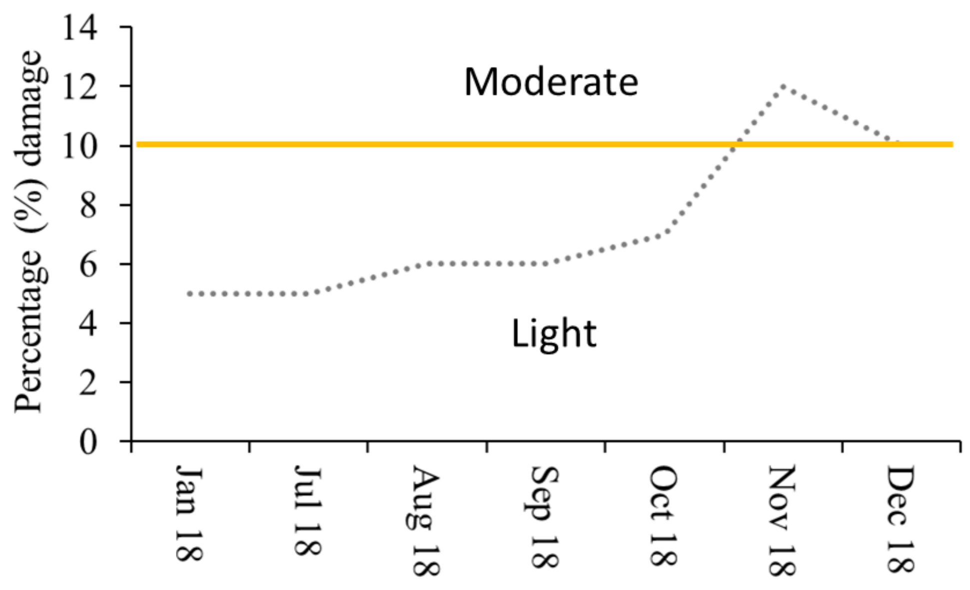

Figure 42. Monthly percentage (%) damage levels in infested field at Numondo replant.

Conclusion

Pheromone trapping and natural *NudiVirus* infection are effective components of the control measures for the management of CRB-S. Further evaluation on the efficacy of *Metarhizim* is required before it can be included as part of the integrated CRB control programme.

Preliminary Recommendations
The following are preliminary recommendations from the study:

- *NudiVirus* must always be introduced into any new fields infested by CRB-S without the virus infection.
- Pheromone traps at the density of 1 per 2ha need to be installed as soon as possible early in the breeding cycle in order to effectively suppress the beetle population from building up.
- Pheromone traps need to be serviced on a weekly basis with any leaning/fallen PVC pipes put back upright immediately and moist organic matter replenished.
- Further studies into the efficiency of *Metarhizium* use needs to be considered.

Evaluation of herbicide control options for the invasive weed, *Thumbergia laurifolia* (Roxb), Acanthaceae (Laurel/Trumpet Vine) using Roundup™ and Arsenal™

Introduction
Biodiversity is essential for the functioning of the ecosystems that provide vital resources such as food, water, fuel, building materials and traditional medicines for its inhabitants (Gamfeldt , et al., 2008). Invasive species of organisms pose a serious risk by altering and degrading the components of biodiversity. They impose negative effect on both the native species of organisms and livelihood of the inhabitants (Pejchar & Mooney, 2009).

Invasive plants can affect native ecosystems. They overcome native plant species subsequently affecting native fauna that depend on them for supply of their resources including food supply. In agricultural systems invasive plants can dominate pastures and crop fields. They can potentially modify nutrient availability by affecting the soil pH and cause land degradation and erosion issues thus disturbing the routine farm management approaches.
Laurel or trumpet vines are native to Northern Indian and Tropical African regions. There are a number of species of the weed that are invasive and have spread to many different parts of the pantropical regions of the world. Some of the species include *Thumbergia alata, T. armemica, T. battiscombei, T. fasciculata, T. fragrans*. *T. grandiflora* and *T. laurifolia*. *Thumbergia grandiflora* and *T. laurifolia* have invaded certain parts of PNG and are aggressively replacing native plants in areas where each species has established. Between these species, the latter has been noticed to be more aggressive. In the Northern Province, both species have established in many different parts of the province engulfing and overtaking the native species of plants. The plants can grow up to heights of around 15m into tree canopies suppressing and killing them. In oil palm cropping systems, the weeds have been observed growing aggressively sometimes outgrowing the palms if not slashed.

The weeds are perennial and live for many years. They can potentially germinate from seeds, vines and tubers. When cut they can keep re-growing from the tuber. This reproduction habits and aggressive vegetative nature can pose major challenges on control efforts. Unfortunately, there are no effective biological control agents available for the weed. Only physical (manual removal) and chemical control options have been used for their management. In Australia, the systemic herbicide, Arsenal™ (250g / kg imazapyr as the active ingredient) at a rate of 7.5ml per litre of water is used for the control of *T. laurifolia*.

Both species of the weed have established in some oil palm catchment areas including buffer zones within the Northern Province. At Mamba Oil Palm Estate, *T. laurifolia* is widely established both within the plantation and adjacent buffer zones. Control attempts within the plantation has been through the blanket foliar application of Roundup™, however, the success rate of containing the weed has been minimal due to continuous re-growth from tubers and roots after the treatment rounds. Hence, there has been a need to evaluate effective chemical control options for the weed.

This study evaluated the effectiveness of Arsenal™ (imazapyr as active ingredient) and Roundup™ (glyphosate as an active ingredient) against the weed. A targeted application approach was taken where the weeds were slashed and re-growth points treated instead of blanket application in areas of infestations. The trial was conducted within infested buffer areas at Mamba Estate, Kokoda, Northern Province.

The primary objective of the study was to determine the herbicide that is able to effectively decompose the tubers/roots and prevent further growth.

Materials and Methods

Sites within the buffer zones infested with *Thumbergia laurifolia* Roxb (Laurel Clock Vine) at Mamba Oil Palm Estate, Kokoda, Northern Province were identified. Three separate locations with excessive *T. laurifolia* infestation were identified and marked out. One location each for each of the 3 treatments coding them with numbers. The 3 treatments included untreated "Control", "Arsenal" (herbicide) and "Glyphosate" (herbicide). The Control was coded as treatment "1", Arsenal™ "2" and Roundup™ "3".

Plate 1. One of the sites with *T. laurifolia* infestation prior to the trial set up.

The selected sites were then cleared by slashing all vines completely to the ground with bush knives and removing them, leaving only the points of original germination for regrowth. From these, 20 original germination points were identified and marked out at each site as replicates (1-20). The treatments and replicates were number coded (For instance T1R1 for treatment 1- replicate 1 and T1R20 for treatment 1- replicate 20).

Plate 2. Slashing and marking out of trial sites (treatments and replicates).

The marked germination points were monitored for 3 weeks to allow for re-growth. The herbicide application was done once the vines had regrown and adequate leaf surface area for herbicide absorption was established.

Three regimes of herbicide application were done. They included 1 round, 2 rounds and 3 rounds of herbicide applications. The 2 and 3 application rounds were done on fortnightly basis. Data collection started 14 days after the final rounds of herbicide applications for the two herbicide treatment and regime. The herbicide application included standard NBPOL plantation application rate of 300 mls per 16L knapsack sprayer used for Roundup™. Same volume was used for Arsenal™ to ensure the application rate was standardised. A 50 ml of LI-700 surfactant was added to each mix to act as sticker. An Osatu™ 16 litre spraying container with a Z–nozzle was used to apply the herbicides ensuring total coverage of the regrown leaves. All standard herbicide application procedures with full Personal Protective Equipment (PPE) were followed for each of the spraying exercises. Treatment one (1) was left unsprayed as a "Control".

Plate 3. Mixing of the herbicides in 16L Osatu™ knapsack sprayer.

Mortality data and photographs of the mortality statuses of the weed stands were taken 1 week after the final spraying of each round and thereafter on fortnightly basis over three months where it was terminated. Vine tuber status (whether rotten, moribund or still fresh) was also assessed and recorded at the end of the trial after the final foliage mortality recording at 98 days after treatment.

Results and Discussion

Generally, there was faster complete foliage mortality for vines applied with Roundup™ than those applied with Arsenal™ for all treatment regimes. For the 2 and 3 treatment round regimes (Figure 43 and Figure 44), this was attained as early as 14 days after the treatment. The effect on foliage mortality by Arsenal™ was much slower for 1and 2 treatment rounds but was quicker for 3 rounds treatment attaining total foliage mortality as early as 14 days after treatment (Figure 45). No foliage mortality was observed from the untreated “Control” treatment.

The root/tuber mortality in both treatments showed similar trends for all 3 treatment regimes. For both Arsenal™ and Roundup™, the mortality in spray regimes with 1 and 2 rounds was gradual, whilst mortality for the treatment with 3 rounds of spraying was high (Plate 4, Plate 5 and Plate 6). Within each regime, as was the case for foliage mortality across treatments, it was much faster in Roundup™ applied vines than those applied with Arsenal™.

Vine re-growths were observed only for Roundup™ treatment. They include 1 from one round spray regime and 2 from 3 rounds spray regime. An example is shown in Plate 7 and Plate 8. For 1 round spray regime treatments, the timing was short for any re-growth to be assessed. The tubers/roots were not fully decomposed (still moribund) when they were removed for assessment.

The vines in the untreated "Control" all grew back after slashing and the tubers/vines were all alive. They started flowering by the time, the trial was completed.

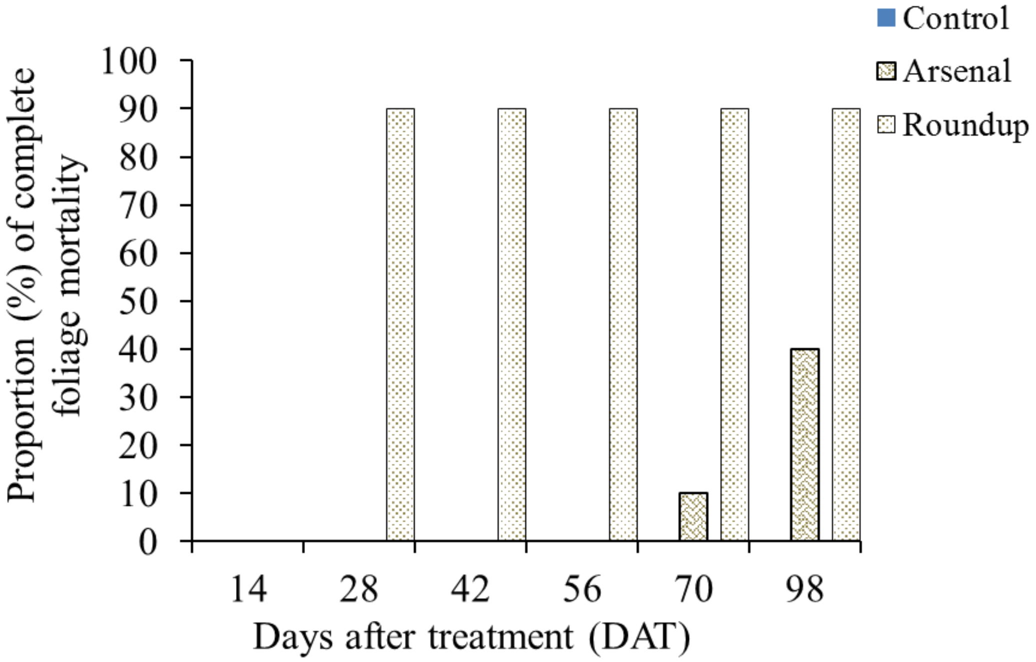

Figure 43. Percentage (%) complete foliage mortality over time (days after treatment) after a single round of spraying.

Plate 4. Statuses of roots after the first round of herbicide application for each treatment (*Left* = Control, *Middle* = Arsenal™, *Right* = Roundup™).

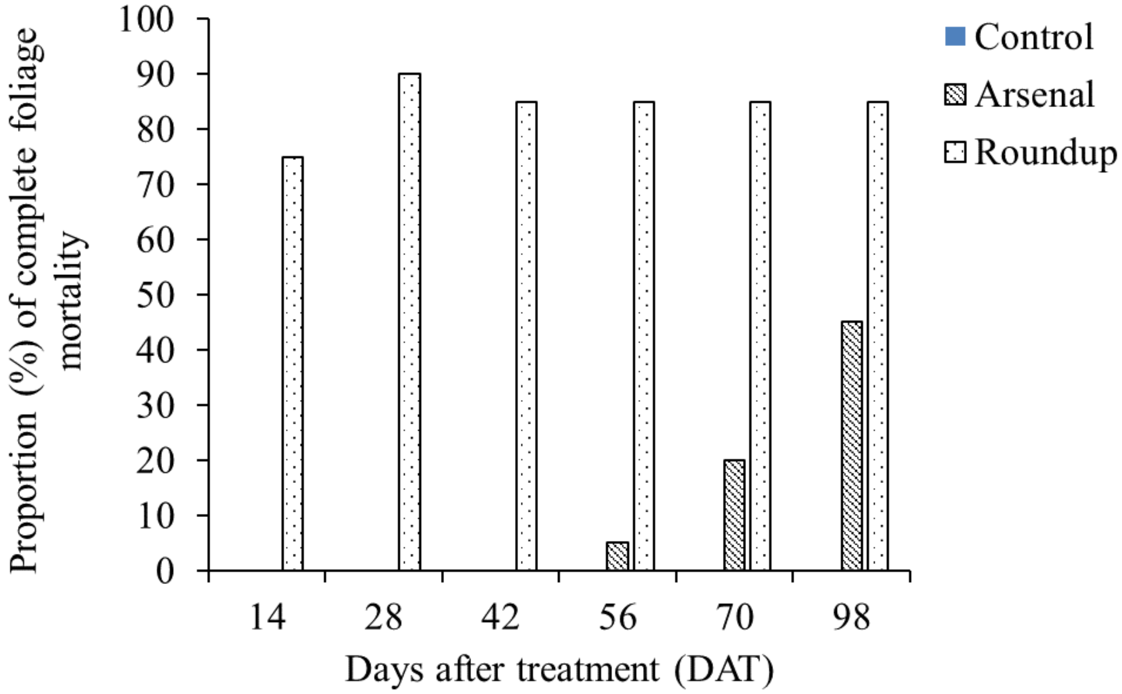

Figure 44. Percentage (%) complete foliage mortality over time (days after treatment) after two spraying rounds.

Plate 5. Statuses of roots after two rounds of herbicide application for each treatment (*Left* = Control, *Middle* = Arsenal, *Right* = Roundup).

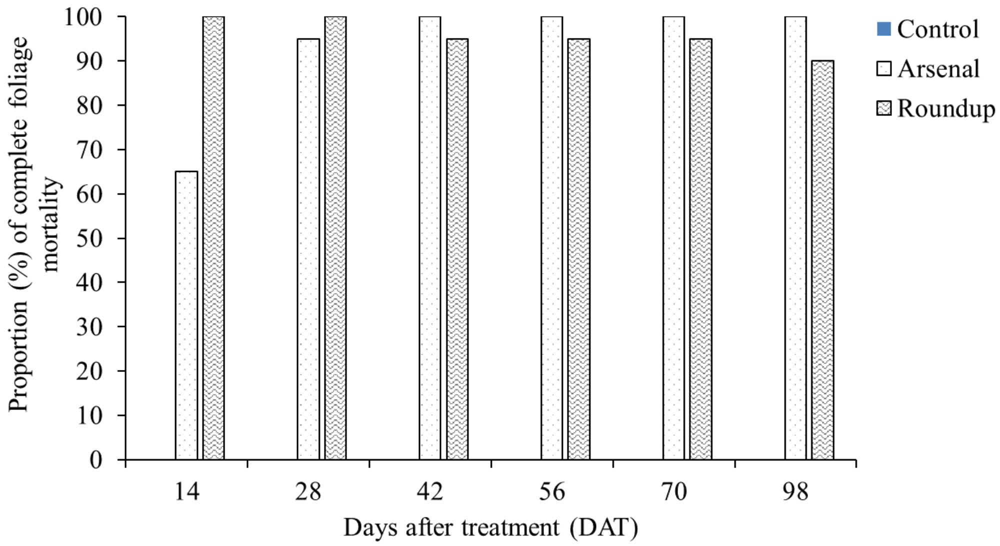

Figure 45. Percentage (%) complete foliage mortality over time (days after treatment) after three rounds of spraying.

Plate 6. Statuses of roots after the three rounds of herbicide application for each treatment (*Left* = Control, *Middle* = Arsenal™, *Right* = Roundup™).

Plate 7. The general situation during the final mortality assessment for the 3 spray round regimes (*Left* = Control, *Middle* = Arsenal™, *Right* = Roundup™).

Plate 8. One of the re-grown vines in three rounds Roundup™ application regime.

When the tubers/roots were removed during the final mortality assessment, the number of vines with tubers and roots respectively were counted and recorded separately. The untreated "Control" had more tubers than the "Arsenal™" and "Roundup™" applied vines. The least number of tubers were found for "Roundup™" treated vines (Figure 46).

All tubers from the untreated "Control" were alive whilst for those treated with "Arsenal™", 4 were dead and 4 were moribund (Table 79). For the "Roundup™" treatment, 2 were dead and 1 was alive. The live vine tuber was from the regrowth (Plate 8). All vines germinating only from roots were killed completely for both "Arsenal™" and "Roundup™" treatments.

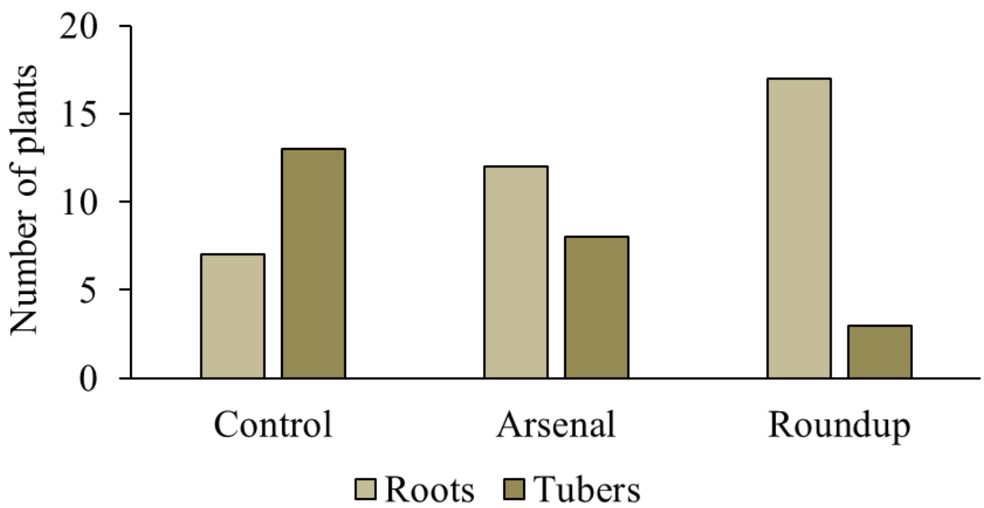

Figure 46. Number of vines with roots and tubers for each treatment counted for the spraying regime with 3 rounds of herbicide application.

Table 79. Number of tubers in different stage when removed after the third round of spraying.

	Tubers killed	Tubers moribund	Tubers alive
Control	0	0	13
Arsenal	4	4	0
Roundup	2	0	1

The study has proven that slashing prior to herbicide application and targeted treatment of the regrown vines and leaves with more than one round of application (2-3 rounds) is the most effective method of controlling the weed.

The difference in the rate of action observed between the two herbicides is mainly due to the different enzymes in the plants and the speed at which it inhibits. They both are systemic broad spectrum herbicides which translocate within the merisystemic tissue of plants and inhibit enzymatic activities. However, glyphosate is fast acting and inhibits the enzyme responsible for the production of amino acids, tyrosine, tryptopan and phenyltalanine (Amrhein, et al., 1980), whilst imazapyr is a slow acting inhibitor and inhibits the production of the branched aliphatic amino acids which are required for DNA synthesis and growth (Tu, 2019).

There is a hint of glyphosphate been less effective on tubers but this result is inconclusive because of the low sample size. The faster action by the herbicide could have potentially killed the vines quicker preventing complete translocation of the chemical to the tubers/roots as fresh tissue is necessary for effective translocation. Despite this set back, the re-growths can also be easily controlled through repeat targeted rounds of herbicide application.

Conclusion

Despite the difference in the rate of action, both herbicides can potentially kill the weed at least after 2-3 rounds of targeted application on re-growths after slashing, thus both herbicides are effective against the weed. The main consideration is the price difference between the two herbicides. Glyphosate is cheaper at around K7.00/L whilst Imazapyr is slightly expensive at K13.00/L.

Recommendations

Here are the recommendations in relation to the results derived from this study:

1. Slash the weed and wait for at least a month for regrowth and establishment of foliage before herbicide application. This will allow for adequate surface area for chemical absorption.
2. Because of the price difference between the herbicides and accessibility, Glyphosate based herbicides should be used for the control of the weed. In the event that Glyphosate becomes restricted, Imazapyr should be considered.
3. At least two rounds of application using the standard application plantation application rate of 19 mls/L should be applied for effective control.
4. In the event of regrowth, repeated applications should be done (on fortnightly basis) until the weed is killed.

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C.5. DONOR FUNDED PROJECTS

There were two external donor funded projects that the section was involved in during the year. It is the Sime Darby Foundation funded CRB-G project. The other which compliments this project is the MFAT funded AgResearch project on CRB management. PNGOPRA assisted in conducting the PNG component of the project inception workshop in Kimbe, West New Britain Province.

C.6. FORMAL PUBLICATION AND TECHNICAL NOTES

There was no formal publication done during the year. Plan to get two publications done during the new year, the first one on *O. bornemanii* been drafted.

C.7. OTHER ACTIVITIES

C.7.6. 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 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 enrolled for an MPhil Programme at the PNG University of Technology (Unitech) during the year. She is expected to complete the programme in 2019.

Most of the trainings provided throughout the year were on pest monitoring and reporting as well as TTI. The trainings that the Entomology Section provided in 2018 are provided in the table below (Table 80). Only one radio talk was done during the year.

All smallholder field days are run on weekly basis for Hoskins Project from April to October and for the other projects as per whenever organised. A total of 20 field days were held during the year. All field days were attended by section staff. Importance of pest issues were highlighted during the field days.

Table 80. Number of trainings provided by Entomology Section in 2017.

Date	Division/Department	Training name	Conducted by	Received by	Area/Location
08-Jan-18	HOPL	TTI Training	SS	Field Staff & Cadets	Hargy Oil Palm Ltd
18-Jan-18	PNGOPRA, Entomology	TTI Training	SS	Supervisory & Field Staff	Hargy Oil Palm Ltd
20-Apr-18	PNGOPRA, Entomology	Pest Training	ME	Cadets	NMC_ Mosa
17-May-18	PNGOPRA, Entomology	TTI Training	ME, TB	TTI Team	Dami OPRS Conference
27-May-18	PNGOPRA, Entomology	TTI Training	ME, TB	TTI Team	Dami OPRS Conference
26-June-18	PNGOPRA, Entomology	Awareness on the impact of Guam Biotype - CRB	ME, SA	Cadets	Higaturu Training Room
27-June-18	PNGOPRA, Entomology	Awareness on the impact of Guam Biotype - CRB	ME	Cadets	Padi Padi Estate Office

ME= Mark Ero, SA= Sharon Agovaua, SS= Solomon Sar, TB= Thom Batari

C.7.7. 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 Heads of Entomology and Plant Pathology. The discussions during the meetings resulted in vigilant monitoring and reporting of pests and diseases for timely damage assessment and treatment applications where required. Bialla project organized general IPM meetings on a quarterly basis.

C.7.8. Visitors to Entomology Section (Dami Head Office) in 2017

A total of 15 visitors passed through the Entomology Laboratory at Dami during 2018 (3 more than 2017). The visitors were from various organizations within the country and Plantations within the Province as well as outside, and the organizations from which they came from are listed below.
Kimbe International School (KIS)
NBNI SDA Mission, East New Britain
NBPOL
National Broadcasting Commission (NBC)
University of Canberra, Australia
Australian Centre for International Agricultural Research (ACIAR)
Curtain University, Australia
PNG Cocoa Board
University of Montana, USA

C.7.9. Entomology Staff Strength in 2018

The Entomology team comprised of 18 staff in 2018. These included 3 executives (including the Head of Section), 4 Technical Supervisors and 11 Recorders.

D. PLANT PATHOLOGY

HEAD OF SECTION III: X

D.1. EXECUTIVE SUMMARY

- Progressive data for BSR monitoring was recorded in 2018 for all plantations and the data is presented
- Cumulative incidences of BSR in all OPRA study blocks in MBE continue to record incidences of BSR. Cumulative counts of audited data range from 23 – 103 symptomatic palms
- Upper stem rots cases continue to increase at Dami with higher incidences for older plantings
- Bracket monitoring studies record continuous bracket production in study blocks
- Continues disease reporting from small growers in West New Britain continue to increase due to combine efforts in farmer field days by all stake holders
- Basal stem rot incidences continue to increase in GPPOL progeny trials. Yield is proportion to bunch numbers and disease the effect of disease incidence on yield is not obvious at this stage

D.2. EPIDEMIOLOGY OF BASAL STEM ROT

Monitoring of BSR disease incidences has continued in 2018 with all plantations mostly for round one surveys only. Large areas of plantations through out all projects sites have under gone a substantial number of replants in the last six years and as such BSR levels were mostly reported for the oldest plantation blocks. The data presented (Figure 47) is unaudited and is only reported for areas that had completed surveys.

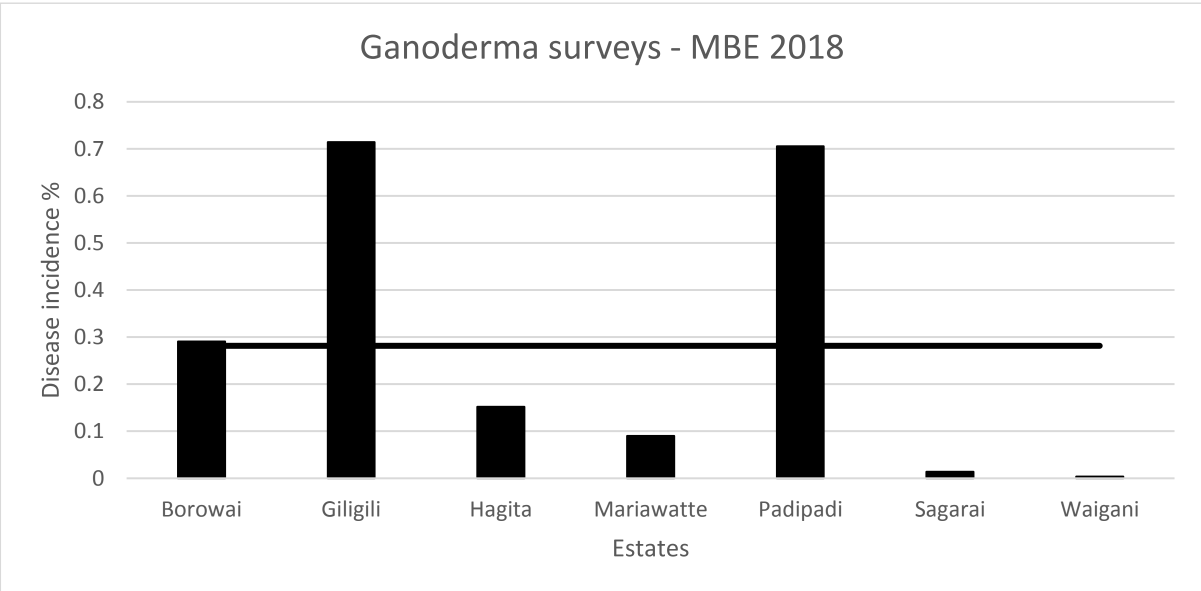

Figure 47 Mean *Ganoderma* disease incidences recorded for all estates at Milne Bay in 2018. The bar represents the mean for all plantations

Disease incidences ranged from 0.03 - 0.71 % in 2018 with a mean disease incidence of 0.28 %. The data is unaudited and reported for only 40% of blocks surveyed in 2018. Salima was replanted in 2017 and therefore no surveys had been carried out. Tamonau was also replanted previously between 2013 - 2015 but recorded not surveys for all blocks. Disease incidences above the mean (Figure 47) were recorded for Giligili (0.71%), Padipadi (0.71%) and Borowai (0.30%). Generally, high disease incidences in Padipadi are expected for 15-18 year old plantings while Giligili which is less than 10 years may possibly have palms recorded from 2017 surveys. Mean disease incidence (0.28%) is lower than 2013 (1.6%) and 2014 (1.4%) due to successive replants between 2012 -2015 but most due to incomplete surveys in 2018.

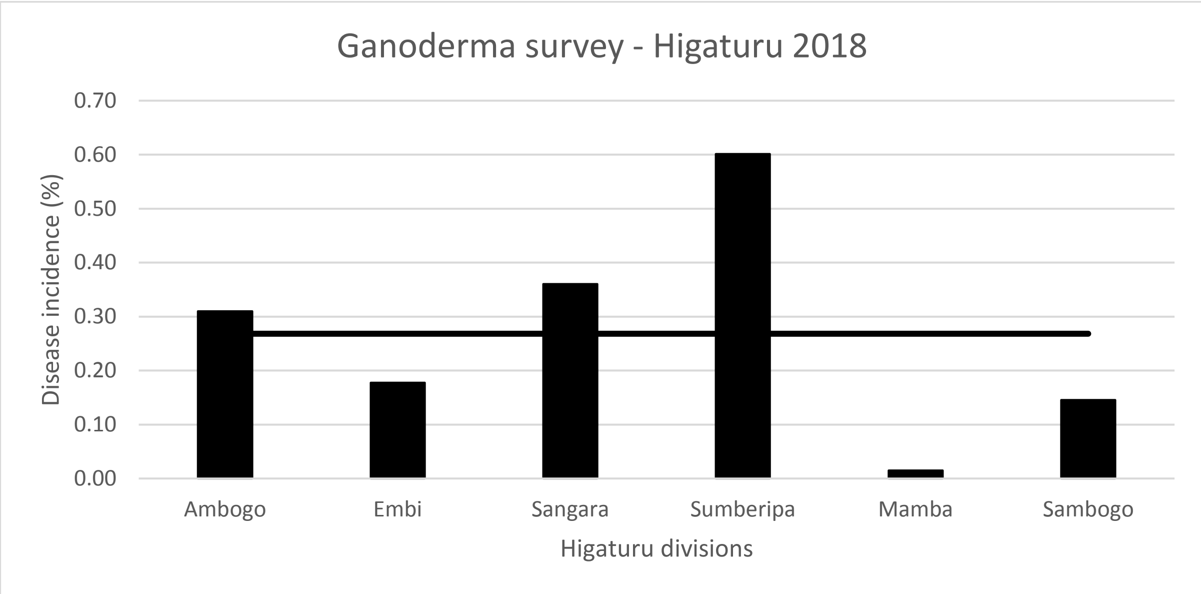

Figure 48 Mean *Ganoderma* disease incidences for six estates recorded for Higaturu Oil Palms Ltd. in 2018

Higaturu plantations recorded a mean disease incidence of 0.27% (Figure 48) in 2018. The disease incidence data for estates in Higaturu are shown in Figure E1. Planting dates with each estate range from 1996 – 2015 of which the oldest plantings are in Sangara and the more recent plantations are in Mamba and Sambogo. Approximately 41% of plantations had been planted out in the last eight years and that the majority of BSR incidences reported are from older plantations. Sumberipa, Sangara and Ambogo while had disease incidences that were above the mean. Sumberipa recorded the highest incidence of 0.6% followed by Sangara with 0.36% and Ambogo with 0.31%. Lower incidences were recorded for Embi (0.18%), Sambogo (0.15%) and Mamba (0.02%) which is expected due to the large areas of young plantings (< 8yrs). Sangara and Sumberipa having older plantings nearing replant and has high BSR incidences therefore plantations should follow closely with management of BSR prior to replant.

Poliamba recorded a mean disease incidence of 0.4 % in 2018 (Figure 49) which was lower than the mean disease incidence of 1 % in 2016. In the last six years (2013 – 2015) more than 50% of the area under planting had been replanted and incidences for these areas were either nil or not surveyed. Matured areas in Madak which have the older plantings (1994, 1997 & 1999) including West coast (1991 & 1997) recorded high disease incidences of 1.21 % and 0.49 % respectively. Low incidences were recorded for Noatsi, Nalik and Kara. Most of the blocks in Kara are all less than 10 years old and as such incidences are relatively low.

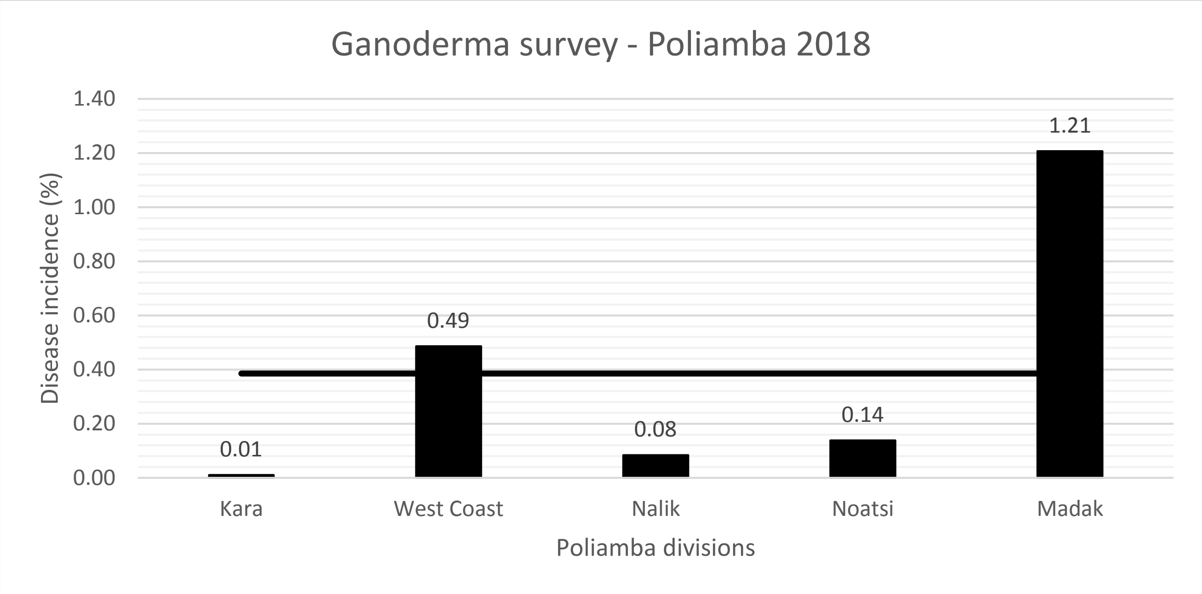

Figure 49 Mean *Ganoderma* disease incidences for five estates at Poliamba Oil Palm Ltd. in 2018

D.2.1. Introduction

Progression of Ganoderma infection levels continue to be monitored in six replanted study blocks in Milne Bay in 2018 (Figure 50). Infection levels for these blocks at replant ranged between 16.7% and 30.7% (OPRA Annual report, 2011) where blocks in access of 20 % infection require close monitoring of BSR disease progress after replant. Data collection of BSR disease progress before and after replant provides crucial information for successive replants where more informed decisions can be made regarding Ganoderma control and management.

D.2.2. Disease progress in second generation oil palm

D.2.2.1. *Replanted fields at Milne Bay Estates*

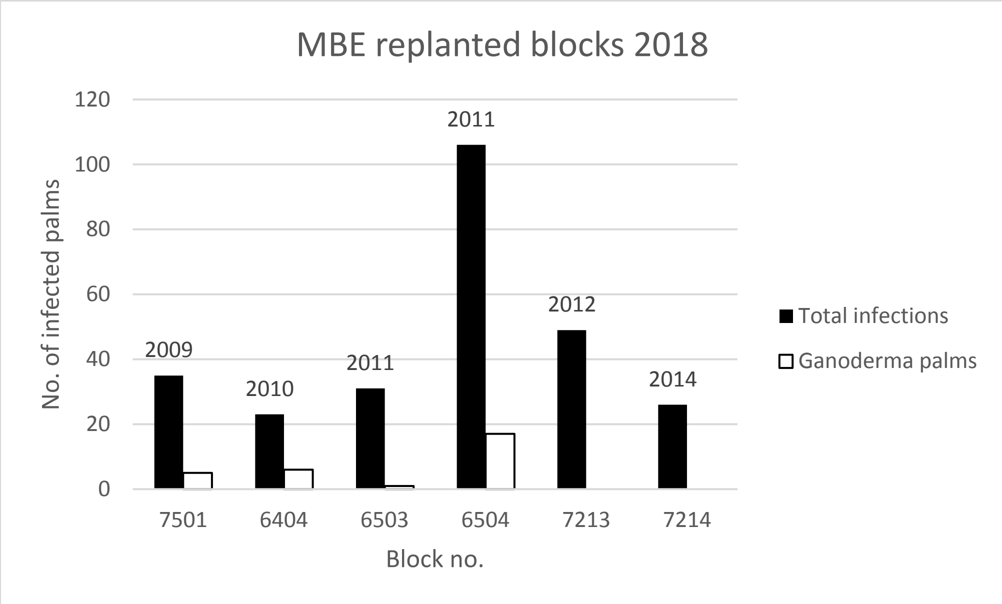

Figure 50 Number of infected palms recorded in replanted blocks in Milne Bay in 2018. Year of planting shown above bars in histogram.

D.2.3. Upper stem rot (USR) survey - Dami Plantation

Upper stem rot surveys continued in 2018 for seven study blocks at Dami. A total of 45 palms were recorded with upper stem rot. Incidences of basal stem rot were also recorded during surveys, but numbers were lower than USR cases. High number of palms recorded with USR (Figure 51) were still observed in the oldest plantings (264A & B).

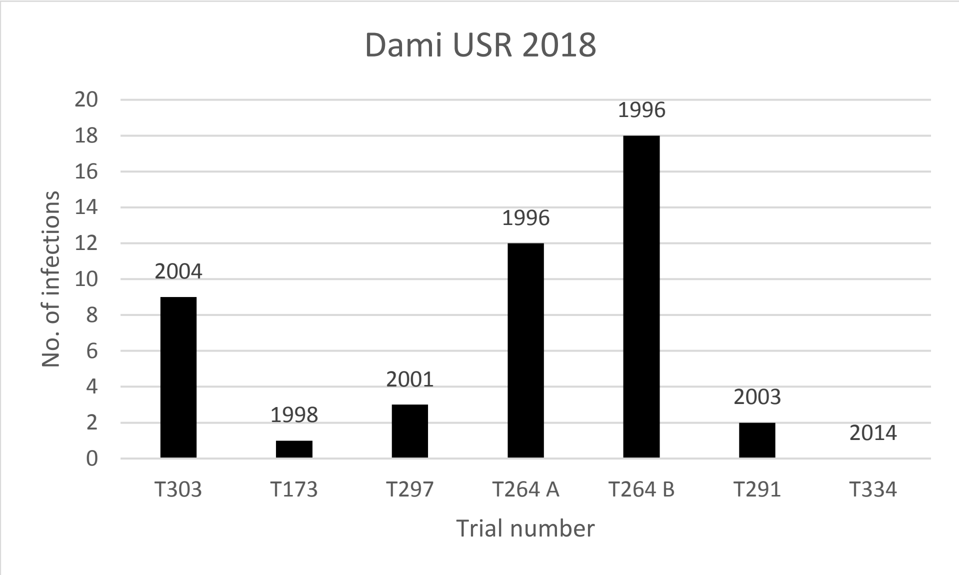

Figure 51 Number of upper stem rot palms recorded in selected blocks at Dami Plantation in 2018. The year of planting is shown above the bars in the histogram.

D.2.4. Smallholder Ganoderma research

Monthly monitoring of bracket production has continued in 2018 for six small holders poisoned – replanted blocks in Kapore, Morokea, Siki, Poinini and Tamba. Bracket production has been variable in the last three years of data collection. In 2018, Morokea recorded 1435 brackets (Figure 52)followed by Siki with 578, Kapore 001-0286 with 311, Tamba with 263 and Poinini with 188 brackets. Kapore 001-0372 had recorded no bracket production in 2018. Data collection from this block has now ceased as of December, 2018.

D.2.4.1. *Bracket monitoring in poisoned replant blocks*

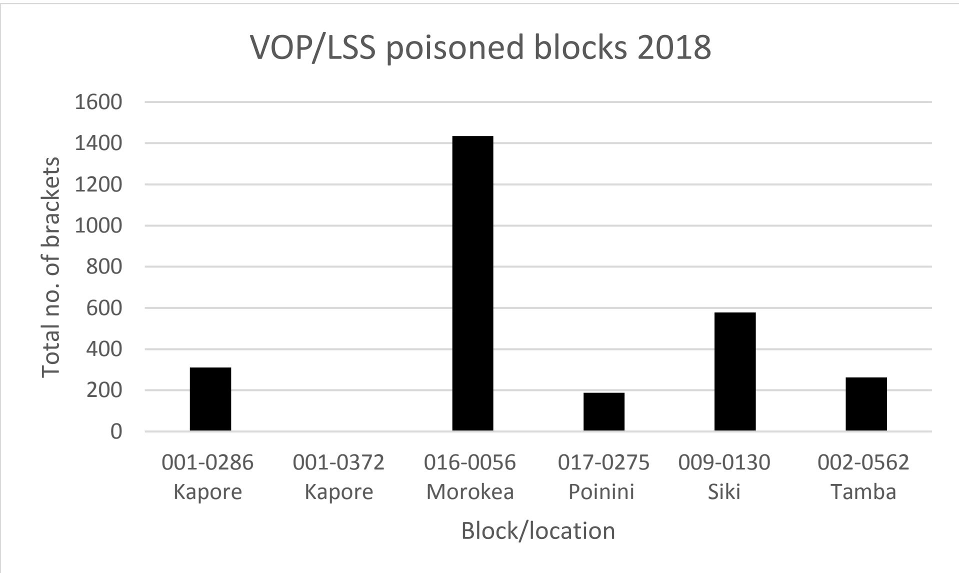

Figure 52 Number of brackets recorded on poisoned palms in replanted blocks in WNB for Kapore, Morokea, Poinini, Siki and Tamba in 2018.

D.2.4.2. *Disease reports*

All divisions for out growers continue to report basal stem rot with the highest number of reports from the Kavui division (Figure 53). Other diseases reported included spear rot and bunch rot possibly associated with wet weather conditions.

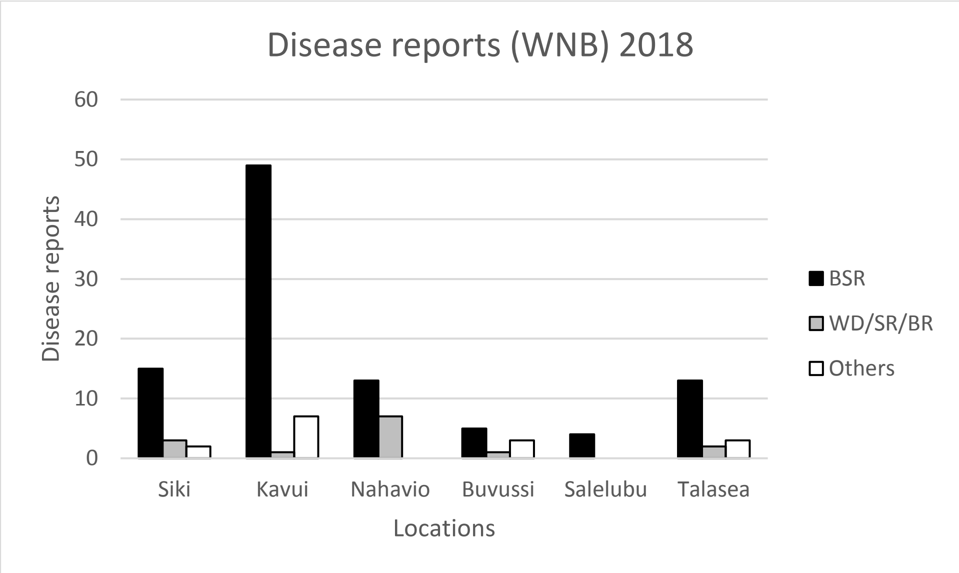

Figure 53 Number of disease reports per division for out growers in WNB for 2018.

D.3. FIELD DISEASE SCREENING

Yield data and BSR disease levels continue to be monitored for progeny testing in fields 12 and 13 at Ngalimbiu plantations, Solomon Islands. Trials were planted in 2010 with data collected beginning in 2013. A total of 81 commercial crosses were planted out in 14 replicates with two treatments. Field 12 had boles removed before planting while field 13 had bole left in soil at replant. All planting material were obtained from Dami Research Station. Cumulative BSR incidences for both fields 12 and 13 observed a slight increase (Figure 54) as comparative to 2016 and 2017. The current cumulative disease incidences are 10.2 % and 11.5 % respective for fields 12 and 13. Current cumulative mortalities indicate 1.4 % in field 12 while 3.4 % was reported for field 13.

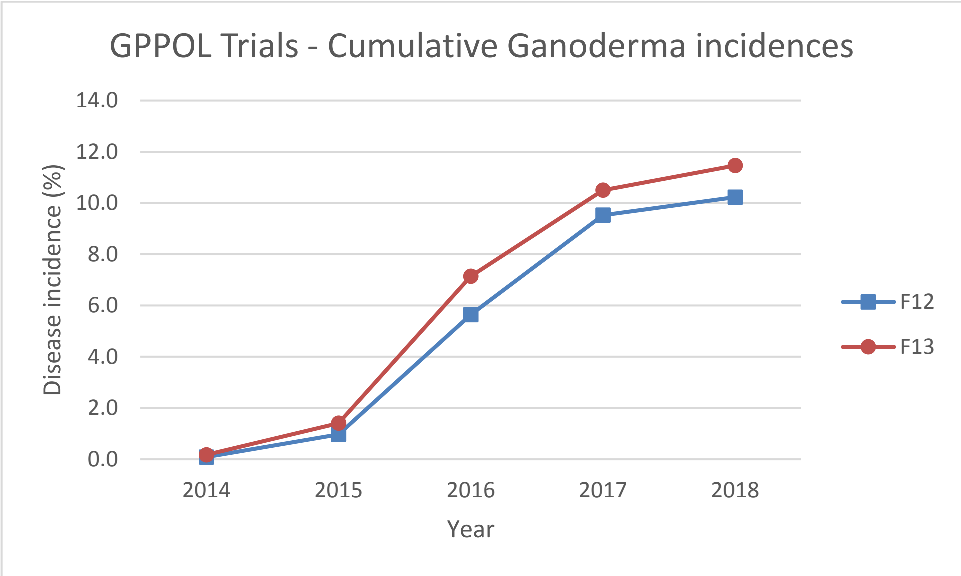

Figure 54 Cumulative *Ganoderma* disease incidences for fields 12 & 13 at GPPOL in 2018

Mean bunch weights (kg) for Fields 12 and 13 respectively were 9.8 and 10 kg (data not shown). Yield (tons) per hectare recorded 26.3 and 26.7 tons per hectare in 2018. Yield data(Figure 57 & Figure 58) indicate bunch weights (kg) are proportional to bunch numbers and that disease incidences now do not shown an apparent effect. Yield data per progeny is highly variable per plot in each field (Figure 55 & Figure 57) and these observations reflect natural variation as an effect on progeny.

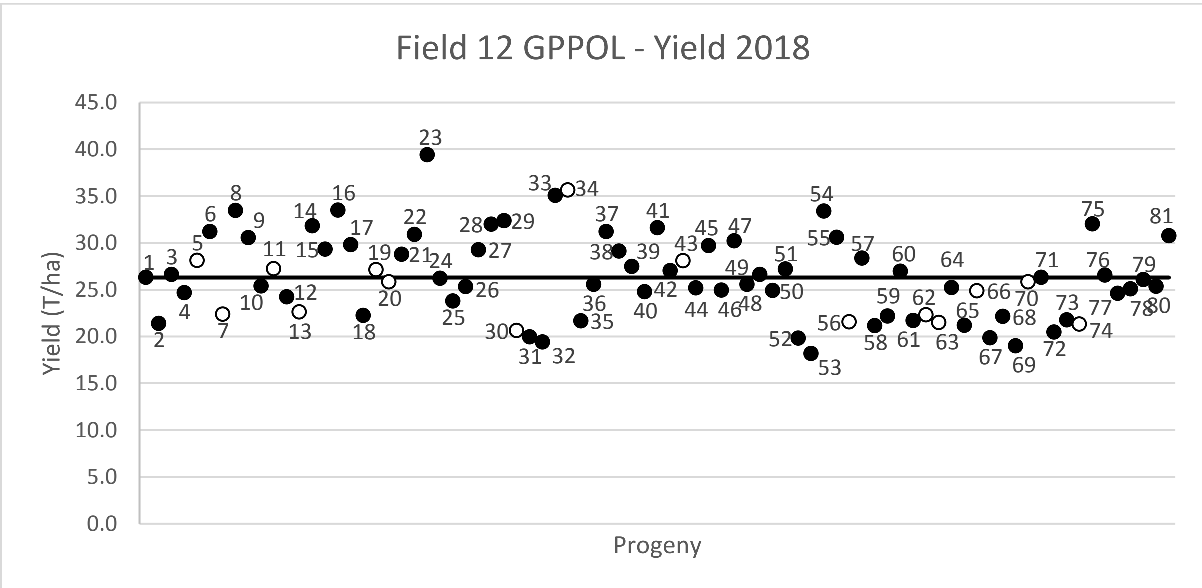

Figure 55 Mean yields (Tha^{-1}) recorded for 81 progenies planted in Field 12, Ngalimbiu Plantation (GPPOL), Solomon Is. The bar is the mean for all palms and the clear circle indicate progeny with mortalities.

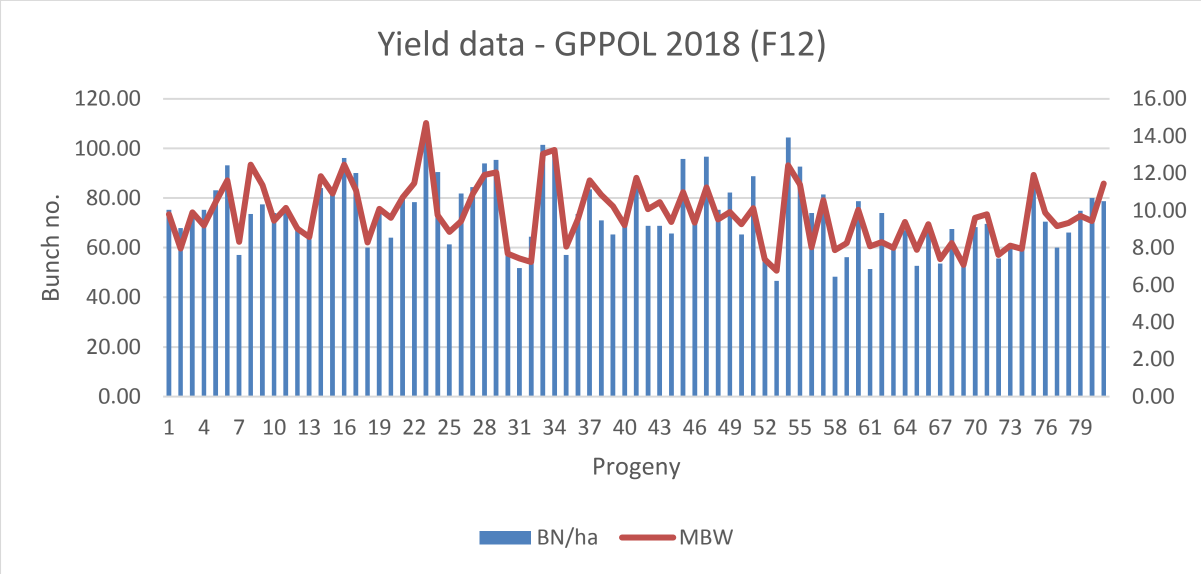

Figure 56 Mean bunch numbers per bunch weights (kg) recorded for 81 progenies planted in Field 12, Ngalimbiu Plantation (GPPOL), Solomon Is.

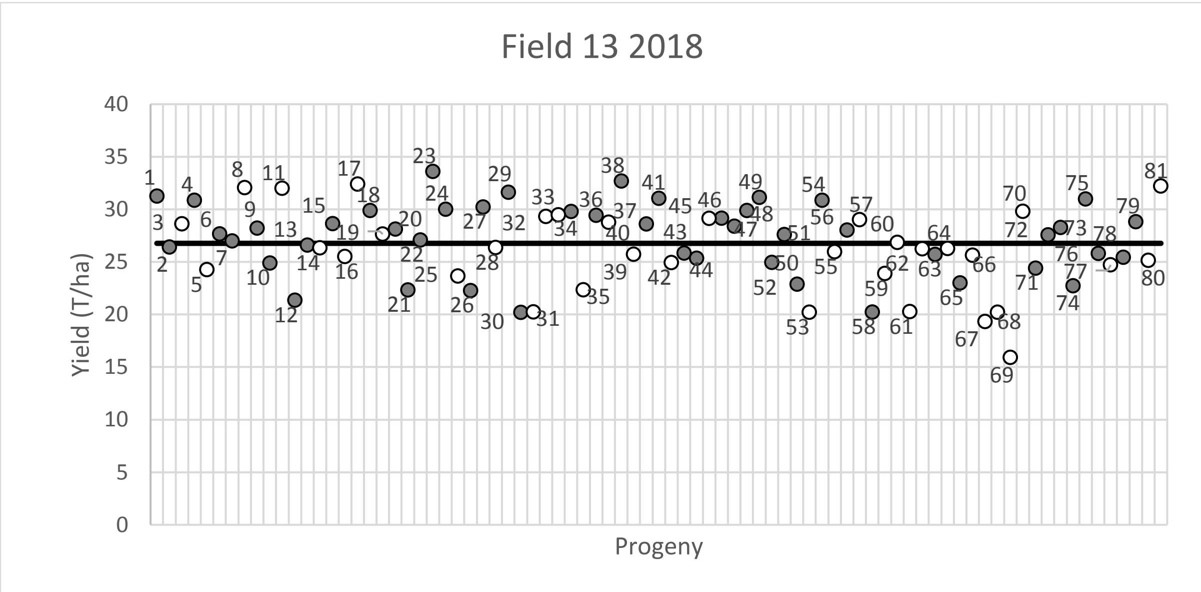

Figure 57 Mean yields (Tha-1) recorded for 81 progenies planted in Field 13, Ngalimbiu Plantation (GPPOL), Solomon Is. The bar is the mean for all palms and the clear circle indicate progeny with mortalities.

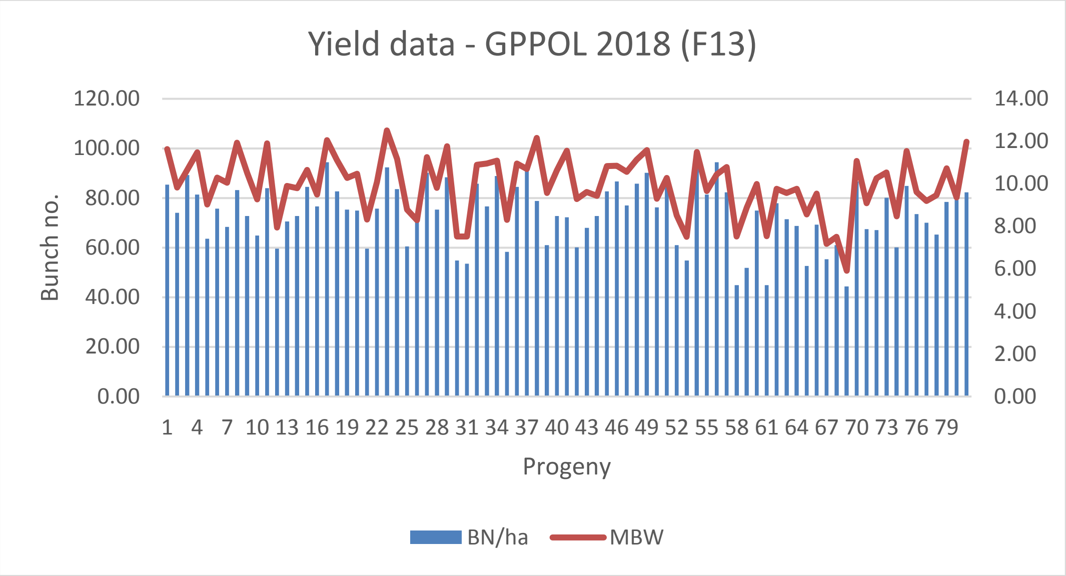

Figure 58 Mean bunch numbers per bunch weights (kg) recorded for 81 progenies planted in Field 13, Ngalimbiu Plantation (GPPOL), Solomon Is.

D.4. LABORATORY STUDIES

D.4.1. Bio-control of Ganoderma using indigenous Trichoderma spp

Work commenced in March, 2017 in an effort to bulk up indigenous Trichoderma spp for use as bio-control against *Ganoderma boninense*. Five isolates have been used in this project. Efforts were focused on utilising liquid culturing methods to harvest start up inoculum that to be used as booster cultures for larger scale production with the potential for field and nursery use. The work was ceased in April, 2018 and has been reviewed. It is suggested that solid culture methods would be trailed in following year as a more practical approach towards rearing inoculum for larger scale field use.

D.4.2. Fungicide testing

Field trials were carried out in two separate blocks in Nomundo, WNB between May and June, 2018 to assess effectiveness of Tilt (propiconazole) via direct trunk injection and copper nails. Both trials included non-treated palms as controls. Both trials are anticipated to run for three years or until the blocks are replanted. Disease symptoms and progress are being monitored every 3 – 6 months. Fruit bunches have been collected and oil extracts have been sent overseas for chemical residual analysis.

D.4.3. Bogia coconut syndrome

Insect and plant samples have been received from Mobdu, Siar, Bogia, Brahman & Bomkalawa. DNA extractions for all plant material has been completed pending molecular identification for Phytoplasma. Dna extractions have been completed for 71 % of all insect samples with the balance pending extraction kits.

D.4.4. In-vitro Pathogenicity testing

In-vitro pathogenicity testing for rapid screening of seedlings was initiated in 2017 throughout 2018. Newly germinated seedlings were exposed to various permutations to assess BSR establishment and infections process. Results for the first lot of testing show variable results and no conclusions can be drawn as yet.

D.5. ACKNOWLEDGEMENTS

Plant Pathology staff in PNG and Solomon Islands for data collection of research data presented in this report.

ACIAR is acknowledge for its contribution to Plant Pathology research under Project PC-2012-086.

Other PNG OPRA sections who assisted in logistic and data collections are acknowledge.

All TSD managers for providing Ganoderma disease data presented in this report.

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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 conduct research and extension that will contribute to improving smallholder productivity and strengthening the economic, environmental and social well-being of the oil palm smallholder households.

The last 2-3 years, we have prioritized to capacity build our staffs through in-house and external training so that we can capitalize on current staffs to conduct and deliver quality research and extension support to our clients. Philip Makai attended a 5-day training on video shooting, editing and production in Port Moresby. The training was facilitated by 10 Lyn Media and Marketing Concepts. After the training, he was able to assist with the production of one of the videos produced by the media unit. Emmanuel Germis successfully completed his MPhil on Socioeconomics from Curtin University, Australia and returned to PNG in September 2018. Two staffs based in Bialla and Popondetta were transferred to Agronomy section at the end of 2018.

The BMP project (SSR101abcde) in Hoskins WNB will be closed end of 2018. This decision was made by the SAC in the 2018 SAC review because the project had achieved it objective in demonstrating to that the smallholder FFB yields can be increased to well over 20t/ha through prudent block management practices, regular harvesting and application of fertilizers. Poliamba, Popondetta and Milne Bay will continue the BMP work in 2019. Smallholder leaf sampling will continue as planned. This year, considerable amount of time was invested towards writing up of the closed projects. In 2018, the section also conducted one socioeconomic study "Investigating low harvesting capacity for Village Oil Palm Growers in Bialla." In 2019 and thereafter, we will be focusing most of our research on socioeconomic indicators for improving productivity of oil palm and livelihood of the smallholders.

The section has also been collaborating with institutions within Papua New Guinea and Australia on projects funded through Australian Centre for International Agriculture Research (ACIAR). These collaborating partners included Curtin University, James Cook University, Cocoa Board (formally CCI), Coffee Industry Corporation and University of Technology (Unitech). The final review of ASEM-2012-072, a project on "Strengthening livelihoods for food security amongst cocoa and oil palm farming communities in Papua New Guinea" was successfully held on the 9th of June Kimbe, WNBP, followed by a field trip to Bialla on the 10th June. The promotion of the eco-zoom stove which is presented in this report is part of this project. The second ACIAR funded project (ASEM-2014-054) on "Identifying opportunities and constraints for rural women's engagement in small-scale agricultural enterprises in PNG" is a 4-year project. This project is current and one of the studies conducted under this project is also presented in section E.7.5.

The other core function of the section is training of smallholders in best management practices (BMP) of oil palm. Since the formation of the section in 2014, a considerable amount of time, resources and funding was allocated towards reviving extension and training in Hoskins and Bialla projects in WNB. Incentives were included in the trainings to attract more farmers to participate and by 2018, the trainings in WNB especially the Hoskins Project has gain popularity with over 100 participants attending the field day training. The number of presenting stakeholders has increased as well from 2-3 stations to well over 8 stations per event. We have also attracted external stakeholders like the commercial banks, micro finance institutions, Nasfund, WNB Provincial Health Authorities and Police. With a lot of resources, time and funding towards training, our future focus will be on evaluating these trainings and assess the level of adoption by the growers so that resources are not put to waste.

E.2. NBPOL WNB

Steven Nake, Emmanuel Germis, Merolyn Koia, Leonard Hura and Ferdinand Baba

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*

Applied research on smallholder blocks is one avenue for dissemination of new agriculture technology to the smallholder growers. Since 2009, a series of BMP blocks were set up in low producing smallholders blocks to determine the impact of BMP on fresh fruit bunch (FFB) yields. Nine years after the inception of these trial blocks, the results showed that current low yields in smallholder blocks can be improved through intensification of block management practices. This also includes regular harvesting and fertiliser application. In 2018, the FFB yields ranged from 16.4 t/ha to 34.2 t/ha with an average of 24.7 t/ha. This contrasts with Hoskins smallholder yields of 14.5 t/ha in 2018. There is potential to produce more crop but close the current yield gap of 10 t/ha.

E.2.1.2. *Background*

As the global population increases with a growing demand for palm oil, an extra 12M ha will be needed over the next 40 years. However, while area under production has increased rapidly during the past 40 years, average achieved oil yields particularly in the smallholder sector remained far below the potential levels. Area expansion also raises environmental concern. Alternatively, increasing productivity in already existing blocks offers scope for improvement and reduces the need to increase area for oil production. Additional, financial returns through yield intensification are expected to be larger because there is no need to invest in new plantings and infrastructure. Furthermore, financial returns are expected to develop more rapidly, because production starts to increase as soon as agronomic constraints are removed.

Increases in production can be met through intensification by improving yields per area. Best Management Practices (BMPs) developed by The International Plant Nutrition Institute's (IPNI) Southeast Asia Program (SEAP) focuses on increasing palm oil yield in existing mature plantations by using agronomic methods and techniques that are cost-effective and practical. Yield improvement efforts in existing blocks thereby focuses on identifying and rectifying management practices that contribute to the emergence of a gap between the yield potential and actual achieved yield which is the yield gap. The growing demand can be met by improving yields in existing oil palm plantations through Best Management Practices (BMPs) by using cost-effective and practical agronomic methods.

In Papua New Guinea, there is huge yield variation between company estates and the smallholder blocks although smallholder oil palm is cultivated on the same soil and climatic condition as the plantations owned by milling companies. PNGOPRA fertiliser trials in NBPOL plantations prove yields of 30 t/ha are achievable. However, the smallholder yields are much lower than the estates production. Therefore, the objective of this project is to convert low yielding into well-managed high yield blocks and demonstrate to smallholder growers that oil palm best management practices can contribute to better yields and better economics.

E.2.1.3. *Methodology*

Block selection and establishment

The project started off in 2009. Poorly managed blocks, with nutritional disorders and low fresh fruit bunch (FFB) production were selected and these blocks were rehabilitated to BMP standard. After rehabilitation, BMP practices (chemical and manual weed control, pruning, frond stacking, fertilizer application, establishment and maintenance of LCP) were routinely carried out on these blocks and yields were also monitored to demonstrate the impact the BMP, through regular harvesting. Surveillance was also carried out for pest and diseases incidences. Fertilizer was also applied every year and leaf sampling also carried out every year to determine nutritional status of these blocks.

Not all blocks lasted up to 2018. Some blocks were closed prematurely because of no positive response due to block owners own negligence or malpractices on the blocks. Others were closed because they achieved the project objective before the 5 years period. Since the inception of the project in 2009, a total of 40 blocks were trialed out. The project results were then used to do training and awareness to the growers on the impact of BMP on yields. Table 81 shows list of both current and closed BMP blocks in Hoskins Project.

Table 81 List of BMP blocks established in Hoskins

No	Block	Trial code	Area	Scheme	Division	Year initiated	Status (Dec 2018)
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	Closed
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	Closed
8	006-1719	SSR101b	Kavui Sect 7	LSS	Kavui	2009	Current
9	004-1169	SSR101c	Buvusi Sect 5	LSS	Buvusi	2010	Closed
10	021-0209	SSR101a	Rikau	VOP	Siki	2011	Closed
11	039-0092	SSR101a	Koimumu	VOP	Siki	2011	Closed
12	009-1055	SSR101a	Siki	LSS	Siki	2011	Current
13	014-0126	SSR101b	Mai	VOP	Kavui	2011	Closed
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	Closed
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	005-2118	SSR101c	Galai 2	LSS	Buvusi	2014	Closed
27	005-1590	SSR101c	Galai 2	LSS	Buvusi	2014	Closed
28	005-1570	SSR101c	Galai 2	LSS	Buvussi	2014	Current
29	002-0475	SSR101d	Tamba Sect 5	LSS	Nahavio	2014	Closed
30	002-0561	SSR101d	Tamba Sect 6	LSS	Nahavio	2014	Closed
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	Closed
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	Closed
38	047-0003	SSR101c	Lilimo	VOP	Buvussi	2016	Closed
39	005-2118	SSR101c	Galai 2, Sect 19	VOP	Buvussi	2016	Current
40	019-0051	SSR101d	Tamambu	VOP	Nahavio	2016	Current

Fertiliser Application

Only urea applied to the blocks using rate of 1.5 kg per palm per year. Urea is applied at the edge of the weeded circle around the palm.

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).

E.2.1.4. *Results and Discussion*

Individual BMP block production in 2018

By the end of 2018, only 17 blocks out of the 40 (43%) initiated between 2009 and 2016 actively engaged/participated in the project. The 23 blocks closed due to non-compliance with the terms of reference for the project. Some of these included illegal practices such as crop diversion either out or into the blocks and frequent skip harvests which affected data quality. Others included internal disputes and lack of interest to participate in the research and not willing to maintain block at the BMP standards. Therefore, the data presented and discussed in this report will only cover the best 17 BMP blocks (Figure 59) that have complied well with PNGOPRA.

The 2018 FFB production are depicted in Figure 59. The 2018 yields ranged from 16.4 t/ha to 34.2 t/ha with an average of 24.7 t/ha. Fifteen (15) of the BMP blocks yielded well above the 20 t/ha mark. Eight blocks produced over 25 t/ha, while two blocks yielded beyond 30 t/ha in 2018. These blocks do regular harvesting and fertiliser application. They also maintain good upkeep of their blocks facilitating high crop recovery. The high yields observed from this applied research demonstrates the potential yields smallholders can achieved if they apply BMP in their blocks regularly.

Only 2 blocks (003-0980 & 256-0042) yielded below 20 tonnes. Block 003-0980 had two phases (4 hectares) of over-aged palms. Over 50% of the palms were too tall to harvest hence the low production. Block 256-0042 is VOP block that had very low yield (<10 t/ha) at the start of the project and with training and technical support by PNGOPRA, the yields gradually increased but at a slow pace over the last 3 years.

The 9-year yield trend (Figure 60) also illustrates well the positive impact of BMP on the oil palm yields. The impact of BMP was more pronounced in the first 24 months (2 years) after initial block rehabilitation. From an average of 12 t/ha, the yields excelled to 16.5 t/ha, then 20.3 t/ha in the first year and second year respectively. This represented a yield increment of 4.5 t/ha and 8 t/ha respectively. It took 2 years after block rehabilitation for yields to be elevated to 20 t/ha mark. After the 3rd year, the yields maintained at an average of 20.5 t/ha.

The average smallholder production in Hoskins for 2018 was 14.5 t/ha while that of the BMP blocks was 24.7 t/ha in the same year. This represented an average yield gap of 10 t/ha.

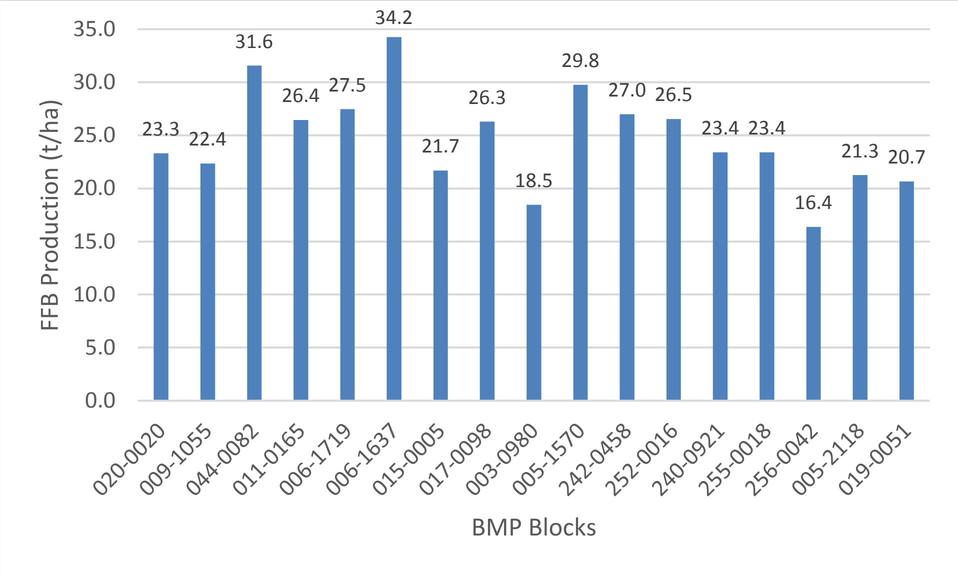


Figure 59. Average production (t/ha) for best managed BMP blocks in Hoskins in 2018

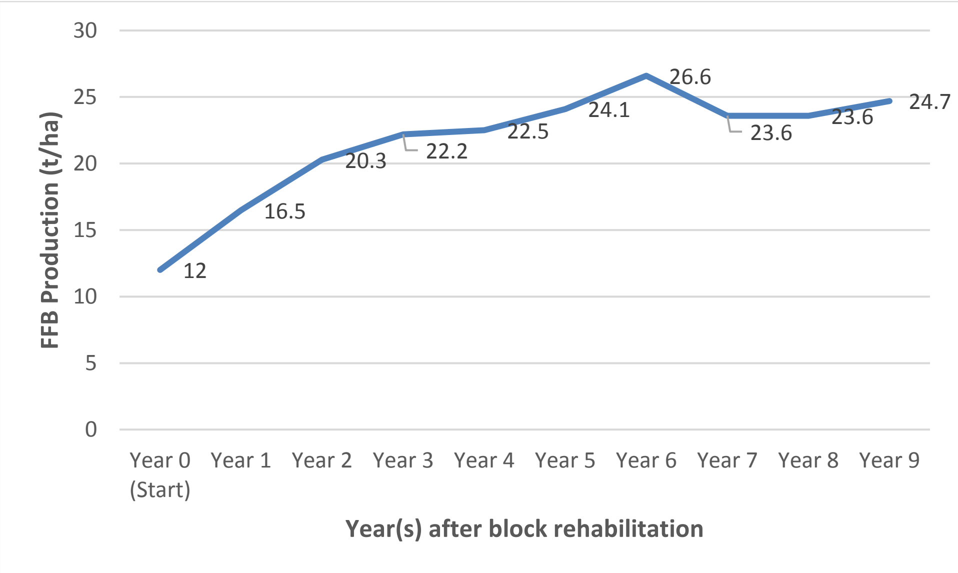


Figure 60. Average production (t/ha) trend for BMP blocks after rehabilitation in Hoskins Project

E.2.1.5. *Conclusion*

The project is of relevance to the smallholder sector by identifying through research and extension possible solution to improving low fresh fruit bunch (FFB) yields in smallholder sector. The long-term yields from the BMP blocks have proven the potential yields that smallholder blocks in Hoskins can achieve under local climatic and environmental conditions so long as they maintain upkeep of their blocks, apply fertiliser every year and harvest regularly. Sustaining yield beyond 20 t/ha is possible.

E.2.2. SSR104: Assessing leaf nutritional status of smallholder blocks, 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 145 smallholder blocks to assess their foliar nutritional status. Samples were processed and dispatched to AAR Laboratory in Malaysia for analysis. Laboratory analysis revealed deficiency in the 4-major nutrient (N, P, K and Mg) in the oil palm leaves. 100% of 145 sampled blocks deficient of N, 97% deficient of P, 99% K deficient and 66% Mg deficient. The number of sampled blocks deficient in N, P and K have increased to over 90% in 2018. In contrast, leaflet B and rachis K were adequately available in the leaflets. The 5-year trend also confirmed a consistent decline in leaflet N, P and K over time. Fertiliser recommendations for smallholders in Hoskins WNB should be reviewed to correct the current deficiencies in the main elements such as N, P and K.

E.2.2.2. *Background*

One of the factors affecting smallholder production is the lack of fertilizer applied to increase production compared to the Plantation sector. The reasons for this has been extensively documented by Koczberski *et al* (2001) in their report. For palm to gain maximum production per hectare, inorganic fertilizers need to be applied to maintain production levels as well as replenishing nutrient loss through plant uptake and other means such as soil organic matter loss, leaching, volatilization, erosion etc. The main fertilizer applied in the smallholder in West New Britain is Nitrogen in the form of Urea (46 % Nitrogen).

The three common diagnostic tools to determine palms health status are; (i) visible symptoms of nutrient deficiency or excess; (ii) tissue (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. Since 2013, leaf sampling was undertaken assess the nutrient status out for 143 smallholder blocks across the 5 divisions in the Hoskins Project. Therefore in 2018, the same blocks were sampled. It is hoped that information generated from this project will be useful for reviewing the current fertilizer recommendations for smallholders in the Hoskins project.

E.2.2.3. *Methodology*

One hundred and forty-five (145) smallholder blocks were randomly selected from the five divisions (Siki, Kavui, Buvussi, Nahavio and Salelubu) (Table 82). 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 AAR Laboratory in Malaysia for analysis.

Table 82. Break up of Smallholder blocks utilized for leaf sampling in 2018

Division	Number of sampling blocks
Siki	32
Kavui	30
Buvussi	28
Nahavio	28
Salelubu	27
Total:	***145***

E.2.2.4. *Results and Discussion*

The leaf and rachis nutrient concentrations are presented in Table 83. Leaflet N, P and K were deficient in all the 5 divisions. Leaflet Mg was adequate in Salelubu division only, while the other 4 divisions (Buvussi, Kavui, Siki and Nahavio) were deficient. In contrast, leaflet Ca, B, Cl and rachis K were above the critical level.

The foliar nutrient concentrations for the individual blocks are shown in Figure 61 to Figure 66. Leaflet N ranged from 1.63% to 2.55 % with all 145 blocks (100%) below the critical level of 2.59% deficient in leaflet N, an indication of deficiency. The average mean leaflet N in 2018 was 2.07%. For leaflet P only 5 blocks (3%) were above the critical level of 0.142 %, while the remaining 140 blocks (97%) were P deficient. Leaflet P ranged from 0.108 % to 0.149%. Leaflet P dropped drastically from a mean of 0.135% in 2017 to 0.125% in 2018.Leaf K ranged from 0.38 to 0.83 %, with mean of 0.51%. Only 1 block was above the adequate level, while rest of the 144 blocks (99%) were deficient.

Leaflet Mg ranged from 0.09 to 0.30% with an average of 0.19 % in 2018. Forty-nine (49) blocks (34 %) were above the critical level of Mg (0.20%). The remaining 94 blocks (66%) were Mg deficient. For Leaflet B, only 1 block was deficient whereas only 3 blocks showed K deficiency in the rachis.

Table 83. Foliar nutrient concentrations for smallholder blocks in the 5 divisions in Hoskins Project in 2018

Divisions	Leaf N (%)	Leaf P (%)	Leaf K (%)	Leaf Mg (%)	Leaf Ca	Leaf B (ppm)	Leaf Cl	Leaf S	Rachis K(%)
Buvussi	2.10	0.126	0.52	0.18	0.85	14.9	0.20	0.19	1.33
Nahavio	2.17	0.128	0.52	0.17	0.80	13.7	0.36	0.21	1.57
Kavui	2.07	0.124	0.52	0.17	0.82	13.3	0.29	0.19	1.52
Siki	1.91	0.118	0.48	0.19	0.80	12.6	0.28	0.18	1.46
Salelubu	2.08	0.128	0.53	0.23	0.82	14.5	0.25	0.20	1.54
Mean	**2.07**	**0.125**	**0.51**	**0.19**	**0.82**	**13.8**	**0.28**	**0.19**	**1.48**
Critical level (Foster 2015)	**2.59**	**0.142**	**0.75**	**0.20**	**0.25**	**8.0**	**0.25**	**0.20**	**0.95**

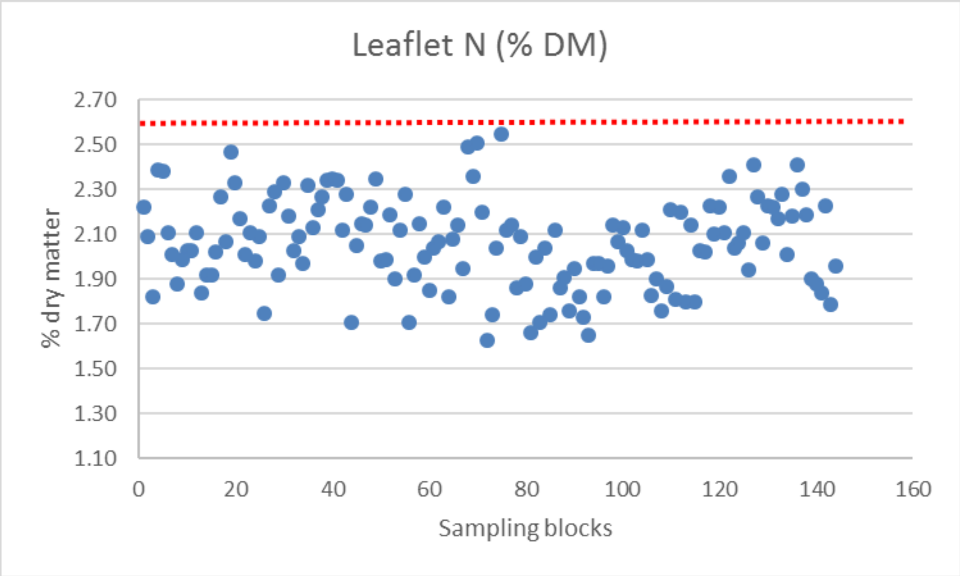


Figure 61. Leaf N concentration for the sampled smallholder blocks in 2018

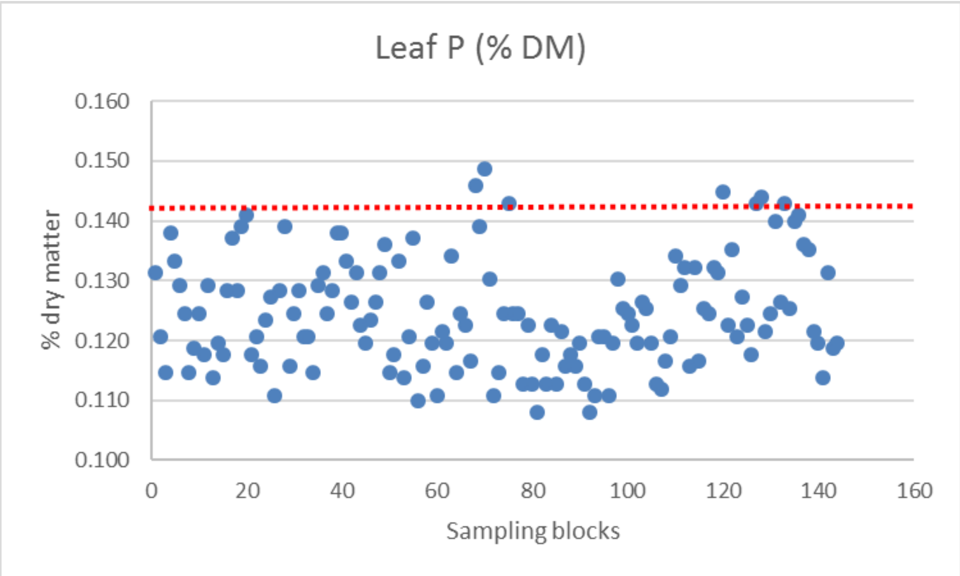


Figure 62. Leaf P concentration for the sampled smallholder blocks in 2018

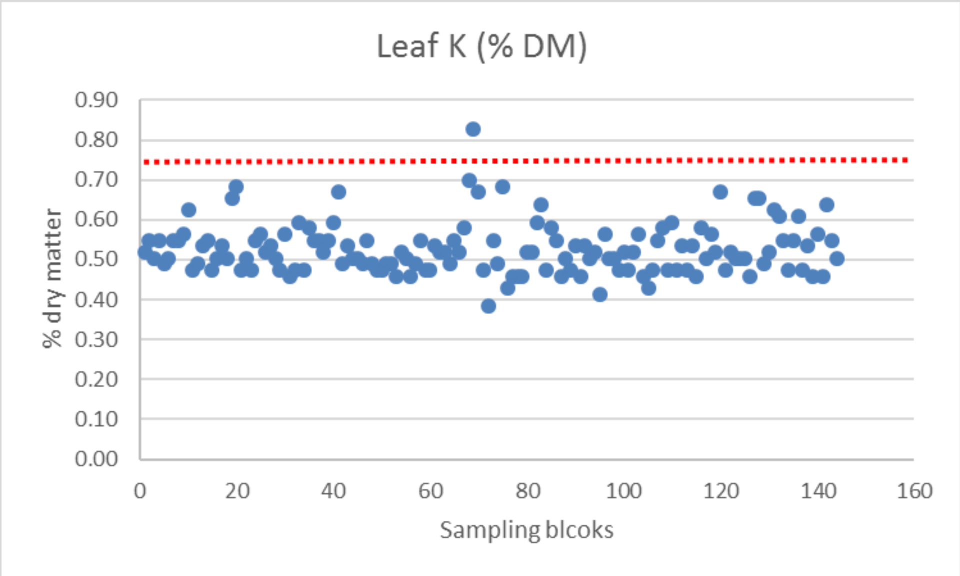


Figure 63. Leaf K concentration for the sampled smallholder blocks in 2018

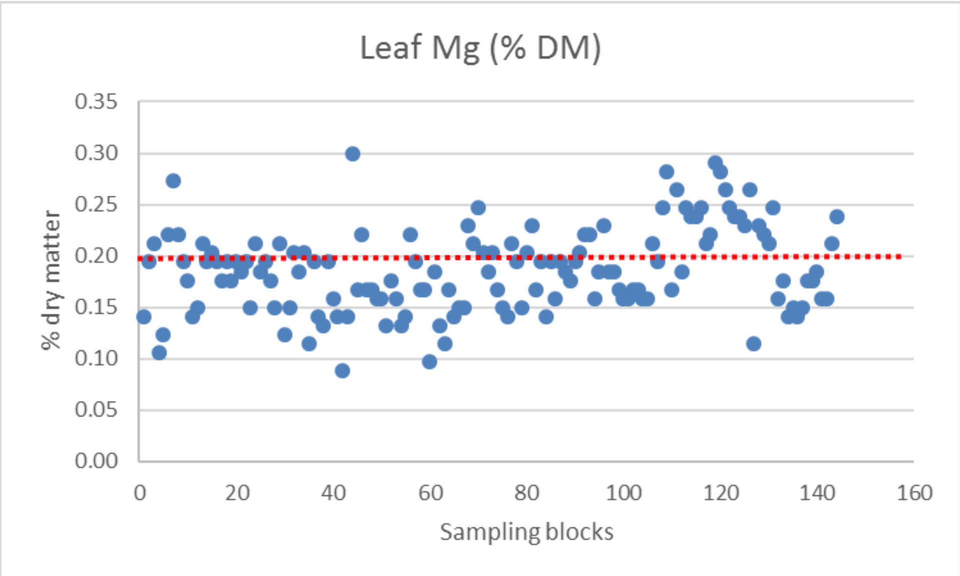


Figure 64. Leaf Mg concentration for the sampled smallholder blocks in 2018

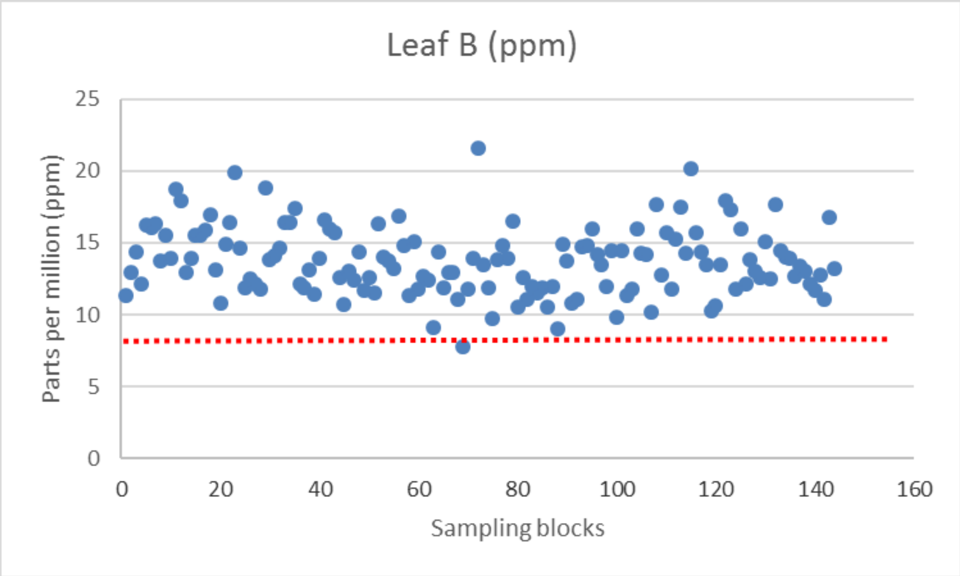


Figure 65. Leaf B concentration for the sampled smallholder blocks in 2018

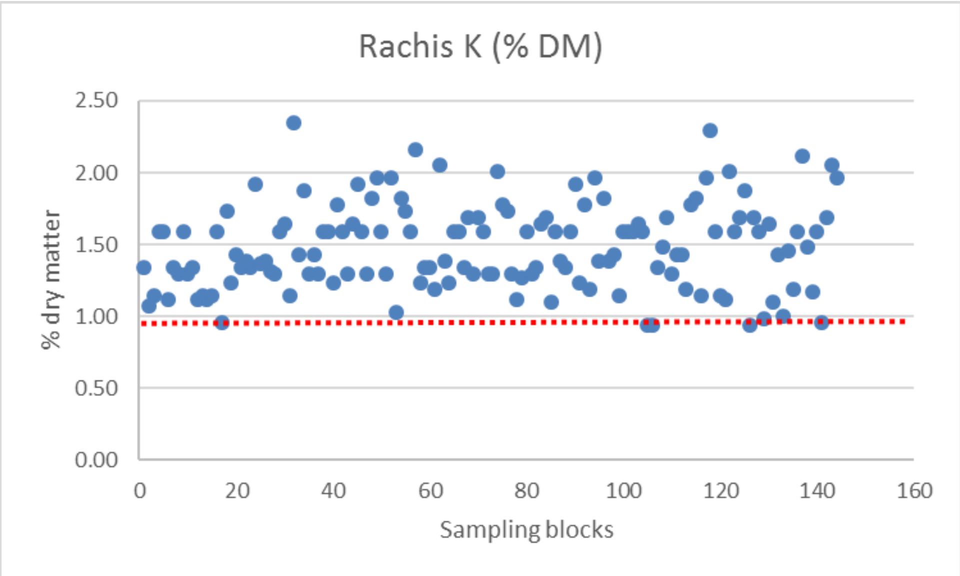
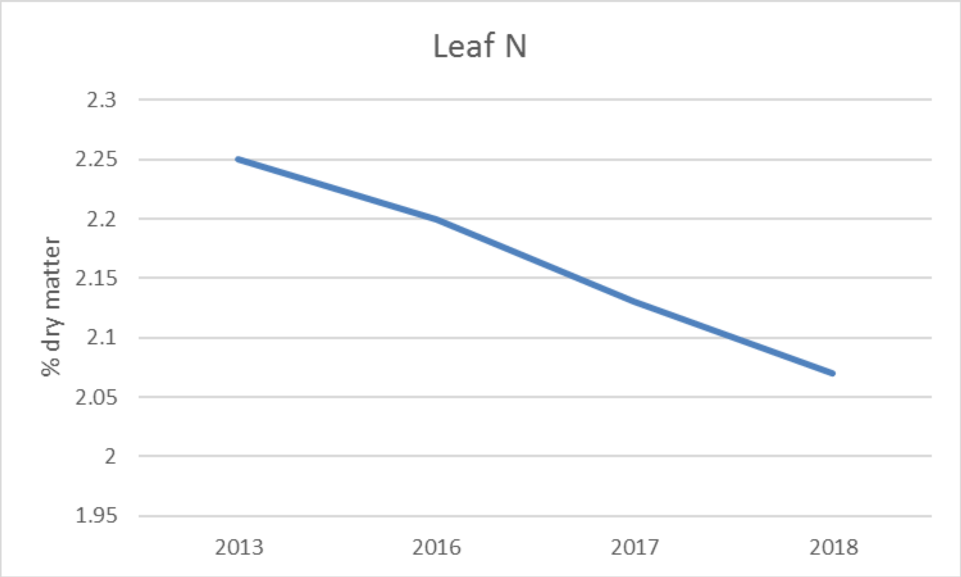


Figure 66. Rachis K concentration for the sampled smallholder blocks in 2018

The 5-year (2013-2018) trend for the foliar N and K are shown in Figure 67. While other elements fluctuated in a declining trend in the last 5 years, Leaflet N and K plummeted consistently from 2013 to 2018. Leaflet N dropped from 2.3% in 2013 to 2.07% in 2018 whereas leaflet K dropped from 0.84 % in 2013 to 0.51% in 2018.



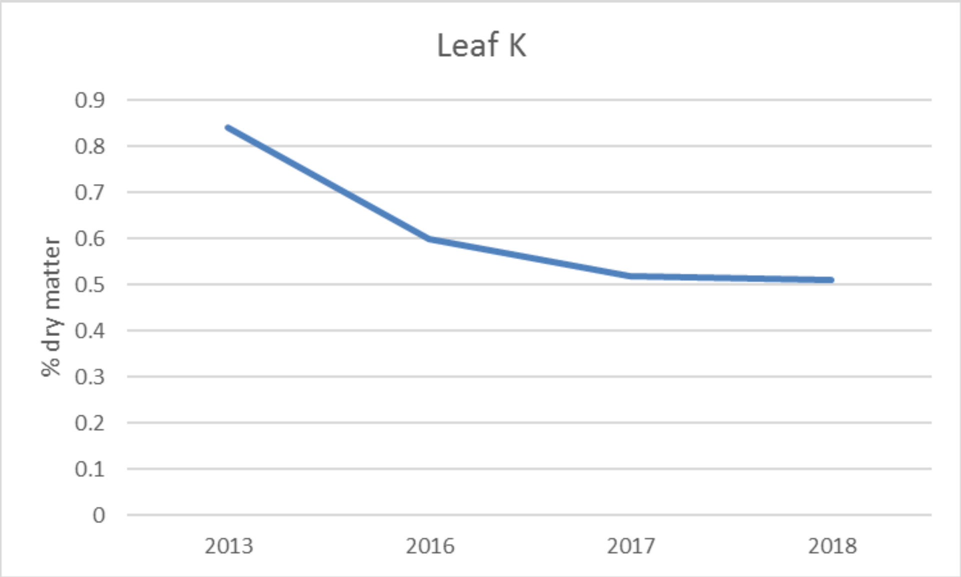


Figure 67. Mean foliar concentrations of N and K from 2013 to 2018

E.2.2.5. *Conclusion*

Leaflet N, P, K, Mg and S were found to be deficient in the oil palm leaflets in 2018. In contrast, leaflet B, Ca, Cl and rachis K were sufficiently available. Leaflet N and K levels continue to plummet in the last 5 years of sampling. Leaflet P also experienced a drastic drop in its level between the years 2017 and 2018. Fertiliser recommendations for smallholders in Hoskins WNB should be reviewed to correct the current deficiencies in the main elements such as N, P and K.

E.3. HARGY OIL PALMS, WNB

Steven Nake, Paul Simin, Peter Mupa and Andy Ullian

E.3.1. SSR203: Assessing leaf nutritional status of smallholder blocks, Bialla Project

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

E.3.1.1. *Summary*

Leaf sampling was conducted in 108 smallholder blocks in Bialla to assess their foliar nutrient status. Laboratory analysis revealed that leaflet N, P, K were below their respective critical level and were deficient on the oil palm leaves. The mean leaf concentration in 2018 for N, P and K were 2.16%, 0.124% and 0.48% respectively. In contrast, Mg and B concentration in the leaf and rachis K were in abundance.

E.3.1.2. *Background*

One of the factors affecting smallholder production is the lack of fertilizer applied to increase production compared to the Plantation sector. The reasons for this has been extensively documented by Koczberski *et al* (2001) in their report. For palms to gain maximum production per hectare, inorganic fertilizers need to be applied to maintain production levels as well as replenishing nutrient loss through plant uptake and other means such as soil organic matter loss, leaching, volatilization, erosion etc. The main fertilizer applied in the smallholder in Bialla, West New Britain is Nitrogen in the form of Urea (46 % Nitrogen).

The three common diagnostic tools to determine palms health status are; (i) visible symptoms of nutrient deficiency or excess; (ii) tissue (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. Leaf sampling in Bialla was initiated in 2016 to determine the leaf nutrient concentrations of oil palm in 108 smallholder blocks. This information is also useful to adjust the current fertilizer recommendations if there is a need. Recently, smallholder leaf sampling plays an important role in supplying information on smallholder oil palm nutrition to Sustainability department as a matter of compliance to RSPO.

E.3.1.3. *Methodology*

One hundred and eight (108) smallholder blocks were randomly selected from the 3 divisions (Cenaka, Maututu and Meramera) (Table 84). The selected blocks were within the prime age group at the time of selection. Immature and over-aged blocks were not considered. 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 AAR Laboratory in Malaysia for analysis.

Table 84. Number of leaf sampling blocks per division in 2018

Division	Number of sampling blocks
Cenaka (Division 1)	44
Maututu (Division 2)	39
Meramera (Division 3)	25
Total:	***108***

E.3.1.4. *Results and Discussion*

Leaflet N, P, K for all divisions were deficient. Leaf Mg, B and rachis K on the other hand were above adequately available (Table 85). Leaflet Mg for all divisions were slightly above the critical mark (0.2%) while leaflet B and rachis K were well above their respective critical mark.

Figure 68 to Figure 73 depict foliar nutrient status for the 108 sampled blocks. Leaflet N ranged from 1.70% to 2.68% with a mean of 2.16%. Only 2 blocks (2%) were above the critical level of 2.59%, while the rest of the blocks were deficient.

Leaflet P ranged from 0.103% to 0.145% with a mean of 0.124%. Only 4% (4 blocks) of the sampled blocks had their P levels above the critical mark, whilst leaflet P was deficient in the other 96% of the blocks. Leaflet K ranged from 0.24% to 0.67% (mean = 0.48%). All sampled blocks (100%) were K deficient. 88 blocks representing 81.5% of the sampled blocks were deficient. The leaf K concentrations ranged from 0.24 to 0.67%, with a mean of 0.48 %.
For leaflet Mg, slightly more than half of the blocks (56%) were adequately available. Leaflet Mg ranged from 0.11% to 0.44% with a mean of 0.22%. Similarly, leaflet B and rachis K levels were generally adequate. All the sampled blocks (100%) were well above the critical level for leaflet B while for rachis K, 98 blocks (91%) were above the critical level. Leaflet B ranged from 8.6 to 39.9 ppm while rachis K ranged from 0.46% to 2.71%.

When comparing 2018 to 2017 foliar nutrient levels (Table 86), leaflet N, P and K have declined to 2.16 %, 0.124 % and 0.48%in 2018 from 2.17%, 0.132% and 0.51% in 2017 respectively. There is not much improvements to leaflet N which is the main driver to oil palm growth and production since 2016. On the other end there is a declining trend for leaflet K over the last three years.

Table 85. Foliar nutrient concentrations for smallholder blocks in Bialla Project

Divisions	Leaf N (%)	Leaf P (%)	Leaf K (%)	Leaf Mg (%)	Leaf B (ppm)	Rachis K(%)
Cenaka	2.21	0.130	0.51	0.22	12.6	1.40
Maututu	2.19	0.123	0.48	0.21	17.0	1.72
Meramera	2.01	0.116	0.44	0.24	21.0	1.42
Mean	***2.16***	***0.124***	***0.48***	***0.22***	***16.1***	***1.52***
Critical Level(Foster, 2015)	**2.59**	**0.142**	**0.75**	**0.20**	**8.0**	**0.95**

Table 86. Foliar nutrients in 2016, 2017 and 2018

Foliar Nutrient	2016	2017	2018
Leaflet N	2.15	2.17	2.16
Leaflet P	0.128	0.132	0.124
Leaflet K	0.57	0.51	0.48
Leaflet Mg	0.26	0.21	0.22

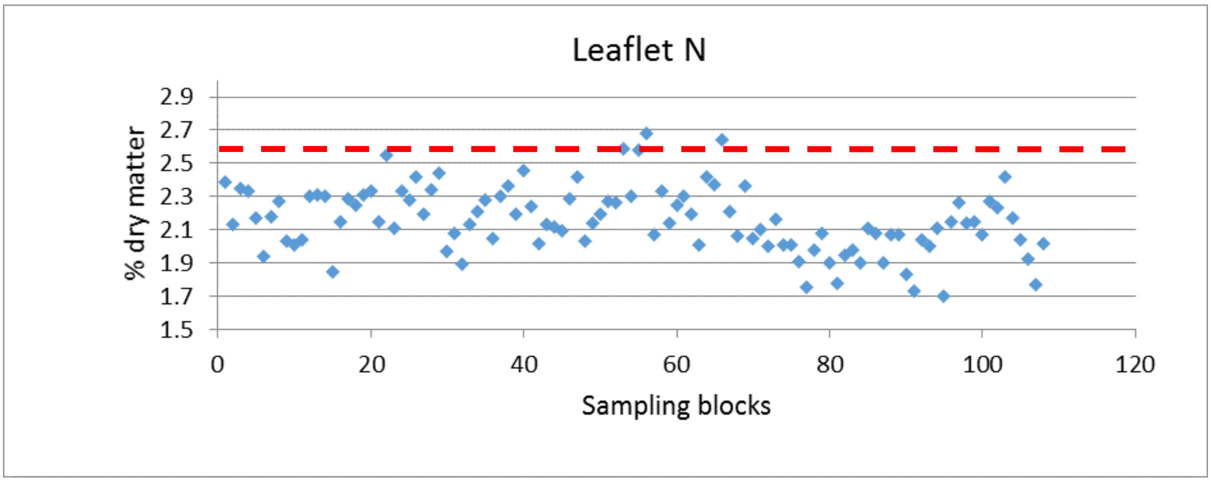


Figure 68. Leaflet N concentration for the sampled smallholder blocks in 2018

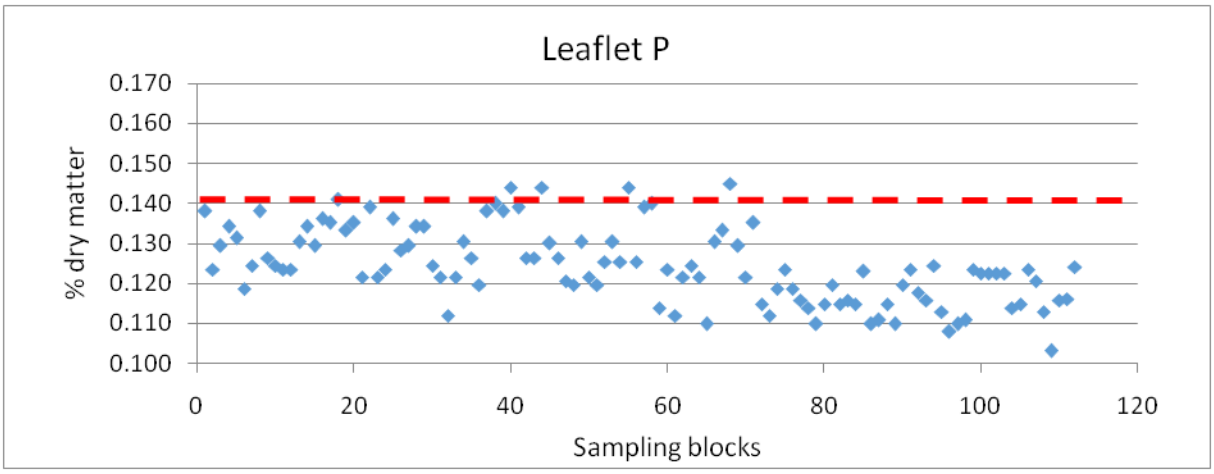


Figure 69. Leaflet P concentration for the sampled smallholder blocks in 2018

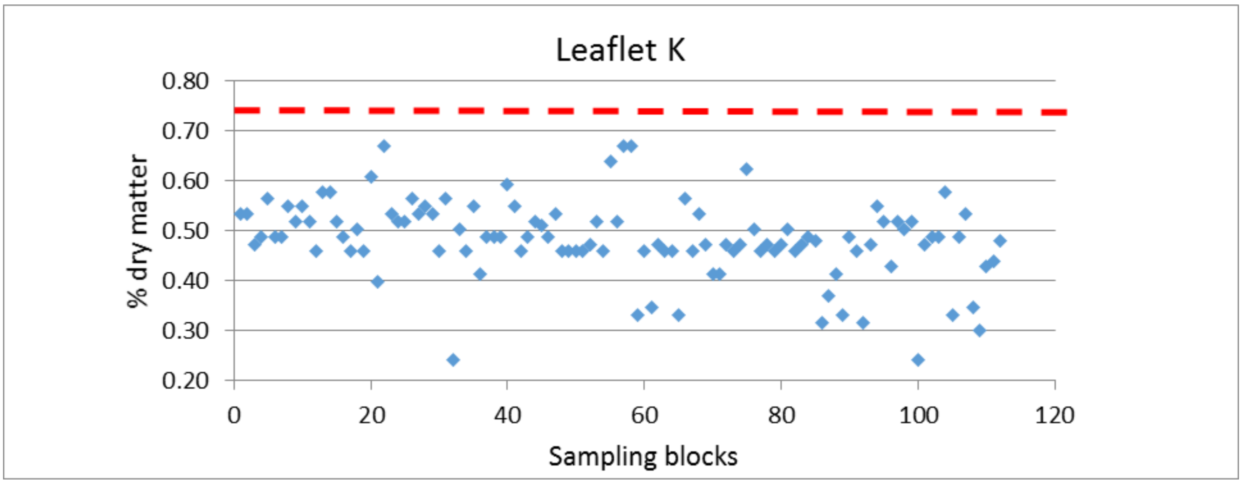


Figure 70. Leaflet K concentration for the sampled smallholder blocks in 2018

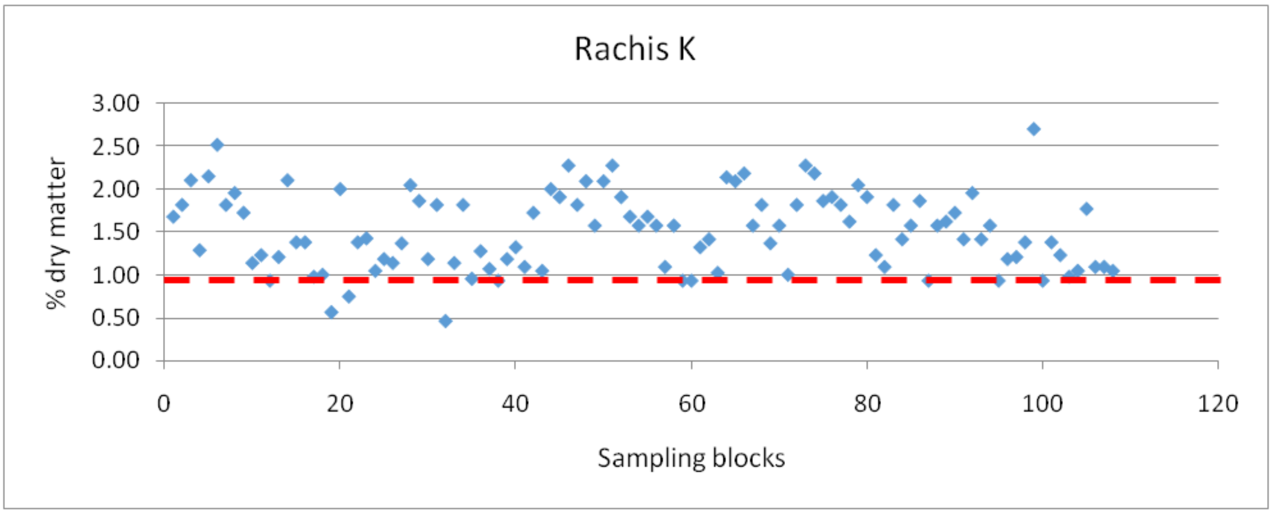


Figure 71. Rachis K concentration for the sampled smallholder blocks in 2018

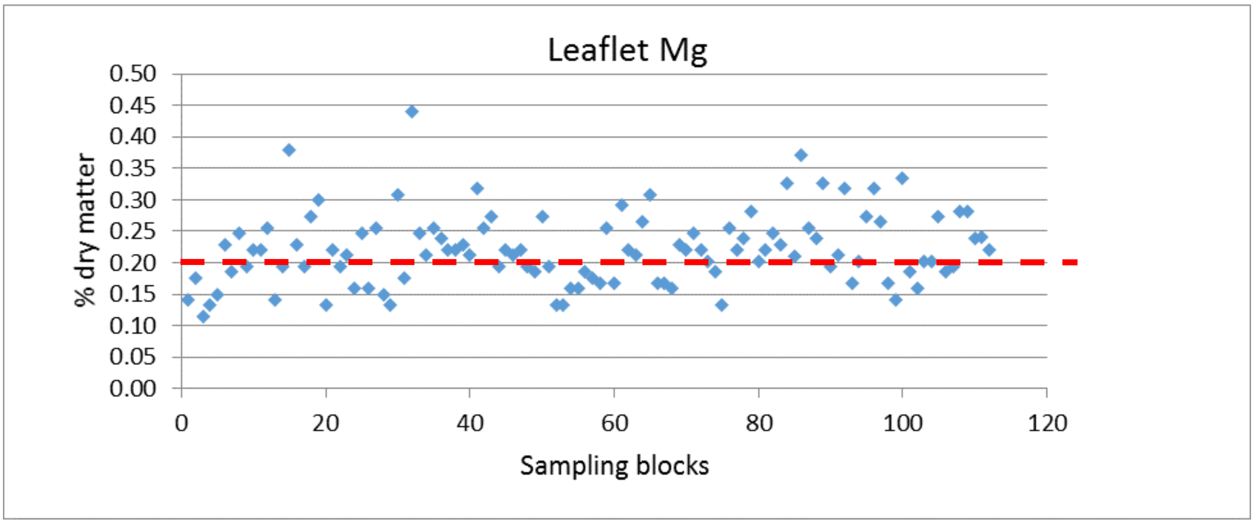


Figure 72. Leaflet Mg concentration for the sampled smallholder blocks in 2018

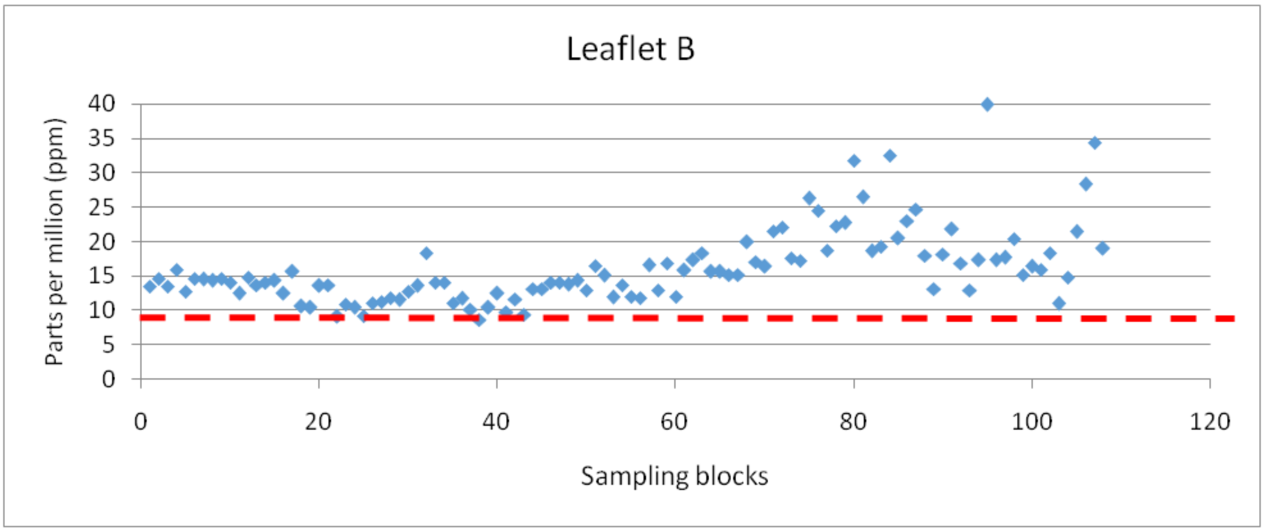


Figure 73. Leaflet B concentration for the sampled smallholder blocks in 2018

E.3.1.5. *Conclusion*

There was a declining trend in foliar nutrient level in N, P, and K. As a result, N, P and K continue to show deficiency on the oil palm leaflets while leaflet Mg, B and rachis K were adequately available. Leaf sampling will continue in 2019 to monitor the foliar nutrient trend with time.

E.4. NBPOL POLIAMBA, NEW IRELAND

Steven Nake, Paul Simin, Henry Seki and Raymond Nelson

E.4.2. 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.4.2.1. *Summary*

Oil Palm Best Management Practices was demonstrated on 3 smallholder blocks with the aim of improving yields. The FFB production from the 3 BMP blocks in 2017 were 10.1 t/ha, 28 t/ha and 32.8 t/ha, which were higher than the mean project yield of 7 t/ha. This result demonstrates the significance of implementing BMP in the smallholder blocks.

E.4.2.2. *Background*

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.4.2.3. *Methodology*

Block selection and establishment

The current BMP blocks in New Ireland are show in Table 87. Since the inception of the project in 2009, 6 blocks have been set up. Three have closed due to targeted yields achieved (S2655 and S1618) and farmer negligence and continuous crop shifting (S4518). The 4th one (S1943) was recently closed in December 2018 due to vandalism of its signboard.

All these blocks were found to be low yielding with poor block hygiene and considerable time and effort spent to upgrade these run-down blocks to BMP standard. After cleanup, fertilizer was applied and block practices such as pruning, weed control, frond staking, circle and paths upkeep and regular harvesting was demonstrated and emphasized to the block owners. Training was conducted on these blocks by OPRA or other stakeholders whenever required.

Table 87. 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	Closed
4	**S2818**	SSR301a	**Lakarol**	VOP	**North**	2015	Current
5	**S1943**	SSR301b	**Luapul**	VOP	**South**	2014	Closed Dec 2018
6	**S2606**	SSR301a	**Lakurumau**	VOP	**North**	2016	Current

E.4.2.4. *Results and Discussion*

The yields for the current 3 BMP blocks are shown in Table 88. The yields from Blocks S2818 and S1943 continued to increase in 2018, while that of S2606 declined by 5 t/ha in the same year. Blocks S2818 and S1943 achieved significantly very high yields demonstration the potential of smallholder oil palm in the New Ireland soils if best management practices are consistently practiced. The yield increment from S2818 was 12.5 t/ha while that of Block S1943 was 10.7 t/ha respectively. Block S2606 witnessed a 5 t/ha decline in its yield in 2018 and this is because the other portion of the block (1 Ha) due for replant and most of the palms were too tall to harvest.

Table 88 Annual Production (t/ha) for BMP blocks in New Ireland from 2013 to 2018

	Yields (t/ha)					
Block	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
S2818			11.8	13.0	15.5	28.0
S1943		10.5	6.1	9.9	22.1	32.8
S2606					15.4	10.1

E.4.2.5. *Conclusion*

The yield increases by blocks S2818 and S1943 in 2018 demonstrate the importance of adopting BMP in smallholder blocks. These two blocks produced yields above the New Ireland project mean (7 t/ha) for smallholders. The declining yield in block S2606 despite improved block management standards also demonstrates how delay in replanting of overage palms can affect oil palm productivity.

E.4.3. SSR303: Assessing leaf nutritional status of smallholder blocks in Poliamba, New Ireland Project

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

E.4.3.1. *Summary*

Smallholder leaf sampling was conducted in 49 smallholder blocks in New Ireland to determine foliar nutritional status of oil palm in smallholder blocks. The results revealed deficiencies in leaflet N (2.25%), leaflet K (0.34%) and rachis K (0.47%). Even though the palms are fertilized with inorganic N and K fertilizers, more than 70% of the blocks were P deficient. In contrast leaflet Mg and B were adequately available.

E.4.3.2. *Background*

One of the factors affecting smallholder production is the lack of fertilizer applied to increase production compared to the Plantation sector. The reasons for this has been extensively documented by Koczberski *et al* (2001) in their report. For palms to gain maximum production per hectare, inorganic fertilizers need to be applied to maintain production levels as well as replenishing nutrient loss through plant uptake and other means such as soil organic matter loss, leaching, volatilization, erosion etc. The main fertilizer applied in the smallholder in Poliamba, New Ireland is Nitrogen in the form of Urea (46 % Nitrogen).

The three common diagnostic tools to determine palms health status are; (i) visible symptoms of nutrient deficiency or excess; (ii) tissue (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. Leaf sampling in Poliamba was initiated in 2016 to determine the leaf nutrient concentrations of oil palm in 49 smallholder blocks. This information is also useful to adjust the current fertilizer recommendations if there is a need. Recently, smallholder leaf sampling plays an important role in supplying information on smallholder oil palm nutrition to Sustainability department as a matter of compliance to RSPO.

E.4.3.3. *Methodology*

Forty-nine (49) 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^{o}C, ground, packed and dispatched to AAR Laboratory in Malaysia for analysis.

Table 89. Number of leaf sampling blocks per division in 2018

Division	**Number of sampling blocks**
North	17
South	21
West	11
Total:	***49***

E.4.3.4. *Results and Discussion*

Leaflet nitrogen (N) was deficient in all 3 divisions, with the project mean of 2.25%. Leaflet P concentration has also declined in all 3 divisions with more than 70% of the blocks below critical level compare to 2017 result. Leaflet K continued to be limiting (deficient) in all 3 divisions, with concentrations far below the critical level (0.70%). Similarly, rachis which acts as the sink for K was also K deficient in all 3 divisions. As expected, there were abundance of leaflet Mg in all the 3 divisions. Leaf B was also well above the critical level of 8 ppm. K deficiency is common in the New Ireland soils because of the excessively high levels of leaflet Mg and Ca which impedes uptake of K from the soils.

The individual block nutrient levels are depicted in Figure 74 and Figure 79. For leaf N, only 4% of the blocks sampled were above the critical level (2.71%), the rest (96% of the blocks) fell under the deficient category. The leaf N levels ranged from 1.65% to 2.80%, with a mean of 2.25%. Leaf P ranged from 0.110% to 0.164%, with a mean of 0.136%. Unlike leaflet N, only 28 % of the blocks (14 blocks) were above the adequate range, while 72% (35 blocks) fell within the deficient range. Potassium (K) was deficient in both the leaflets and the rachis. For leaf K, all sampled blocks (100%) were K deficient with a declining trend since 2016, while 92% of the blocks had rachis K deficiency. Leaflet K ranged from 0.23% to 0.62% (mean = 0.34%), while rachis K ranged from 0.25% to 1.58% (mean = 0.47%). Leaf B was adequately available (100%) from all the blocks sampled, ranging from 9.7 ppm to 21.9 ppm with a mean of 15.16 ppm, while leaf Mg was also in abundance with 98% of the blocks sampled ranging from 0.18% to 0.70% with a mean of 0.40%.

The mean nutrient concentrations obtained from 2016, 2017 and 2018 sampling exercise are summarized in Table 91. Leaflet Mg and rachis K increased their leaflet concentrations in 2018 compared to 2017, whereas leaflet N, P, K and B concentrations plummeted in 2018.

Table 90. Summary of leaflet and rachis nutrient concentrations in 2018

Division	**Leaf N%**	**Leaf P%**	**Leaf K%**	**Leaf Mg%**	**Leaf B ppm**	**Rachis K%**
North	2.18	0.134	0.34	0.39	14.7	0.45
South	2.27	0.137	0.31	0.37	14.9	0.43
West	2.33	0.139	0.38	0.47	16.3	0.58
Project Mean	***2.25***	***0.136***	***0.34***	***0.40***	***15.16***	***0.47***
Critical level(Foster, 2015)	**2.71**	**0.142**	**0.75**	**0.20**	**8.0**	**0.95**

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Figure 74. Leaflet N for all sampled blocks in New Ireland

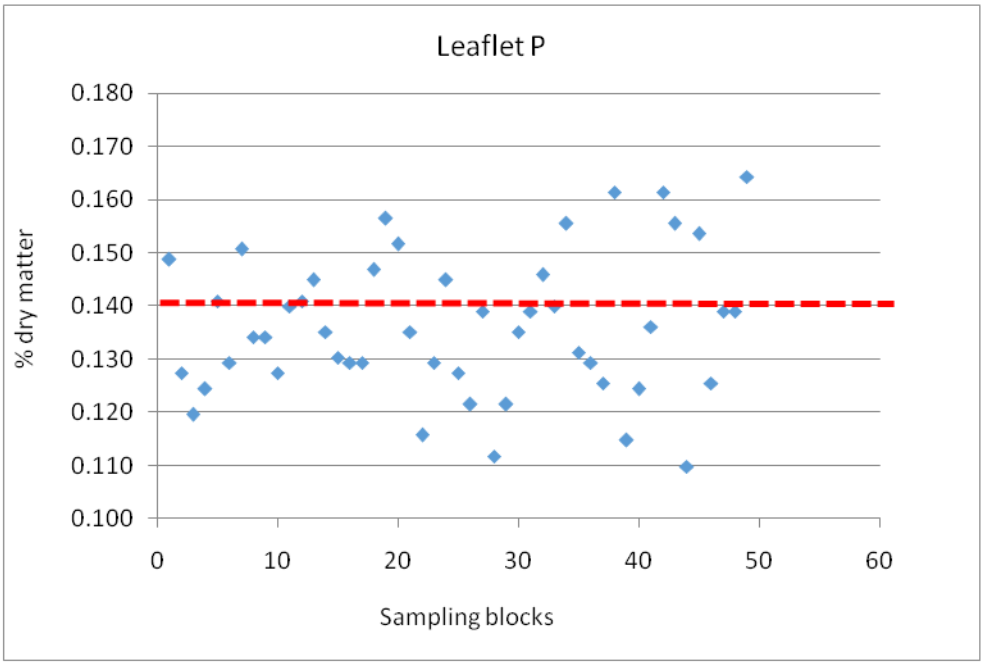

Figure 75. Leaflet P for all sampled blocks in New Ireland

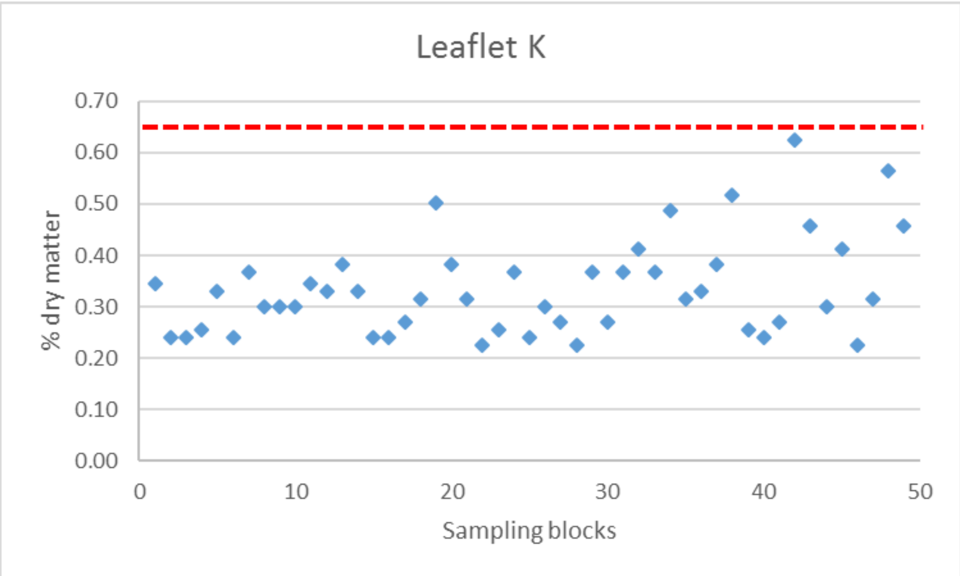

Figure 76. Leaflet K for all sampled blocks in New Ireland

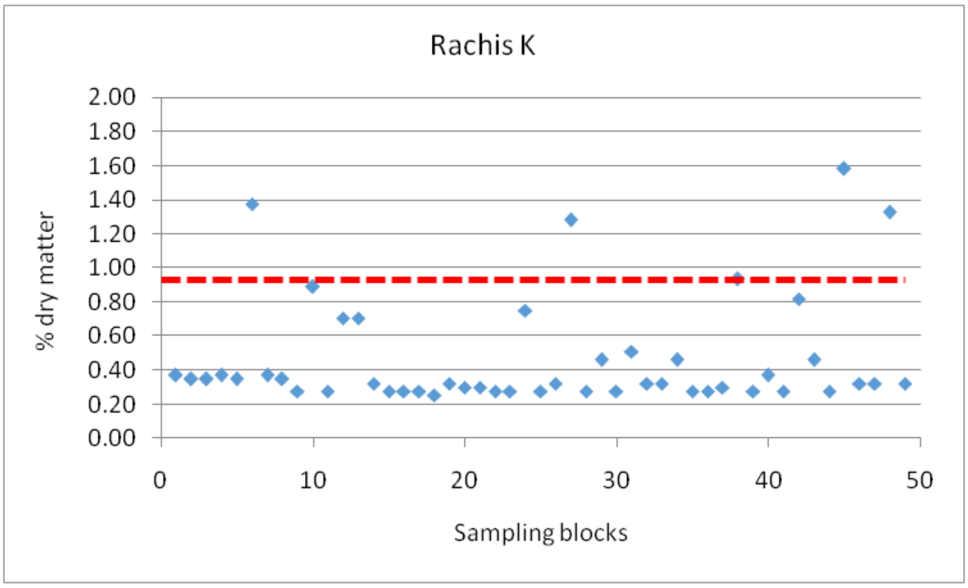

Figure 77. Rachis K for all sampled blocks in New Ireland

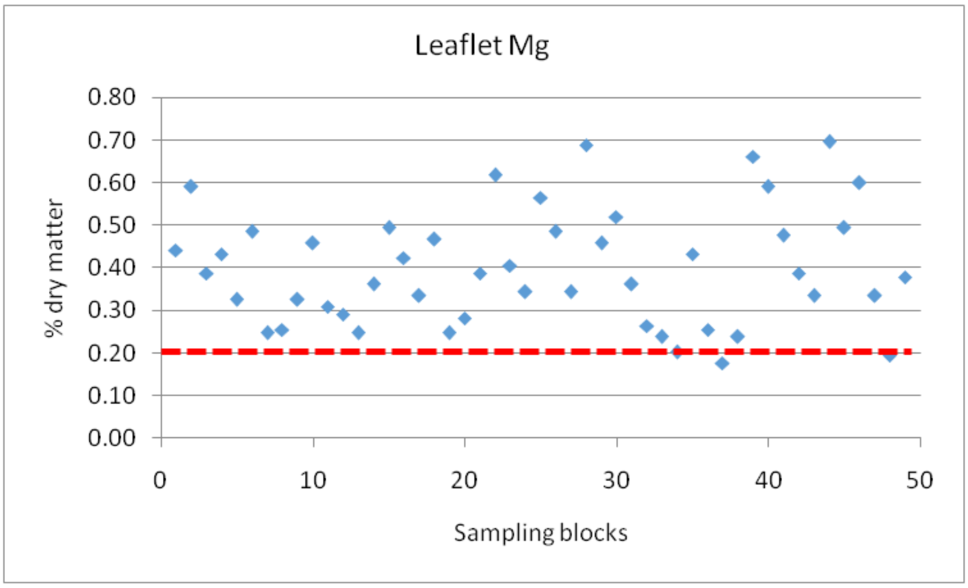

Figure 78. Leaflet Mg for all sampled blocks in New Ireland

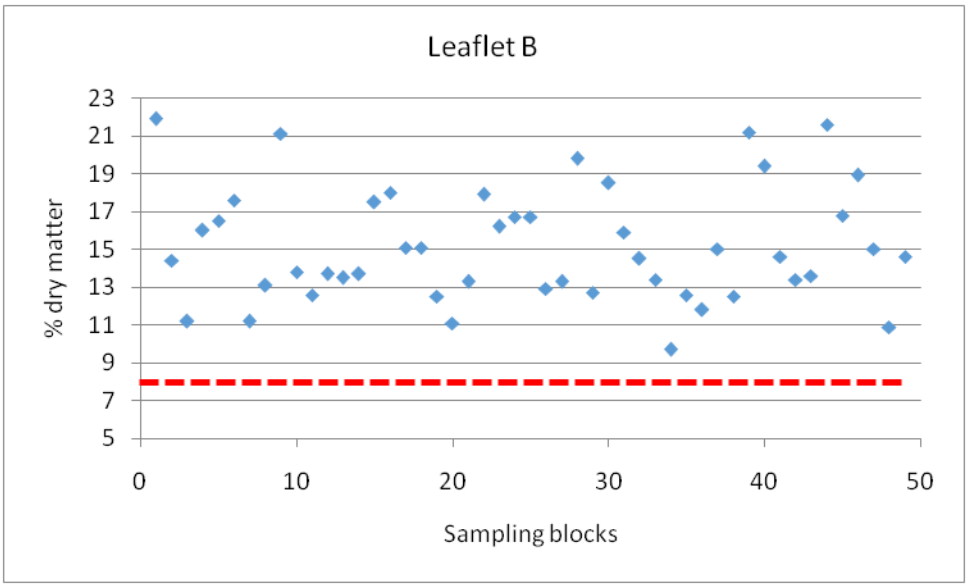

Figure 79. Leaflet B for all sampled blocks in New Ireland

Table 91. Nutrient concentrations in both leaflet and rachis in 2016, 2017 and 2018

Nutrient	**Nutrient concentration (% for all and ppm for leaflet B)**		
	2016	**2017**	**2018**
Leaflet N	2.31	2.34	2.25
Leaflet P	0.144	0.148	0.136
Leaflet K	0.39	0.36	0.34
Rachis K	0.52	0.46	0.47
Leaflet Mg	0.40	0.37	0.40
Leaflet B	16.1	16.5	15.60

E.4.3.5. *Conclusion*

Leaflet N, P and K were found to be deficient in sampled smallholder blocks. While more than 90% of leaflet N, K and rachis K were deficient, P deficiency was observed in 72% of the sampled blocks. Leaflet Mg and B were adequately available. K deficiency is severe in both the leaflets and rachis of smallholder oil palm in New Ireland because of high Ca in soils of New Ireland. Comparing divisions, West has higher nutrient concentrations than the other two divisions. 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 fertilizer recommendations.

E.5. NBPOL POPONDETTA

Richard Dikrey and Steven Nake

E.5.4. SSR401: Demonstration of best management practices in smallholder blocks, Popondetta Project

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

E.5.4.1. ***Summary***

Popondetta Project increased by 1 new block to add up to a total of 6 fully established Best Management Practice Demonstration blocks (BMP) in 2018. This project helps to demonstrate importance of adopting best management practices in smallholder blocks. 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 5-year duration, 2018 sees all blocks increased in fresh fruit bunch production with an average yield of 25.1 t/ha compared to 19.0 t/ha in 2017. In addition to that the overall smallholder yields of the project increased by 5.2% in 2018. This confirms the importance of fertilizer, regular and prudent harvesting and the application of best management practices which was encouraged. There is still huge potential in smallholder production in future.

E.5.4.2. ***Background***

The smallholder blocks make up 50 % of the total area planted with oil palm in Oro Province, but contributes less than 50% of total crop at an average of 11.1 t/ha (Higaturu Oil Palms Smallholder Crop Data, 2018). PNGOPRA fertilizer trials in plantations across the country proved that yields of 30 -35 t/ha are achievable. Smallholders has profound importance in substantial potential in contributing to increasing production for the oil palm industry at large. Demonstration plots in smallholder blocks pave way for disseminating practical information and technical knowledge to growers as an avenue for alleviating low productivity in the smallholder sector through the adoption of best management practices.

The objective of the project is to demonstrate to smallholder growers that best management practices can contribute to better yields by way of transforming run-down blocks with low yields into well-managed high yielding blocks.

E.5.4.3. ***Methodology***

Block selection and establishment

Blocks were selected in 2015, 2016, 2017 and 2018 respectively with assistance from OPIC Popondetta. The selection targeted poorly managed blocks with obvious symptoms of nutrient deficiencies (oven canopy, small fronds, yellowing of leaves, die back of leaflets or fronds, and small bunches). Block selected ranges from 1.28ha to 2.07ha with an average of 1.58 ha depicting smallholder growers in the project. Table 92 gives the list of active BMP blocks

Table 92. List of BMP blocks in Popondetta Project

No	Block No.	Trial Code	Area	Scheme	Division	Year initiated	Status
1	800158	SSR402	Urio	VOP	Sorovi	2015	Active
2	840049	SSR402	Inota	VOP	Sorovi	2017	Active
3	690042	SSR402	Ajeka	VOP	Illimo	2015	Active
4	680096	SSR402	Kanandara	VOP	Illimo	2015	Active
5	050400	SSR402	Sangara Top	LSS	Sorovi	2016	Active
6	410029	SSR 402	Sakita	VOP	Aeka	November 2018	Newly initiated

Fertiliser application

In 2018, Urea and MOP were applied to these trial blocks in respect to locality and smallholder fertilizer recommendations. Urea, a nitrogen source was applied to all blocks at the rate of 1.5kg per palm per year, which is three (3) large empty tinned fish can (425 grams ~0.425 Litres) per year. Muriate of Potash (MOP), source of potassium was also applied but only to blocks at Ilimo – Kokoda area at a rate of 1.0kg per palm per year, which is two (2) large empty tinned fish can (425 grams ~ 0.425 Litres) per year. Fertilizer application demonstrations were done in all 5 blocks prior to applications.

Harvesting
Frequent harvesting was encouraged as a component of BMP and there was zero tolerance on skipped harvests. The 5 demonstration blocks were expected to harvest at least 20 rounds in a year.

Data collection and analysis
Each individual trial block monthly fresh fruit bush (FFB) production from TSD- SH OMP data base was compiled for the year and that was converted into tonnes per hectare (t/h).
Leaf samples and vegetative growth measurements were also collected for the trial blocks.

E.5.4.4. *Results and Discussion*

Block 410029 was initiated during the year increasing the number of active BMP demonstration blocks to 6 in 2018. Data from this block will not be presented as it is too early to see the impact of BMP, hence the project started in November 2018.

The blocks' yields for the last four (5) years are shown in Table 93.All blocks showed yield increments in 2018. Block 800158 increased its production in 2018 by 25.6%, from 28.8 t/ha in 2017 to 36.2.8 t/ha in 2018. The positive increment in FFB production (t/ha) was a result of grower adoption of BMP concept and consistency in block management.

Block 050400 produced 35.4 t/ha in 2018, representing a yield increase of 41% from 25.1 t/ha in 2017. Block 680096 observed a huge increase on its production from 6.8t/ha in 2017 to 22.1 t/ha in 2018. This result shown the impact of fertilizer application. Block 690042 increased its production in 2018 by 59% compared to 15.4 t/ha in 2017.

Table 93. Annual Production (t/ha) BMP blocks from 2014 to 2018

Block	**Yields (t/ha)**				
	2014	**2015**	**2016**	**2017**	**2018**
800158	15.2	16.4	24.6	28.8	36.2
50400			18.9	25.1	35.4
680096	11.9	6.5	2.5	6.8	22.1
690042	16.4	14.2	13	15.4	24.5
840049					**7.5**
Smallholder Popondetta	**14.7**	**14.5**	**10.7**	**10.6**	**11.1**

E.5.4.5. *Conclusion*

There is huge potential to increase smallholder yields beyond the current actual yields, as observed from the improved yields from the demonstration blocks in 2018.This work has also proven that there is potential to push yields further to 30 t/ha in Popondetta. However, high yields can only be achievable if the block is consistently managed at BMP standard, fertilizer is applied every year and block is harvested regularly. OPRA must work in partnership with Smallholder, TSD and Sustainability department of HOP, OPIC and Grower Representatives to promote the BMP concept.

E.5.5. SSR403: Assessing leaf nutritional status of smallholder blocks, Popondetta Project

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

E.5.5.1. *Summary*

Total of 105 smallholder blocks were sampled to determine their nutritional status. Laboratory analysis revealed the smallholder palms in Popondetta were deficient in N, P and K. Mean leaflet N, P and K were 2.01%, 0.127 % and 0.48 % respectively. Similarly, rachis K was also deficient with mean of 0.95%. Leaflet Mg and B levels were adequately available.

E.5.5.2. *Background*

The three important diagnostic tools to determine palms health status 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 (fertilizer management tool) for optimal oil palm growth and production. Leaf analysis is also used to protect the environment from over-fertilizer application (Asher et al, 2001).

Leaf sampling for smallholder blocks in Popondetta was initiated in 2017 to determine the leaf nutrient concentrations of oil palm. This information is also useful to adjust current fertiliser recommendations if there is a need. Recently, smallholder leaf sampling plays an important role in supplying information on smallholder oil palm nutrition to Sustainability department as a matter of compliance to RSPO.

E.5.5.3. *Methodology*

Total of 105 blocks were randomly selected from the 5 divisions (Sorovi, Igora, Aeka, Saihio and Ilimo). The selected blocks were within the prime age group at the time of selection. Immature and over-aged blocks were not considered. 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^{0}C, ground, packed and dispatched to AAR Laboratory in Malaysia for analysis.

E.5.5.4. *Results and Discussion*

The leaf levels against the critical levels (Foster, 2015) are shown in Table 94. Leaflet N, P and K were deficient while leaflet Mg and B were adequate in all 5 divisions. Rachis K was deficient in 3 divisions except for Sorovi and Aeka. At the divisional level, Leaflet N was deficient in all divisions except Ilimo. Leaflet P and K was deficient in all the 5 Divisions. Generally, for Popondetta smallholder blocks, leaflet Mg and B were the only two nutrients adequately available. All other essential elements were deficient (below critical level).

The individual block nutrient concentrations are depicted in Figure 80 to Figure 85. Leaflet N ranged from 1.61 % to 2.66 %. Only 1 block (1%) was above critical level, the rest (99%) were N deficient. This may have been the result of low N application yearly. Leaflet P levels were between <0.107% and 0.161%, with 10 blocks (10%) above the critical level whereas the other 95 blocks were deficient. Leaflet K level ranged from 0.24% to 0.74%, while rachis K levels were between 0.35 % to 1.96 %. For Potassium, 45% and 79 % of sampled blocks were deficient in the leaflets and rachis respectively.

K deficiency was more pronounced in the Ilimo division, however all other divisions (Saiho, Aeka, Igora and even Sorovi) also showed exhibited deficiency. Leaflet Mg ranged from < 0.10% to 0.47 %. Most of blocks (71%) sampled showed adequate leaflet Mg across all 5 Divisions. This is quite interesting given the fact that Mg in the form of Kieserite has never been applied in the smallholder blocks. Leaflet B was not an issue in nearly all (99%) of the sampled blocks. B levels ranged between 8.20 ppm to 20.90 ppm (7.7 ppm to 27 ppm), with an average of 11.25 ppm.

Table 94. Summary of leaflet and rachis nutrient concentrations at the Divisional level

Division	LN%	LP%	LK%	LMg%	LB%	RK%
Sorovi	1.92	0.125	0.50	0.23	12.61	1.35
Igora	1.99	0.125	0.49	0.21	11.66	1.07
Aeka	1.98	0.126	0.48	0.24	10.43	0.97
Saihio	1.94	0.123	0.45	0.23	11.12	0.68
Illimo	2.21	0.135	0.49	0.23	10.41	0.68
Project total	10.04	0.634	2.41	1.14	56.23	4.75
Project mean	**2.01**	**0.127**	**0.48**	**0.23**	**11.25**	**0.95**
Critical level (Foster, 2015)	***2.59***	***0.142***	***0.55***	***0.20***	***8.00***	***0.97***

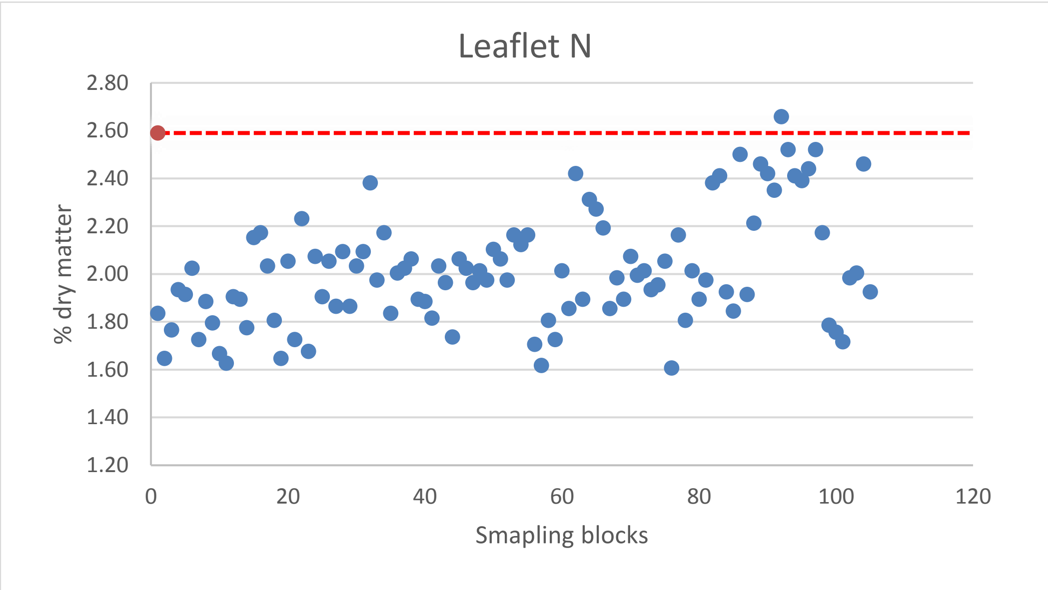

Figure 80 Leaf N concentration for all sampled blocks in Popondetta

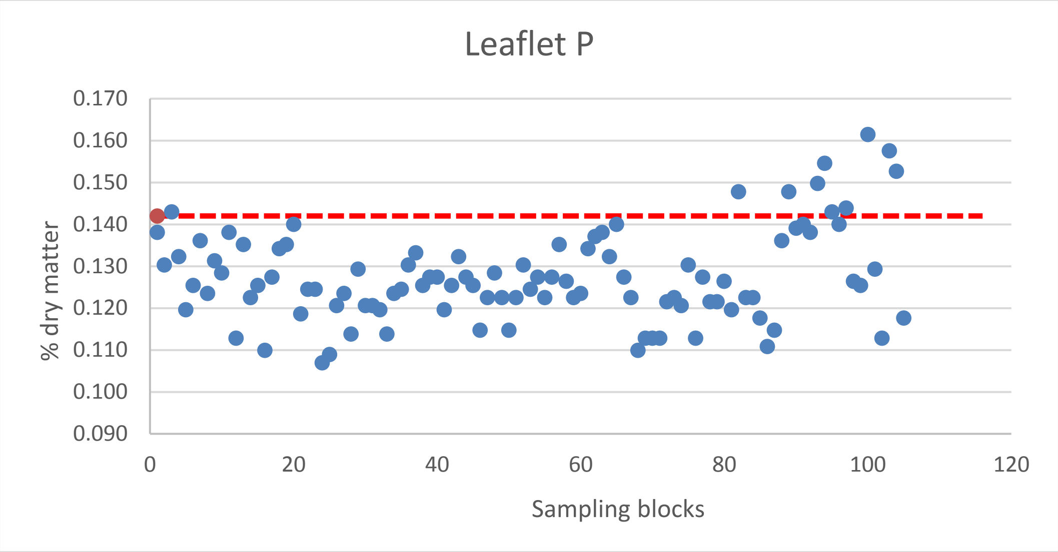

Figure 81. Leaf P concentration for all sampled blocks in Popondetta

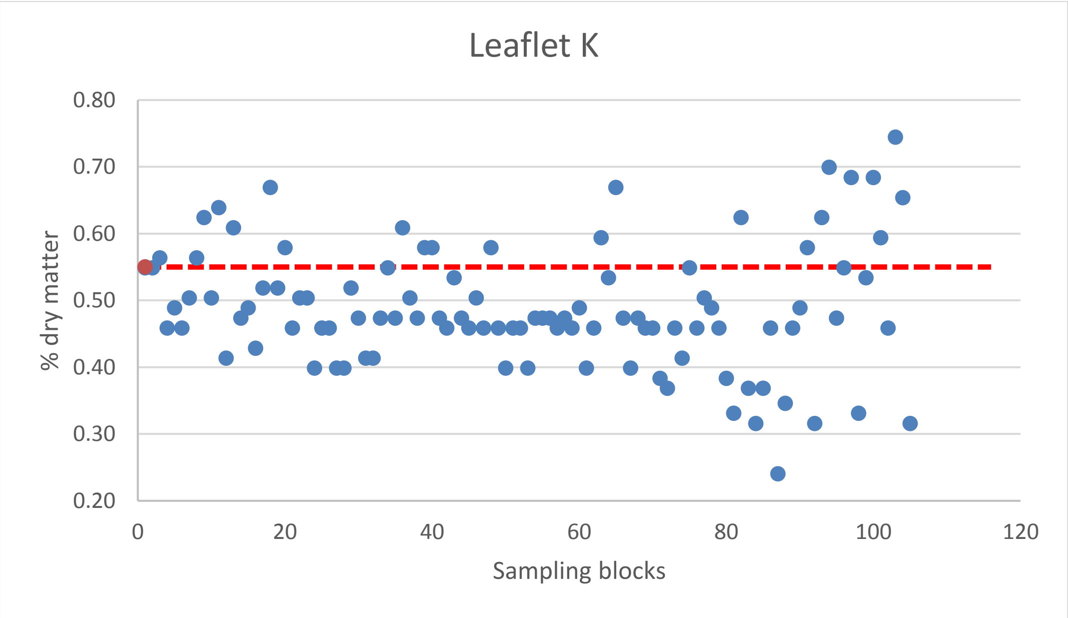

Figure 82. Leaf K concentration for all sampled blocks in Popondetta

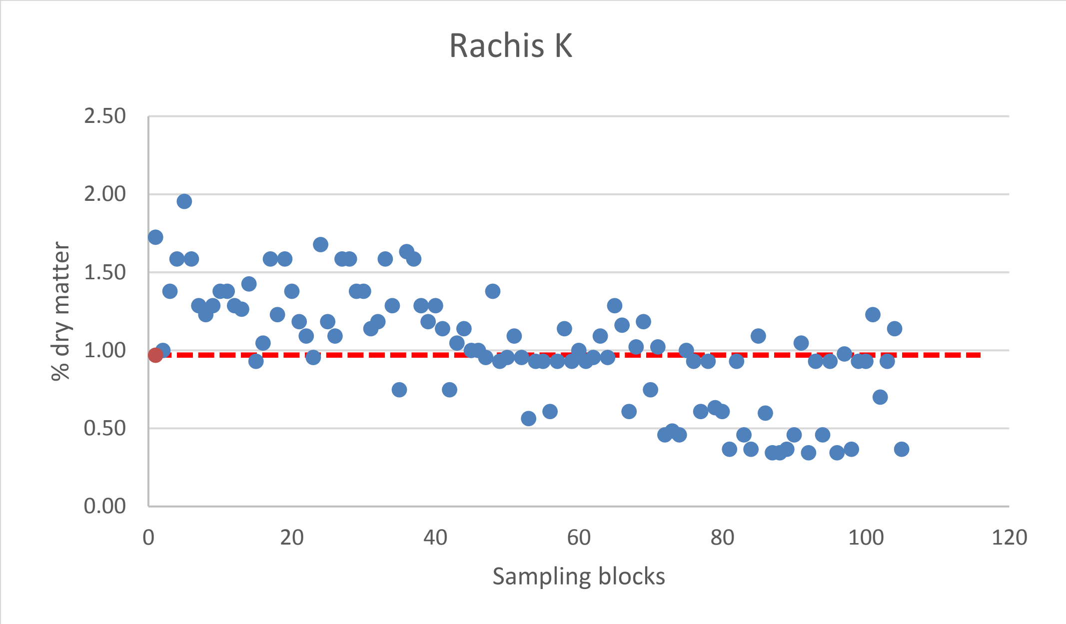

Figure 83. Rachis K concentration for all sampled blocks in Popondetta

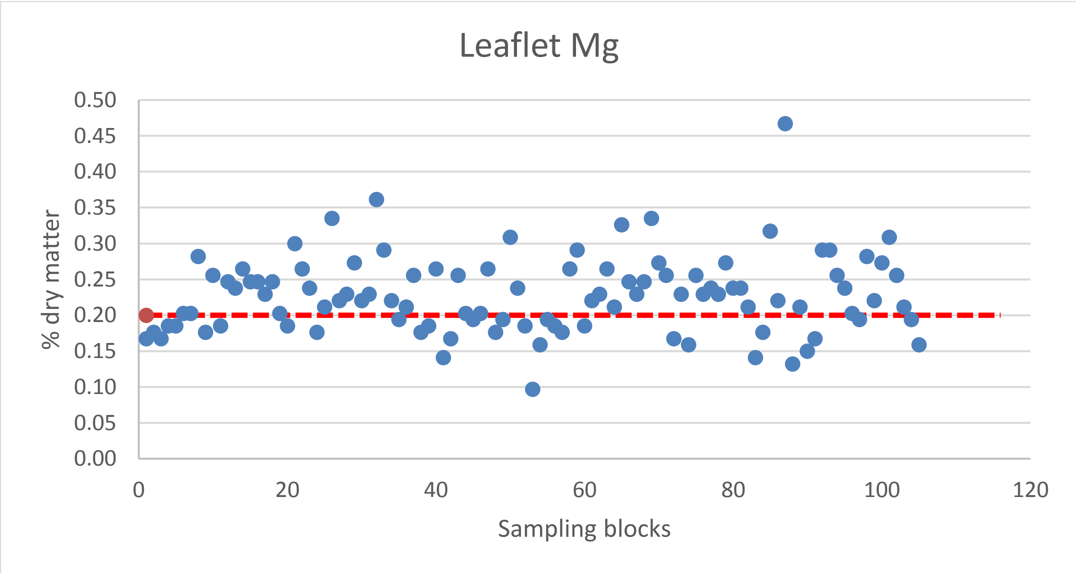

Figure 84. Leaflet Mg concentration for all sampled blocks in Popondetta

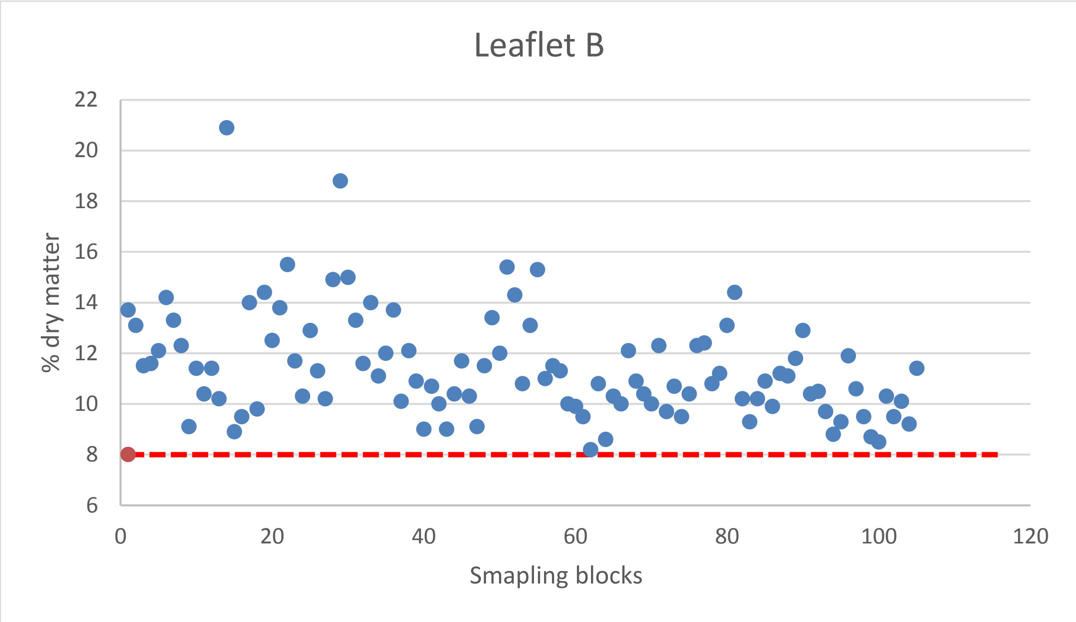

Figure 85. Leaflet B concentration for all sampled blocks in Popondetta

E.5.5.5. *Conclusion*

Leaflet N were deficient in all divisions. Leaflet P and K were both deficient and rachis K was also low. Ilimo had a more pronounced K deficiency compared to other divisions. Leaflet Mg and B levels were adequately available. All in all, there was declining trend with the major elements such as Nitrogen (N)in smallholder oil palm catchment areas in Oro Province.

E.6. NBPOL MILNE BAY

Steven Nake, Emmanuel Germis, Wawada Kanama and Sharon Agovaua

E.6.6. 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.6.6.1. *Summary*

The number of BMP blocks in Milne Bay has increased to 10 which the establishment of 8 new blocks between the months of January and February 2018. Their yields (t/ha) ranged from 4.1 t/ha to 24.4 t/ha. The highest yielding block (24.4 t/ha) since its inception in 2009 had been practicing all the best management practices of oil palm in the block, hence the positive impact. As for the other new blocks, some have recorded positive yield responses and others have not in the last 12 months. Currently, it is still early to judge their performance, but anticipate positive outcome in the next 12 months.

E.6.6.2. *Background*

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.6.6.3. *Methodology*

Block selection and establishment

The number of number BMP blocks were increased to 10 with the setup of 8 new blocks in 2018 (Table 95). These 8 blocks went through a major rehabilitation program (clean up) to bring the condition of the blocks to BMP standard. These blocks were low yielding with poor block upkeep. Initial work done on these blocks included slashing, pruning, frond stacking and harvest path cleaning. Fertiliser were ordered from Milne Bay estates to apply in the blocks. In the two old blocks, activities continued as normal.

Table 95. SSR501ab, Block information

No	Block	Trial code	Area	Division	Area (Ha)	Scheme	Year of initiation
1	09017	SSR501ab	Figo	Sagarai East	1.59	VOP	2009
2	19022	SSR501ab	Waema	Gurney East	1.27	VOP	2009
3	02024	SSR501ab	Kapurika	Gurney West	1.81	VOP	2018
4	11050	SSR501ab	Borowai	Sagarai West	2.26	VOP	2018
5	11069	SSR501ab	Borowai	Sagarai West	0.76	VOP	2018
6	12030	SSR501ab	Yaneyane	Gurney East	0.47	VOP	2018
7	15020	SSR501ab	Marayanene	Gurney West	1.59	VOP	2018
8	19036	SSR501ab	Waeme	Gurney East	0.37	VOP	2018
9	24037	SSR501ab	Ipouli	Sagarai West	1.42	VOP	2018
10	25010	SSR501ab	Gumini	Gurney West	1.34	VOP	2018

E.6.6.4. *Results and Discussion*

The long-term yield (t/ha) for the BMP blocks for 2017 and 2018 are shown in Figure 86. In 6 of the blocks, there were yield increments in 2018 ranging between 6 % and 28 %. Instead, the trial blocks experienced peaks and troughs throughout the entire duration of the trials (2009-2017). Block 19022 which is one of the two earlier established blocks in 2009, produced the highest yield of 24.4 t/ha in 2018. Yield from 5 (63%) of the 8 recently setup blocks were increased in 2018 and that was due to BMP which improved crop recovery. The yields from block 9017 declined in 2018 because the palms are due for replanting and too tall to harvest. The trial block was closed end of 2018.

By 2018, only 1 block was producing over 20 t/ha, while 3 yielded over 10 t/ha, 5 blocks produced between 5 and 10 t/ha whereas only 1 block was produced below 5 t/ha. Fertiliser has been applied in all the blocks and we expect to see its effects 2-3 years’ time. The current improvements made to the 5 newly established blocks are due to BMP and not fertiliser.

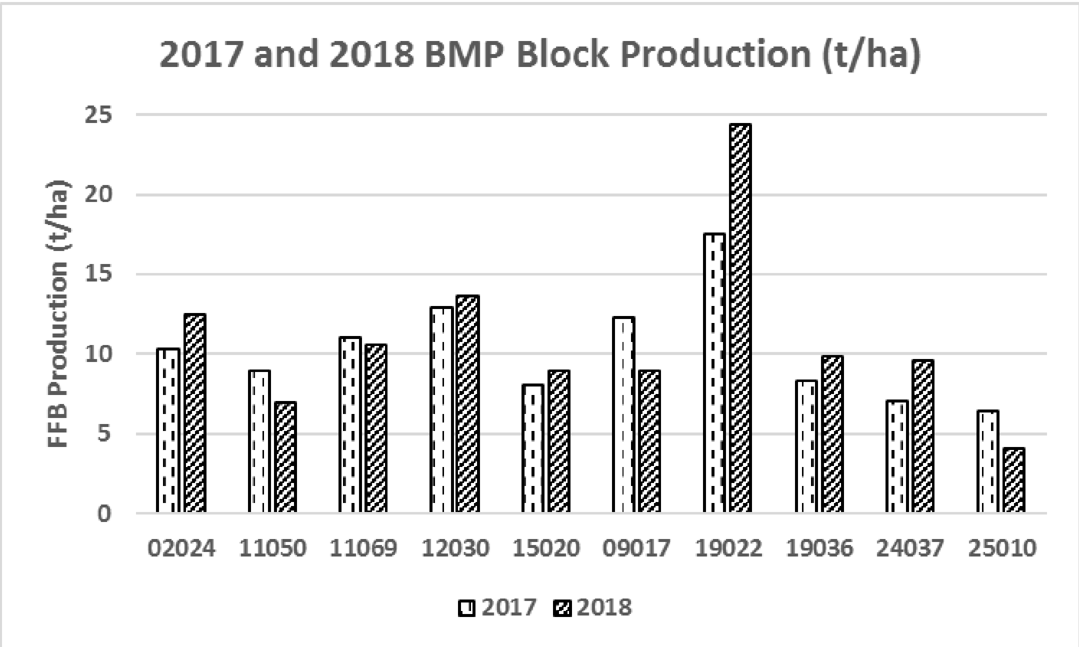

Figure 86. Production trend for BMP blocks 09017 and 19022 from 2009 to 2017.

E.6.6.5. *Conclusion*

In 2018, yields from 6 of the blocks were increased while the other 4 blocks did not record yield increments. One of the two oldest BMP blocks established back in 2009 and currently yielding well over 20 t/ha. This demonstrates the positive impact of adopting BMP practices on the block regularly.

E.6.7. SSR502: Assessing leaf nutritional status in smallholder blocks, Milne Bay Project

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

E.6.7.1. *Summary*

In 2018, 78 smallholder blocks were sampled in Milne Bay to determine their nutritional status. Leaflet N, P and K remained deficient in both the oil palm leaflets and rachis, whereas, B and Mg were in abundance. Mean values of leaf N, P, K, Mg, B and rachis K were 2.08%, 0.128%, 0.39%, 0.48%, 13.5% and 0.95 % respectively. K deficiency and high Mg/Ca is common in these soils due to presence of clay minerals (smectite and vermiculite).

E.6.7.2. *Background*

One of the factors affecting smallholder production is the lack of fertilizer applied to increase production compared to the Plantation sector. The reasons for this has been extensively documented by Koczberski *et al* (2001) in their report. For palm to gain maximum production per hectare, inorganic fertilizers need to be applied to maintain production levels as well as replenishing nutrient loss through plant uptake and other means such as soil organic matter loss, leaching, volatilization, erosion etc. For smallholders in Milne Bay, both nitrogen in the form of Urea (46 % Nitrogen) and potassium in the form of Muriate of Potash (MOP) are applied to the palm. MOP is applied with nitrogen due to low levels of exchangeable K ions in the soil which affects K availability, causing severe K deficiency to palms in Milne Bay.

The three common diagnostic tools to determine palms health status are; (i) visible symptoms of nutrient deficiency or excess; (ii) tissue (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. Since 2016, leaf sampling was undertaken assess the nutrient status out for 78 smallholder blocks across the 2 divisions in Milne Bay. The same blocks were sampled in 2018. It is hoped that information generated from this project will be useful for reviewing the current fertilizer recommendations for smallholders in the Milne Bay project. The same information is required for RSPO audit in the smallholders.

E.6.7.3. *Methodology*

Seventy-eight (78) 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°C, ground, packed and dispatched to AAR Laboratory in Malaysia for analysis.

E.6.7.4. *Results and Discussion*

Similar to the 2017 leaf analysis, leaflet levels of N, P, K and rachis K were deficient, whereas leaflets Mg and B were in abundance for both the Gurney and Sagarai divisions (Table 96). The nutrient concentrations for the 78 sampled blocks are shown in Figure 87 to Figure 91. For leaflet N and leaflet K, 100% of the sampled blocks were deficient, whereas only 99 % of blocks were P deficient and 61% low in rachis K. In contrast, leaflet Mg and B were in abundance in all the sampled blocks. Mg levels were in abundance because the alluvial clay soils of Milne Bay are reasonably high in Mg and Ca ions, resulting in low K levels.

The 2018 leaf analysis also indicated a considerable decline in the nutrient concentrations of leaflet N, leaflet P, leaflet K and leaflet B compared to 2017 analysis. The drop in leaflet N and K could be the result of insufficient or no fertiliser (urea and MOP) application in those sampled blocks. Both MBE NBPOL and OPIC MB must put more emphasis on the importance of these two fertilisers and most importantly correct management (4 Rights) of these fertilisers. Leaflet P is mostly influenced by leaflet N, meaning an increase or decrease in leaflet N has a same effect of P levels.

Table 96. Foliar nutrient concentration in smallholder blocks at Gurney and Sagarai divisions

Division	**LN%**	**LP%**	**LK%**	**LMg%**	**LB (ppm)**	**RK (%)**
Gurney	2.11 (2.34)	0.129(0.153)	0.37(0.40)	0.50(0.46)	14.0 (14.8)	0.76 (0.74)
Sagarai	2.03(2.27)	0.127 (0.150)	0.43(0.44)	0.44 (0.43)	12.7(13.8)	0.16 (0.98)
Project Mean	***2.08(2.31)***	***0.128(0.152)***	***0.39(0.41)***	***0.48(0.45)***	***13.5(14.4)***	***0.95(0.83)***
Critical level(Foster, 2015)	**2.58**	**0.142**	**0.69**	**0.20**	**8.0**	**1.02**

Note: Figures in brackets are 2017's nutrient concentrations.

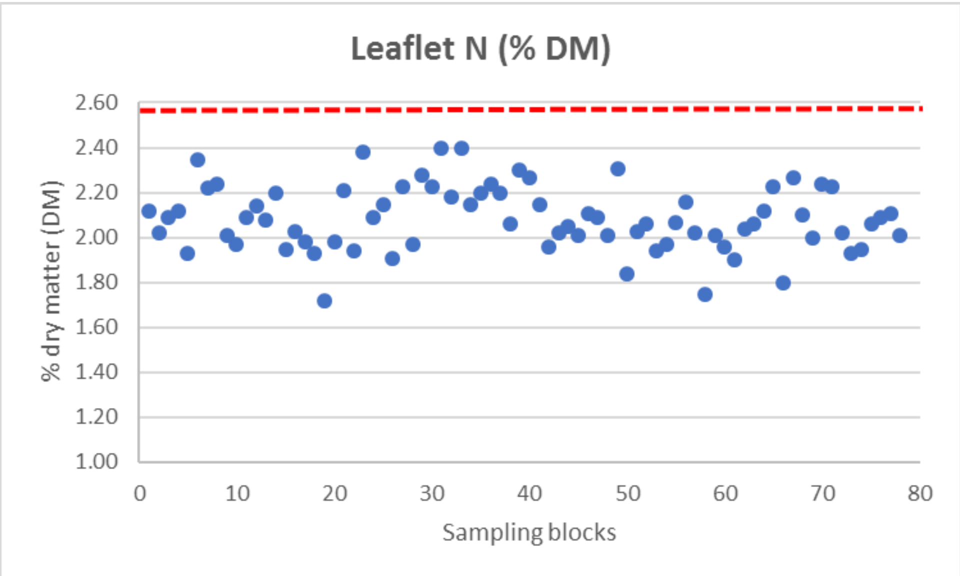

Figure 87. Leaflet N concentration for sampled blocks in Milne Bay

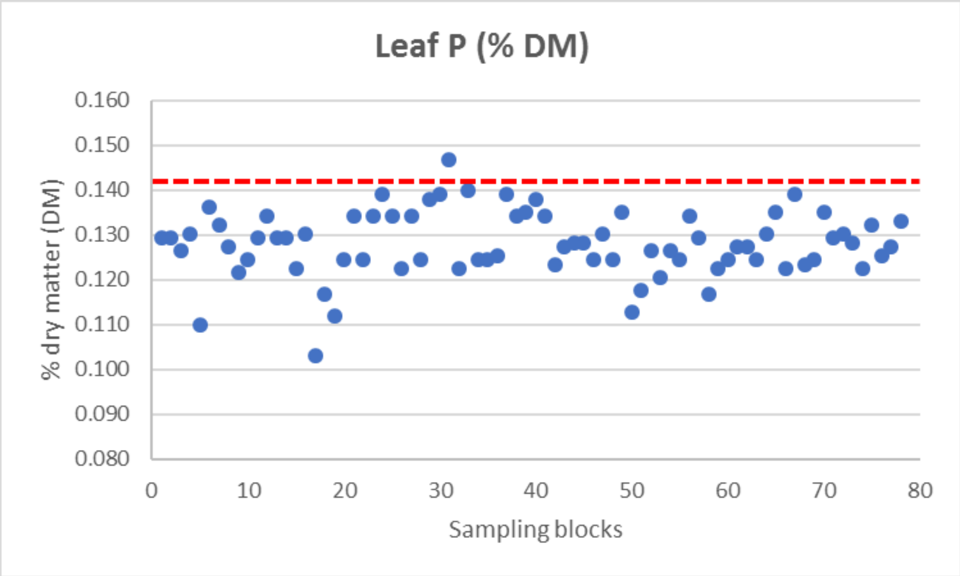

Figure 88. Leaflet P concentrations for sampled blocks in Milne Bay

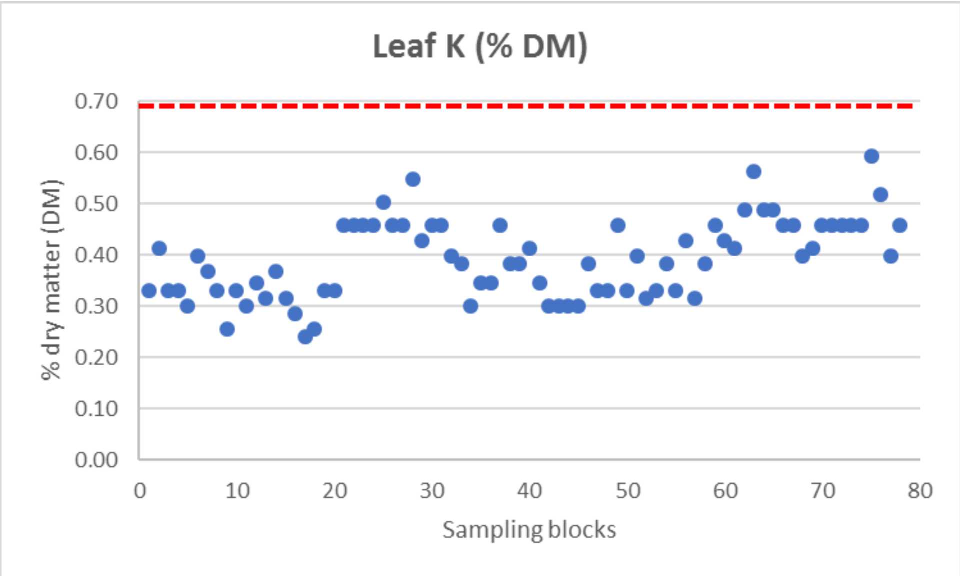

Figure 89. Leaflet K concentrations for all sampled blocks in Milne Bay

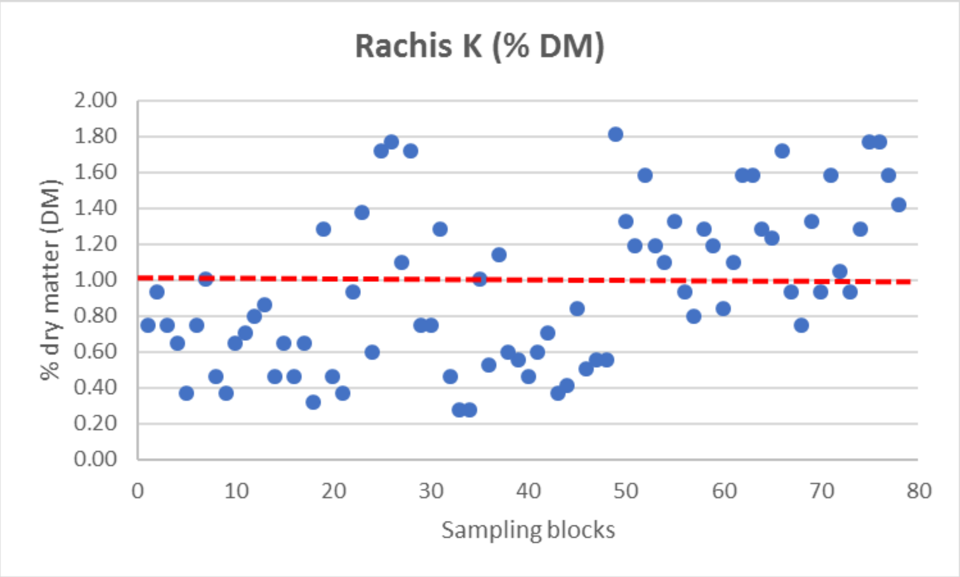

Figure 90. Rachis K concentration for all sampled blocks in Milne Bay

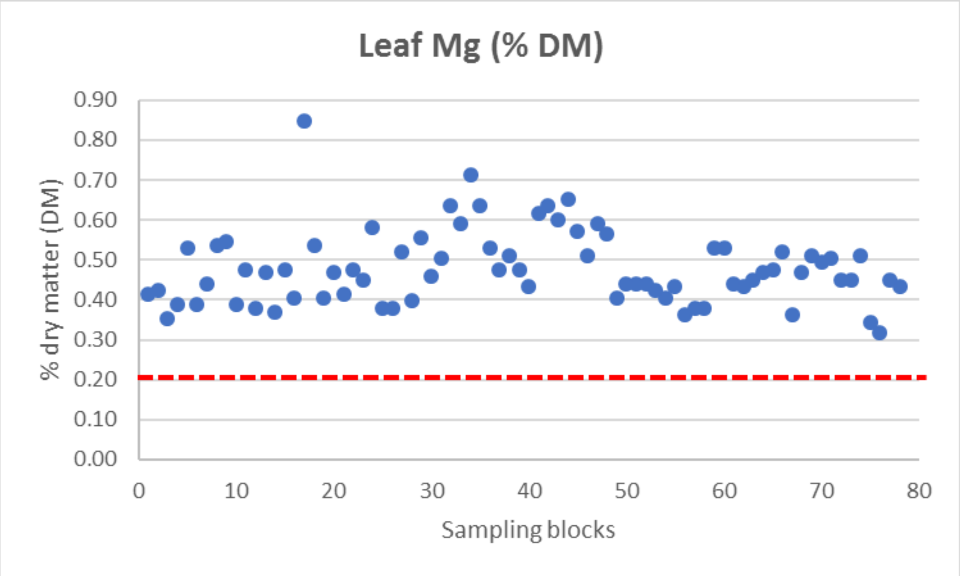

Figure 91. Leaflet Mg concentrations for sampled blocks in Milne Bay

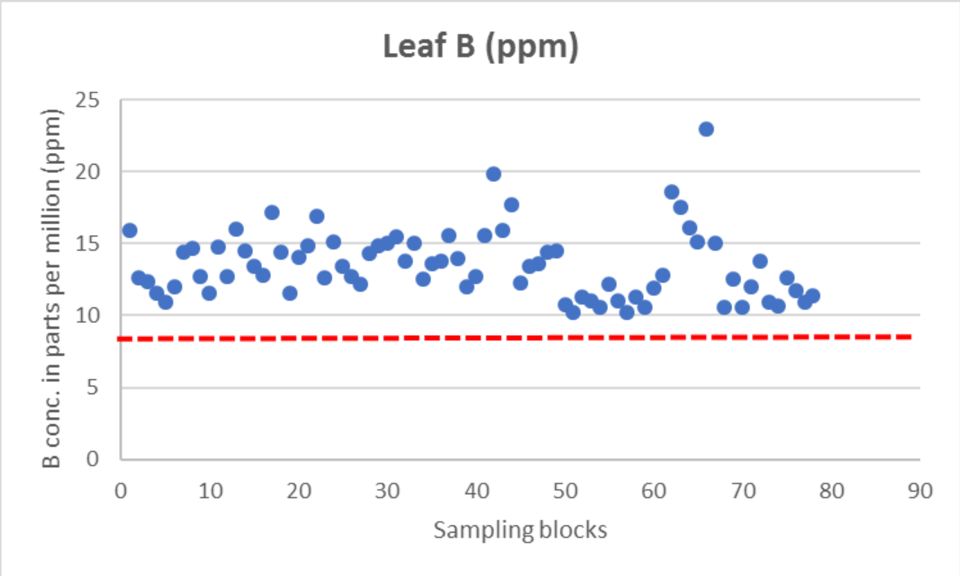

Figure 92. Leaflet B concentrations sampled blocks in Milne Bay

Table 97. 2016, 2017 and 2018 foliar nutrient concentrations

	Nutrient concentrations		
Foliar Nutrients	**2016**	**2017**	**2018**
Leaflet N (%)	2.19	2.31	2.08
Leaflet P (%)	0.136	0.152	0.128
Leaflet K (%)	0.41	0.41	0.39
Leaflet Mg (%)	0.45	0.45	0.48
Leaflet B (%)	13.9	14.4	13.5
Rachis K (%)	1.04	0.83	0.95

E.6.7.5. *Conclusion*

The 3 macro nutrients; N, P and K were limiting in the leaflets of the smallholder palms in Milne Bay with mean concentrations of were 2.08%, 0.128% and 0.39% respectively. Rachis K was also limiting at 0.95 %. In contrast, leaflet Mg and B were in abundance with levels well above their respective levels. 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.

E.6.8. SSR503: Socioeconomic baseline study for smallholders in Milne Bay.

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

E.6.8.1. *Summary*

This report is a summary of a detailed baseline study conducted among the smallholder households in Milne Bay between the years 2015 and 2016. The study investigated the socioeconomic statuses of the smallholder households. It shed light on the arrangement and rearrangement of social and economic activities and how these activities are operating. Village Oil Palm (VOP) is the dominant smallholder oil palm scheme in Milne Bay. Most blocks sampled were from the VOP scheme with mostly 2ha and 4ha of land area under oil palm cultivation. Most of these blocks were established between the periods of 1985-1994. Majority of the smallholder plantings are undergoing their replanting phase. Majority of the smallholder blocks still have their original owners living on block whilst those blocks that their owners are not on block, are either managed by their sons or daughters. There is less population pressure on block with minimal inter-household disputes. The smallholder households do gardening activities off their blocks. Oil palm income remain their primary income source, however, marketing of garden food tends to be the main source of income to finance daily living cost of most smallholder households but only on selected days during each week. The level of agronomic practices on the blocks are low with a mixture of one or two harvest rounds of FFB per month mainly because of low FFB, lack of tools and some due to Ganoderma deceased palms in smallholder blocks.

E.6.8.2. *Background*

The Oil Palm Project in Milne Bay was initiated in 1985 following government approval of developing a K60 million oil palm and cocoa project (Grieve 1986), whereby 4,000 hectares of oil palm and 750 hectares of cocoa were planted. In 1986 Milne Bay Estate began planting and by 1991, 4,661 hectares of estate plantations and 383 hectares of VOP blocks were under oil palm cultivation. VOPs are established on customary land under the Clan Land Usage Agreement (CLUA) to facilitate loan requirements. To date 1,947 ha of smallholders are planted in the project (POC report, 2016).

Since the first planting in 1986, demographical characteristics of the blocks have changed affecting livelihood and other social and economic activities on the block. There was no proper baseline study done before or at the set up of the project. As a result, this project was developed to form the basis of a baseline data for the oil smallholder sector in Milne Bay project.

E.6.8.3. *Methodology*

The study used a mixed research technique in the data collection. The data were gathered from randomly selected smallholder blocks. The main specification for selecting smallholder blocks were based on alternative blocks along main road access, and those further away from main road access, those having owners living on or off the smallholder blocks and the number of households living in each smallholder blocks. A total of 169 smallholder households took part in the interview surveys conducted.

E.6.8.4. *Results and Discussion*

Block details

Smallholder oil palm in Milne Bay were developed on state alienated and customary land. The smallholders are composed of two main oil palm schemes of Land Settlement Scheme (LSS) and Village Oil Palm (VOP) (Table 98). The LSS blocks are mostly large mixed farming blocks of more than 2-hectares whilst the VOP blocks are mostly 2-hectare blocks of oil palm. The number of VOP blocks out-numbered that of the LSS (Table 98).

Table 98. Two main smallholder oil palm schemes in Milne Bay

Scheme	Count	Percentage
LSS	1	1
VOP	168	99
CRP	0	0
Total	169	100

The planting of oil palm as in new development and additional/expansion planting on existing smallholder blocks has been declining since the initial development in the mid-1980s (

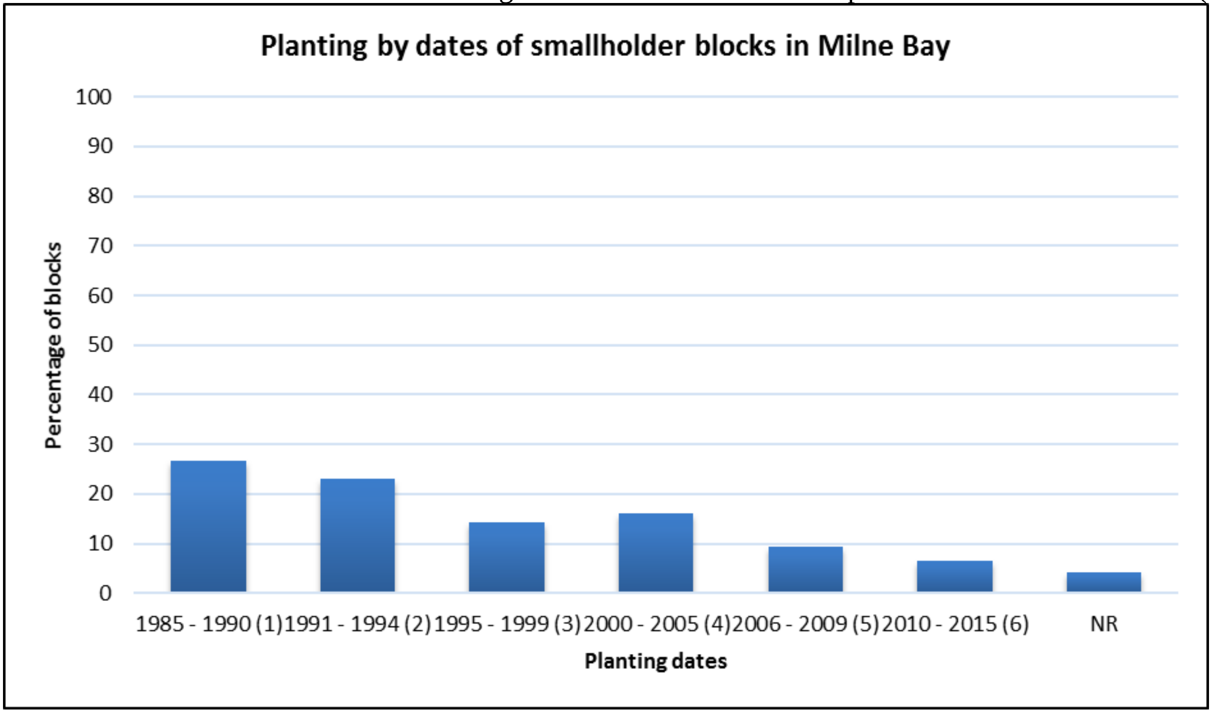

Figure 93).

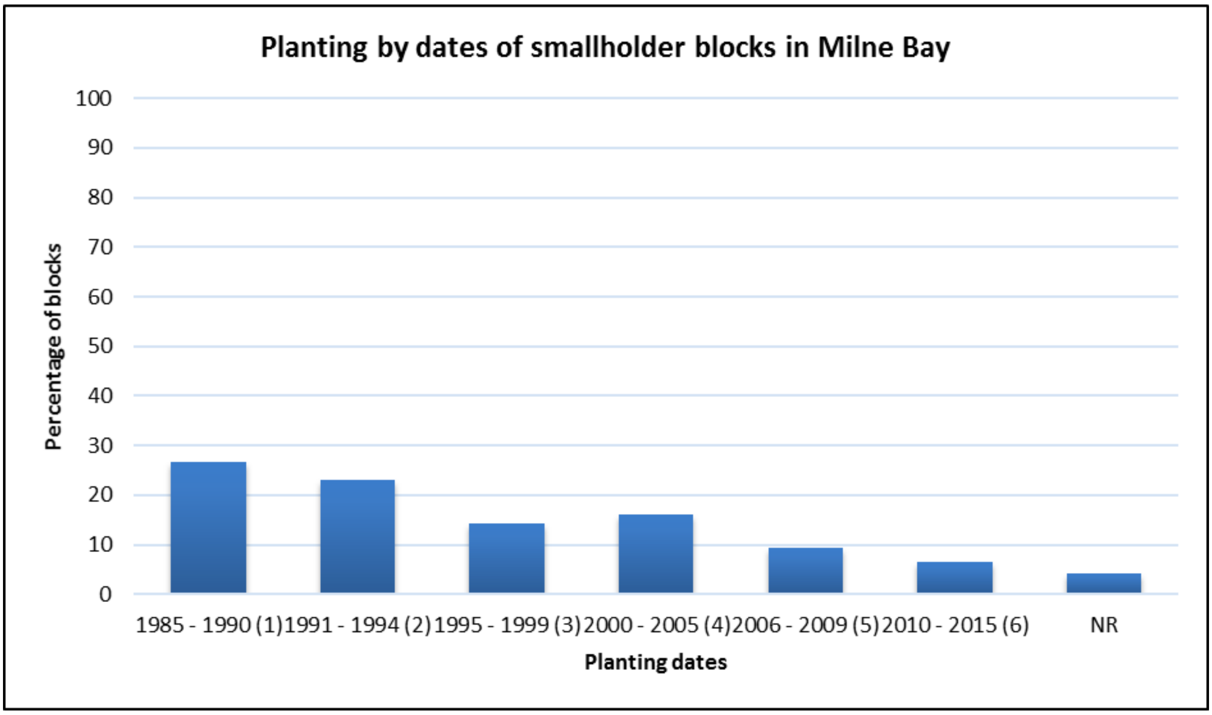

Figure 93. The planting dates of smallholder oil palm blocks in Milne Bay (n=169)

The most common area of land planted to oil palm by smallholder households were 2 and 4 hectares (

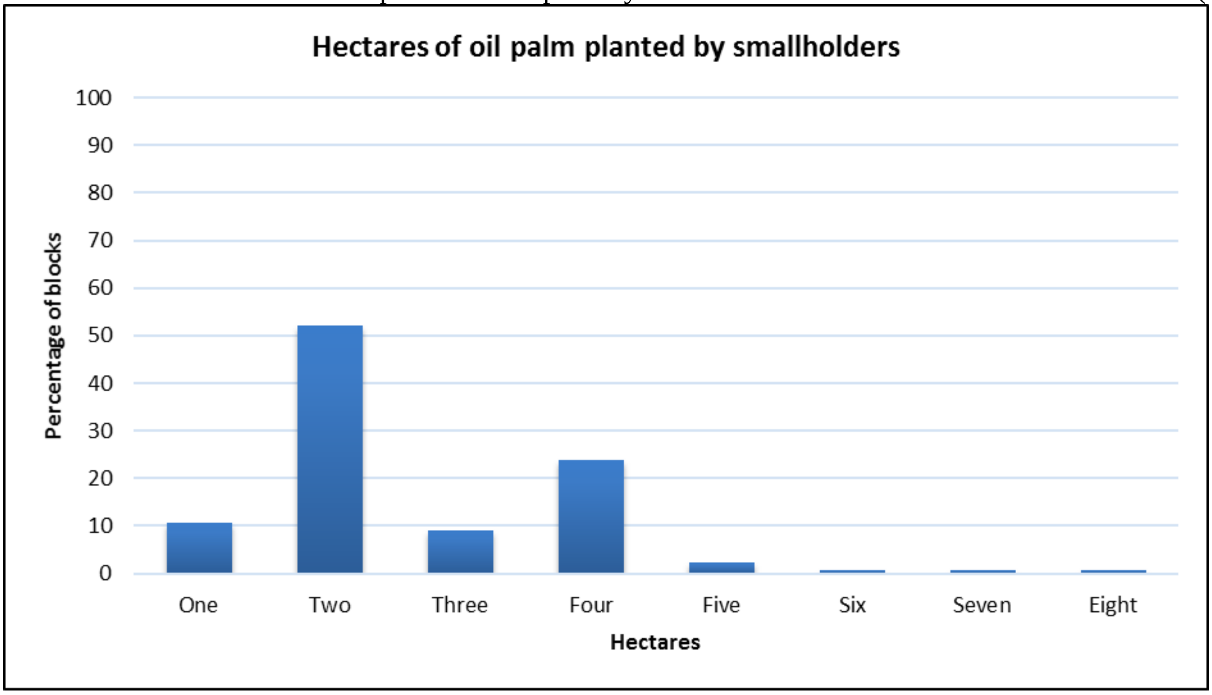

Figure 94). Two hectares of oil palm planting are commonly practised by VOPs. VOPs are developed on customary land and can go beyond 2-hectares of oil palm planting, depending on various socio-cultural considerations as most customary land are communally owned and not individualised as those of the LSS.

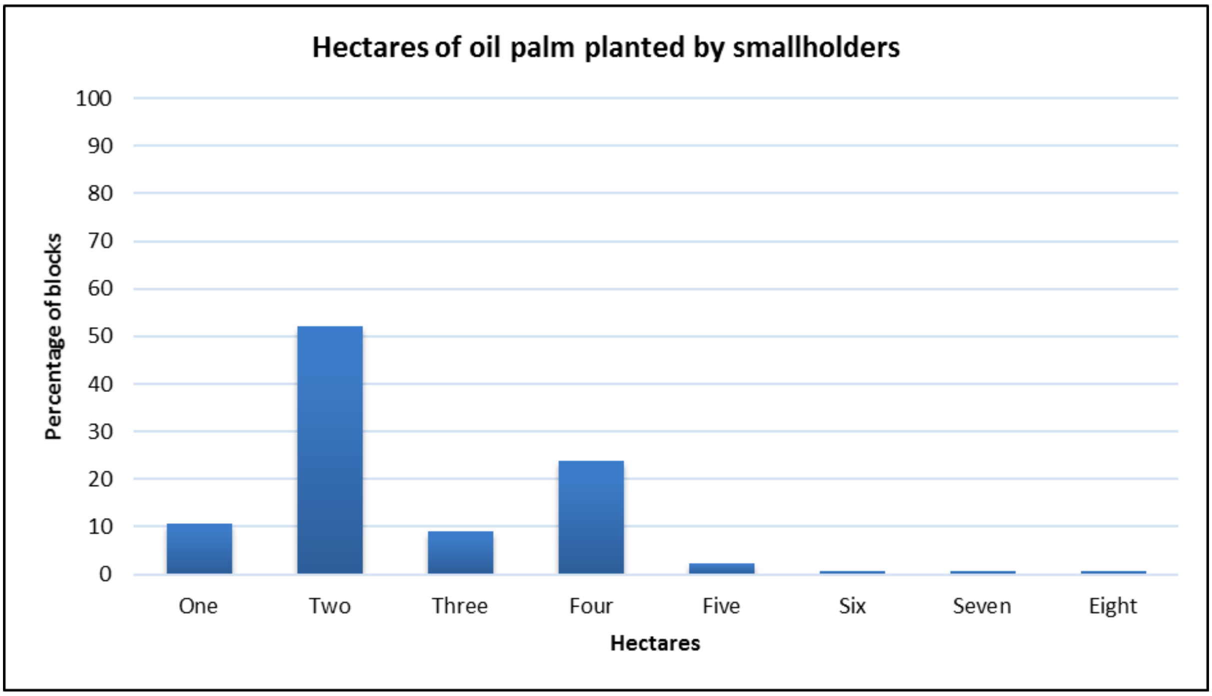

Figure 94. The number of hectares planted by smallholders (n=167)

As discussed earlier in (

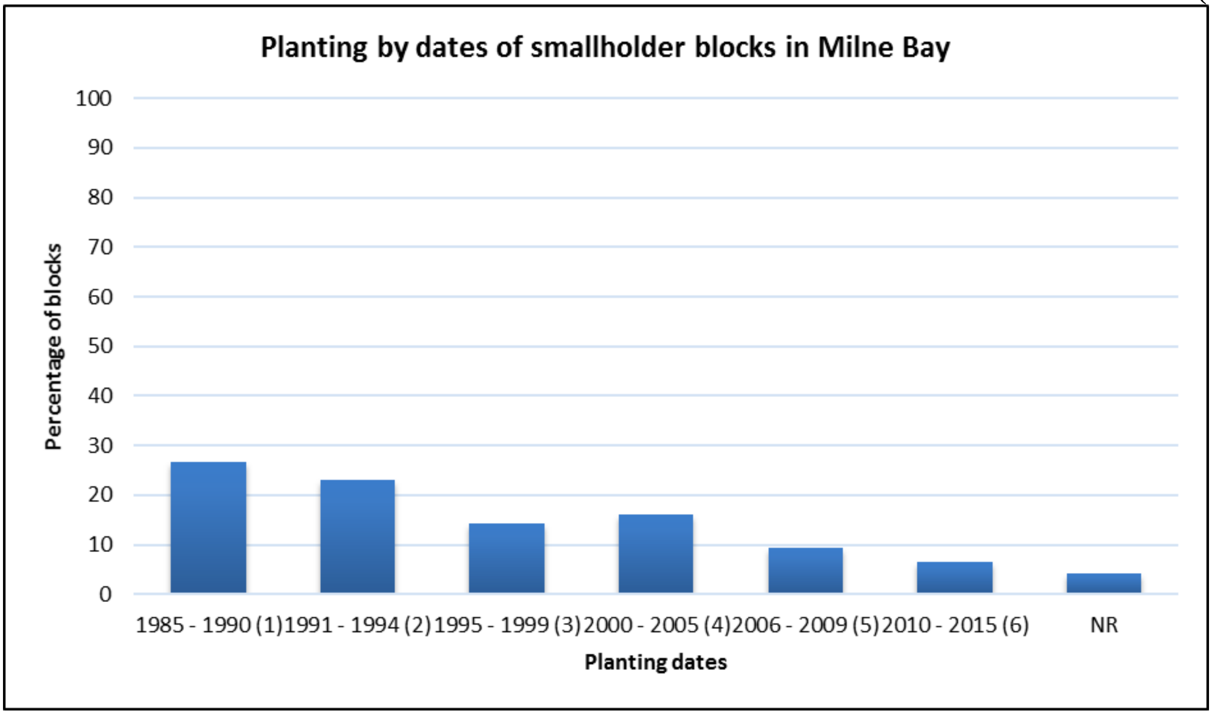

Figure 93), most smallholder blocks that were planted in the mid 1980s-1990s were over-aged with low crop bearing trees. These blocks are undergoing replanting phase (Table 99).

Table 99. The replant status of smallholder blocks in Milne Bay

Replant status	Count	Percentage
Yes	136	81
No	31	19
Total	167	100

Ownership status

Most of the blocks in the study have indicated that their block ownership statuses (name on title/CLUA) are still with the original owners of the block (Table 100). Most of these original block owners are currently living on the blocks (

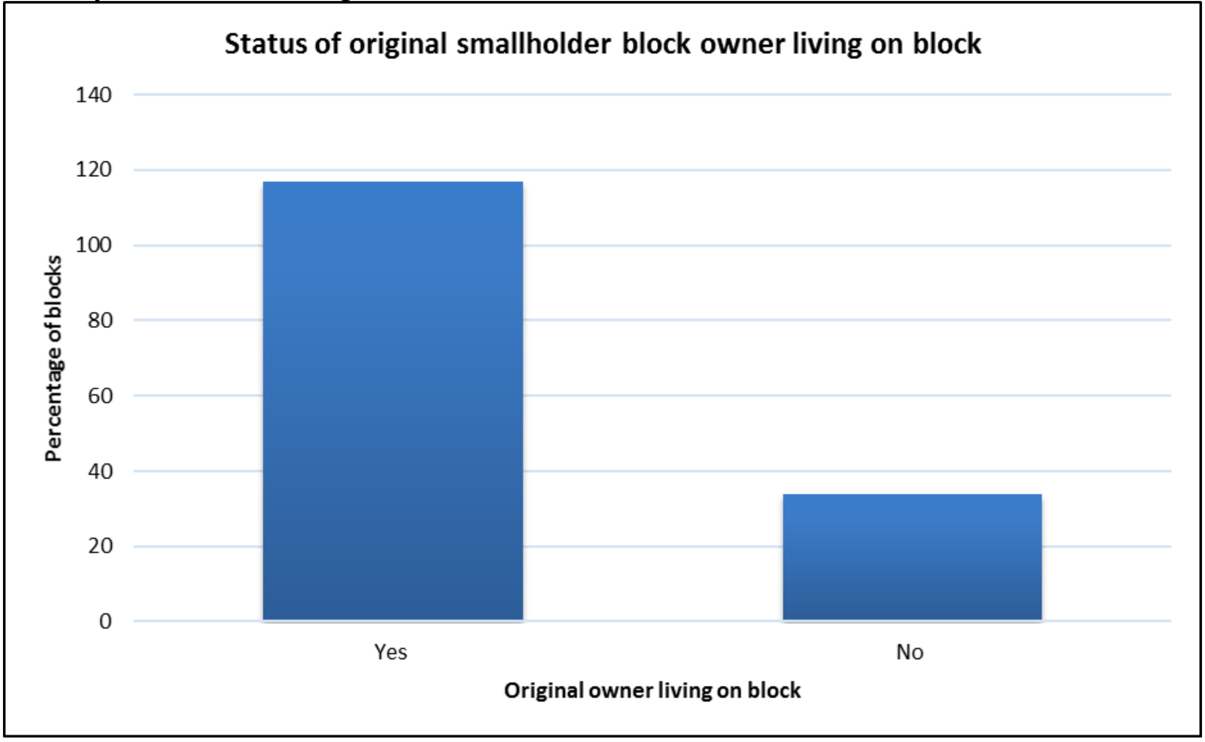

Figure 95).

Table 100. The status of block ownership by original owner

Original owner name of CLUA/Title?	Count	Percentage
Yes	148	98
No	3	2
Total	151	100

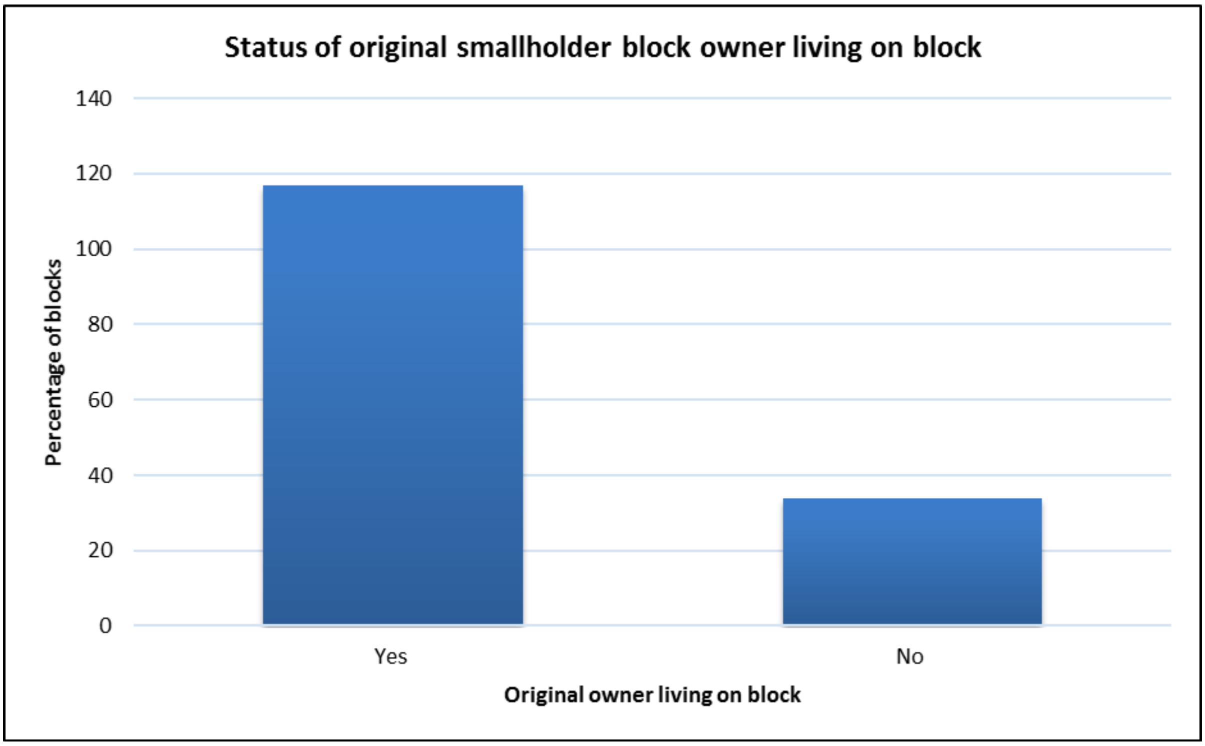

Figure 95. The status of original owner whether currently living on block or not (n=151)

Most original block owners are still managing their oil palm blocks. However, there is an emerging trend of original block owners losing their block management statuses (Table 101). Most of the upcoming block managers are either the sons or daughters of the original block owners (

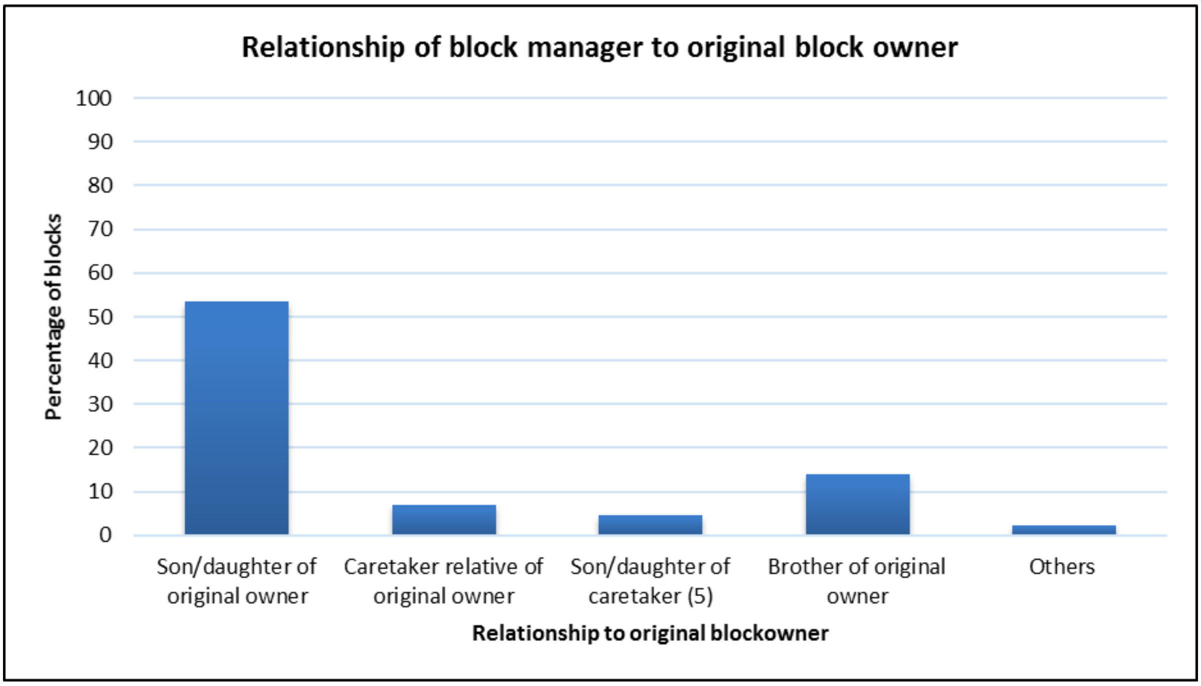

Figure 96).

Table 101. The status of current block management by original owner

Original block owner managing block	**Count**	**%**
Original owner still looking after the block	108	72
Original owner no longer looks after the block	43	28
Total	151	100

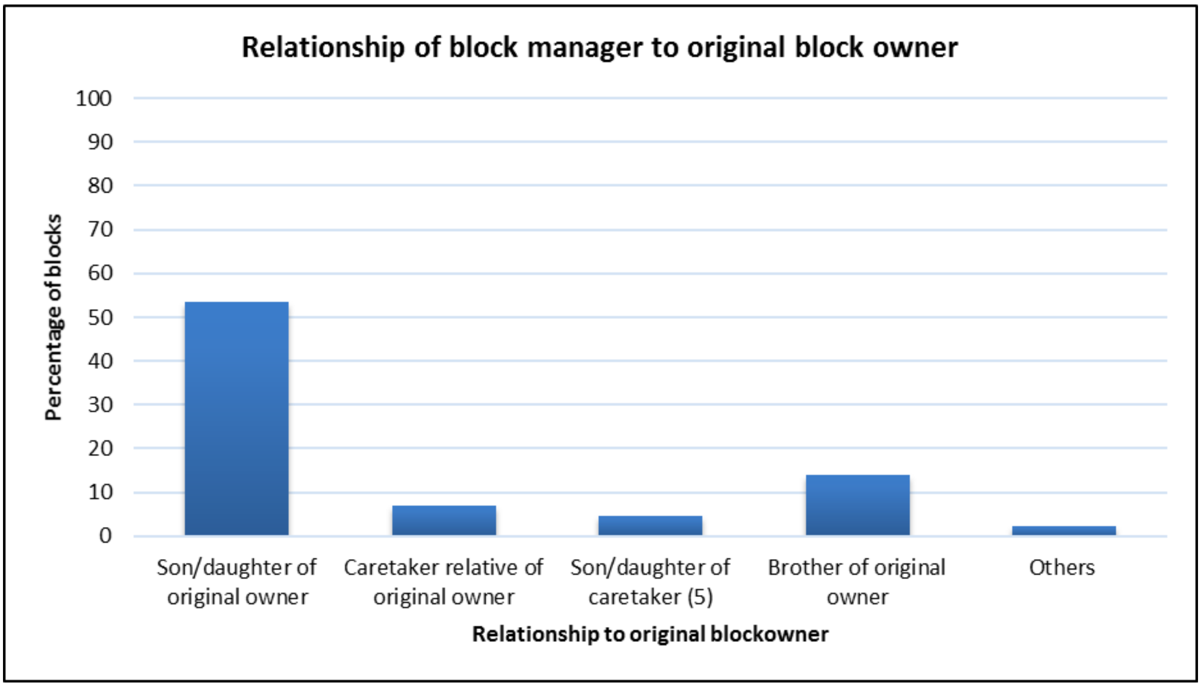

Figure 96. The relationship between the current block manager and original block owner (n=43)

There are less internal block disputes relating to block ownership and management (Table 102). This is due to the less population density among the smallholder households (Table 103) to compete for space, income distribution and, block ownership and management.

Table 102. The status of smallholder block ownership dispute

Block under dispute	**Count**	**Percentage**
Yes (1)	11	7
No (2)	140	93
Total	151	100

Block population

The average household per block in Milne Bay is 2.2 (Table 103) which is lower compared to other smallholder project sites like Hoskins (Koczberski et al. 2001, p. 73). Therefore, there is still less pressure on smallholder blocks.

Table 103. The residential status of smallholder households

Resident status of smallholder households	
Max	4
Min	1
Av	2.2

Food security-garden survey

Most smallholders do gardening on customary land while some prefer to do gardening on vacant part of their own block (

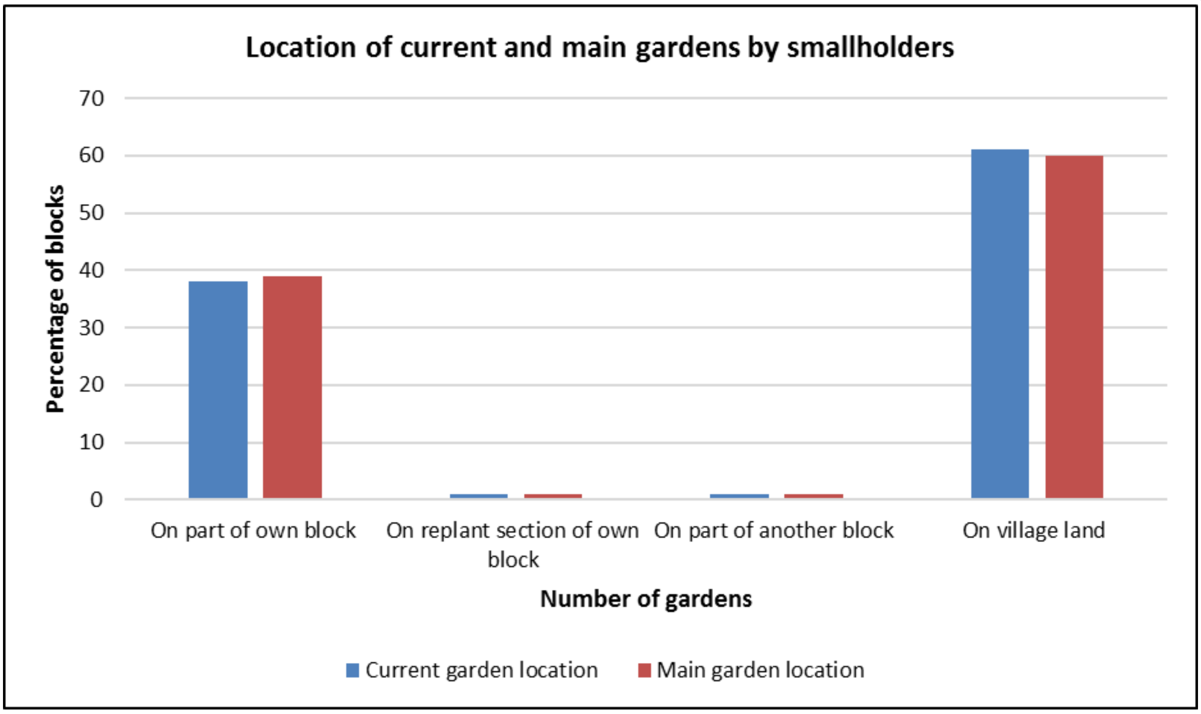

Figure 97). As stated above (Table 103), there is less household per block consequently, there is enough land availability either on or off block for gardening purposes. Most of the cultivated gardens by smallholder households are mainly for their own consumption and for sale at the markets to earn income

to facilitate their immediate household expenses (

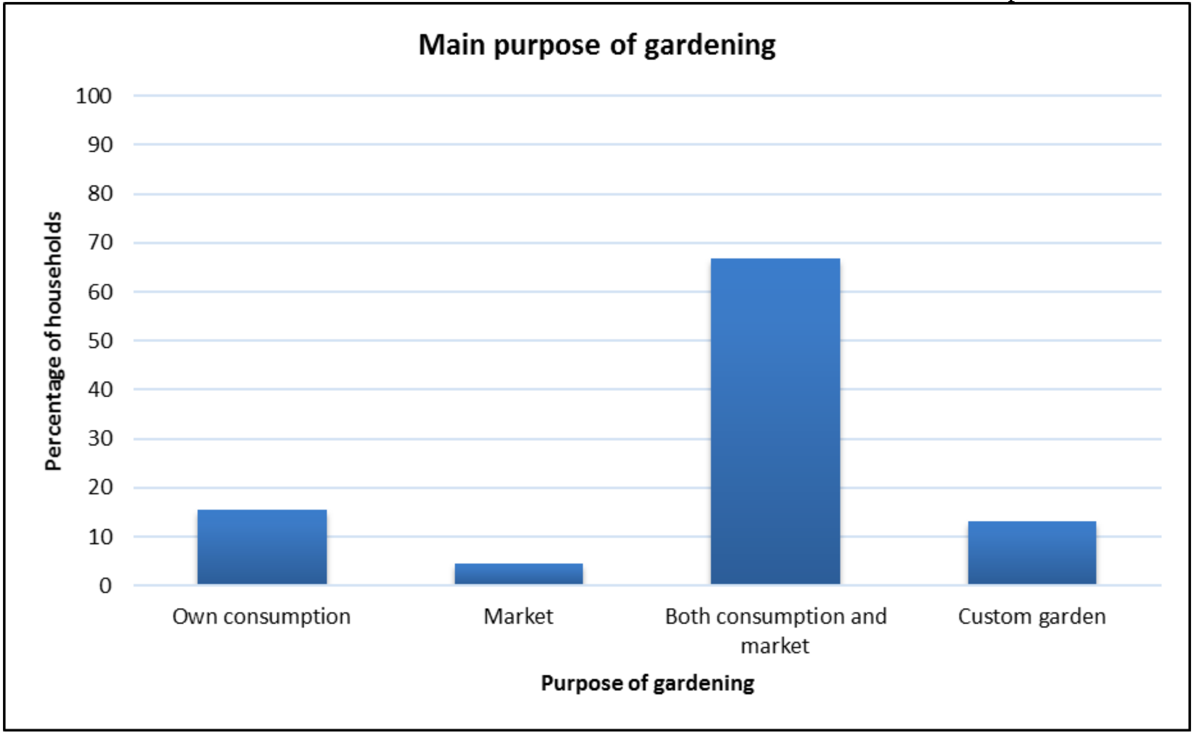

Figure 98). Others cultivate gardens for their own consumption, for customary activities or mainly for marketing purposes (

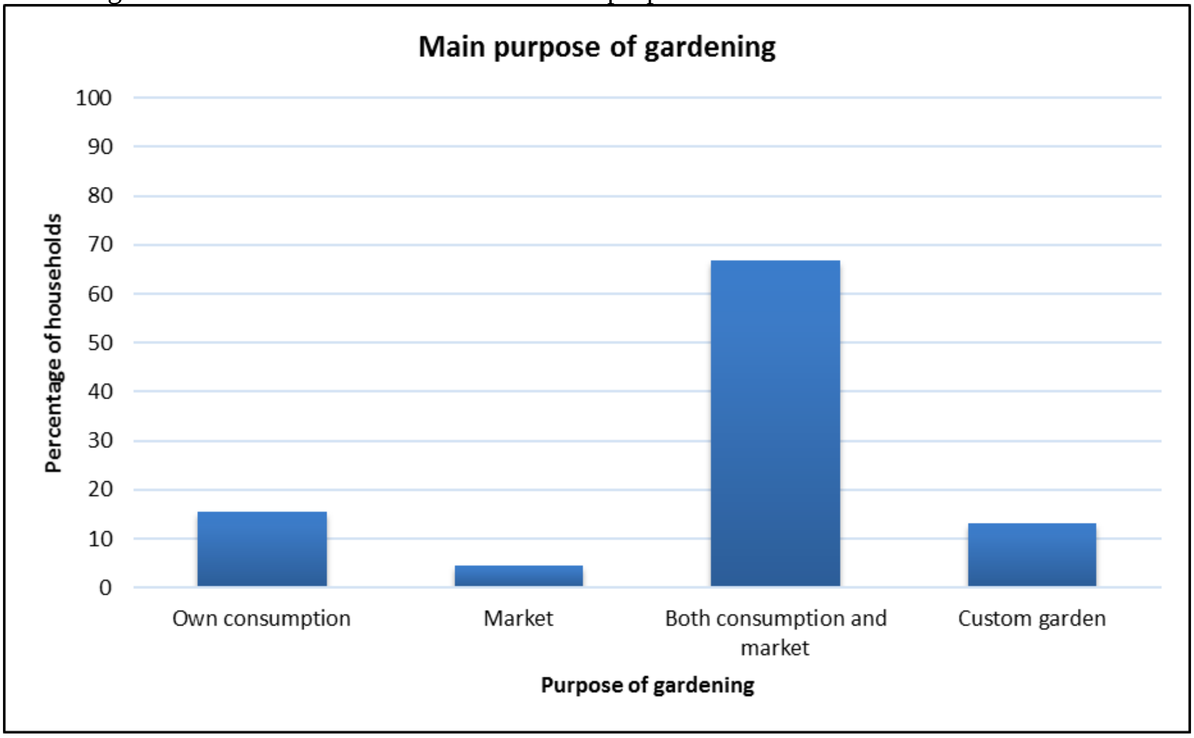

Figure 98).

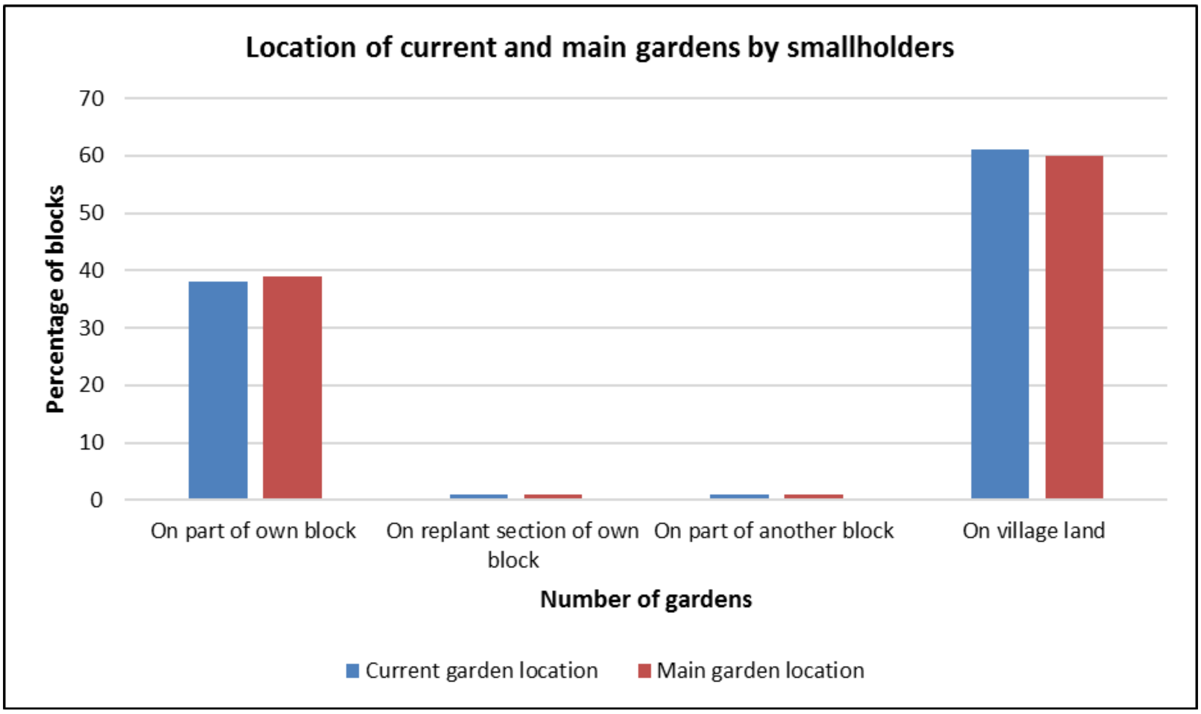

Figure 97. The location of gardens owned by smallholders (n=202)

The gardens that are cultivated on customary land are mainly by smallholder households who are customary landowners or people from the same area. Others are from parts of Milne Bay especially the island areas who have worked or spent most of their lives working in the plantation estates and have developed social relationship with the landowners to access customary land for oil palm block development and gardening.

Those growers from other areas of Milne Bay and outer island areas usually get donation of additional garden food crops from their relatives back in their villages, whilst some purchase from the local markets or from sale of food crops by other smallholder households (

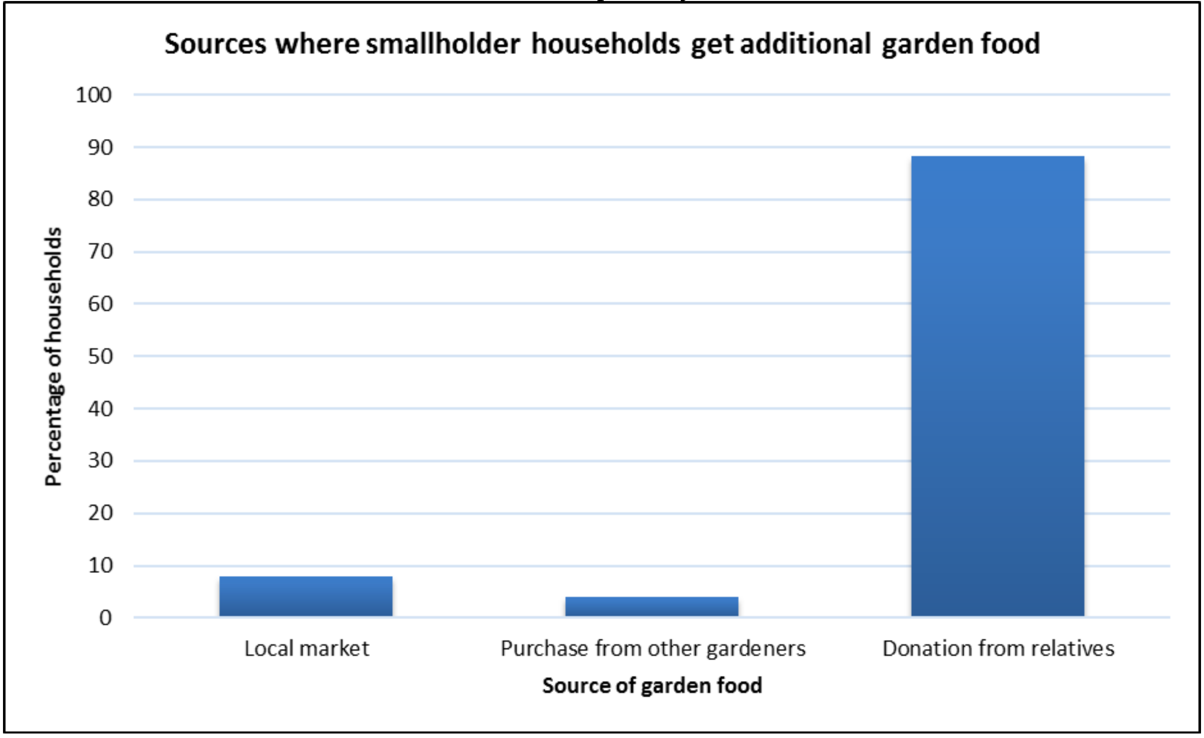

Figure 99).

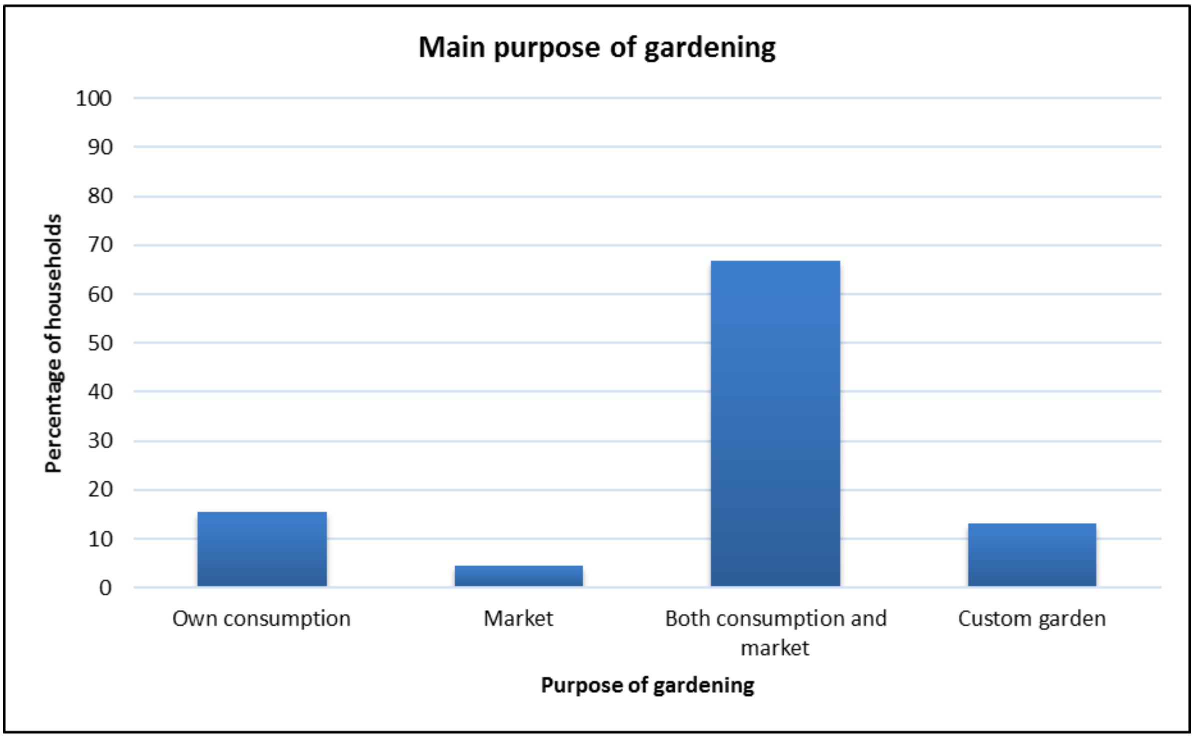

Figure 98. The reasons for cultivating food gardens by smallholder households (n=181)

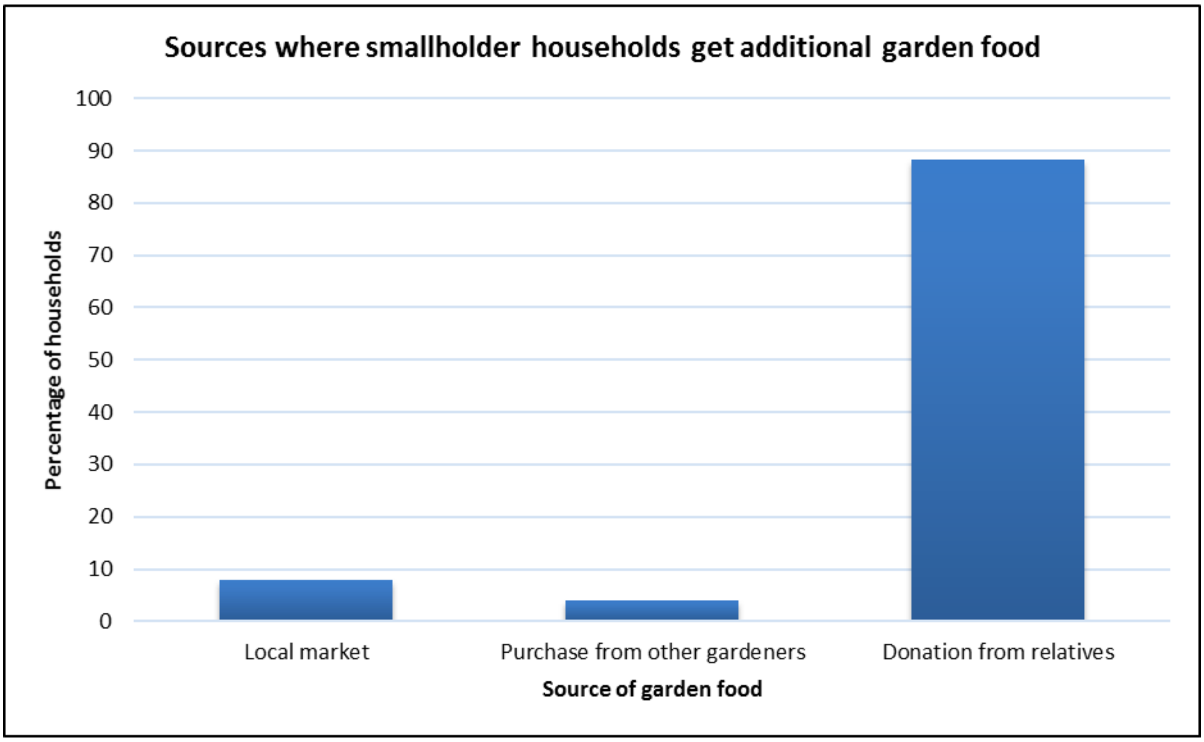

Figure 99. Other sources where smallholder households get their garden food (n=102)

Nutrition

Apart from cultivating garden food crops, about 50 percent of the study households indicated the raising of livestock on their blocks on purpose (for consumption, sale, etc.) or as a hobby (

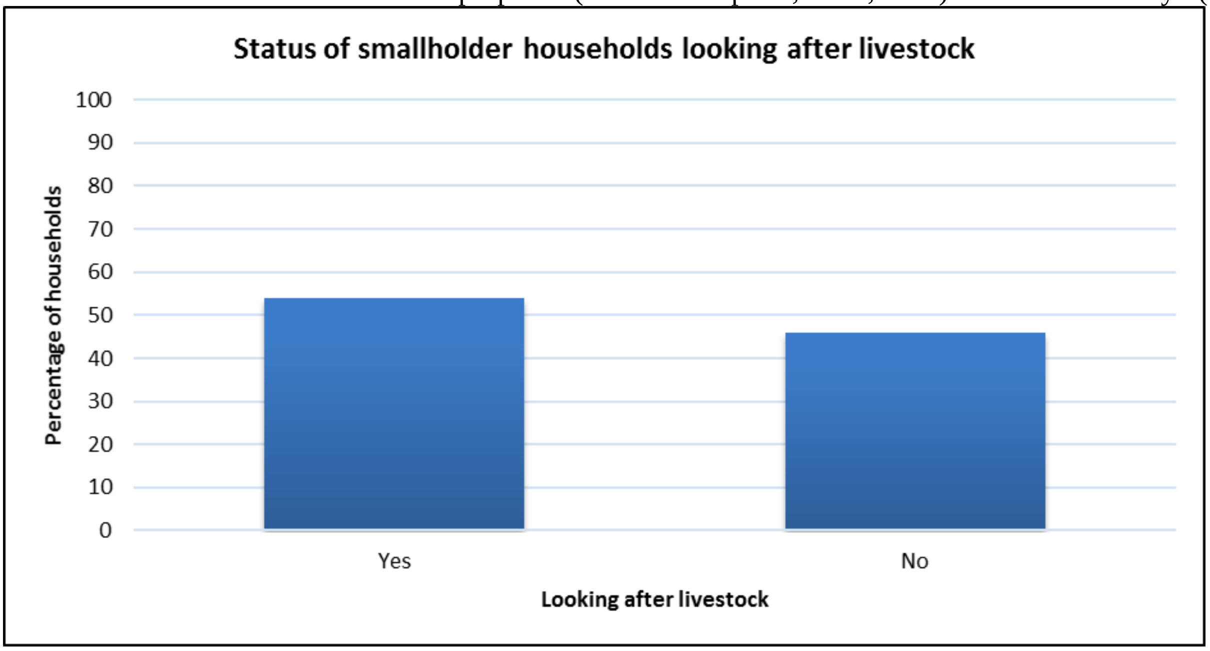

Figure 100).The main purpose of rearing livestock is for both their own consumption and for sale (

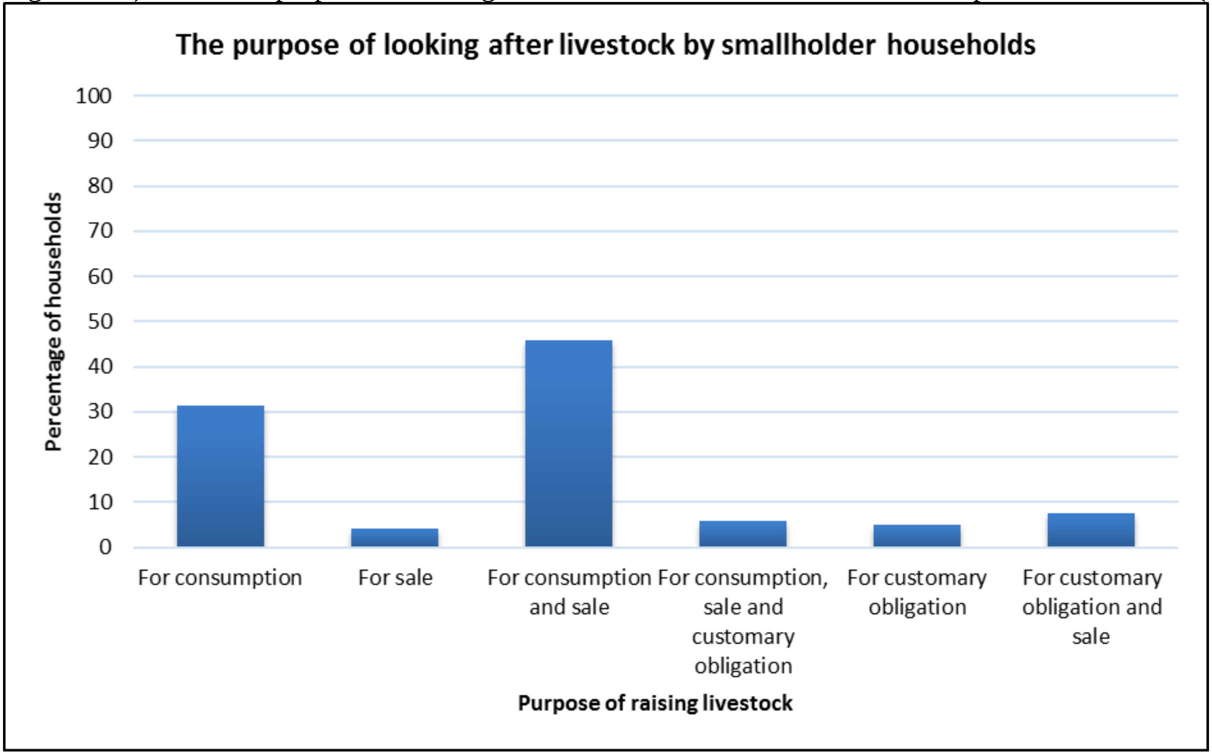

Figure 101). Others raise livestock mainly for their own consumption, for sale and customary obligations purposes and other minor purposes (

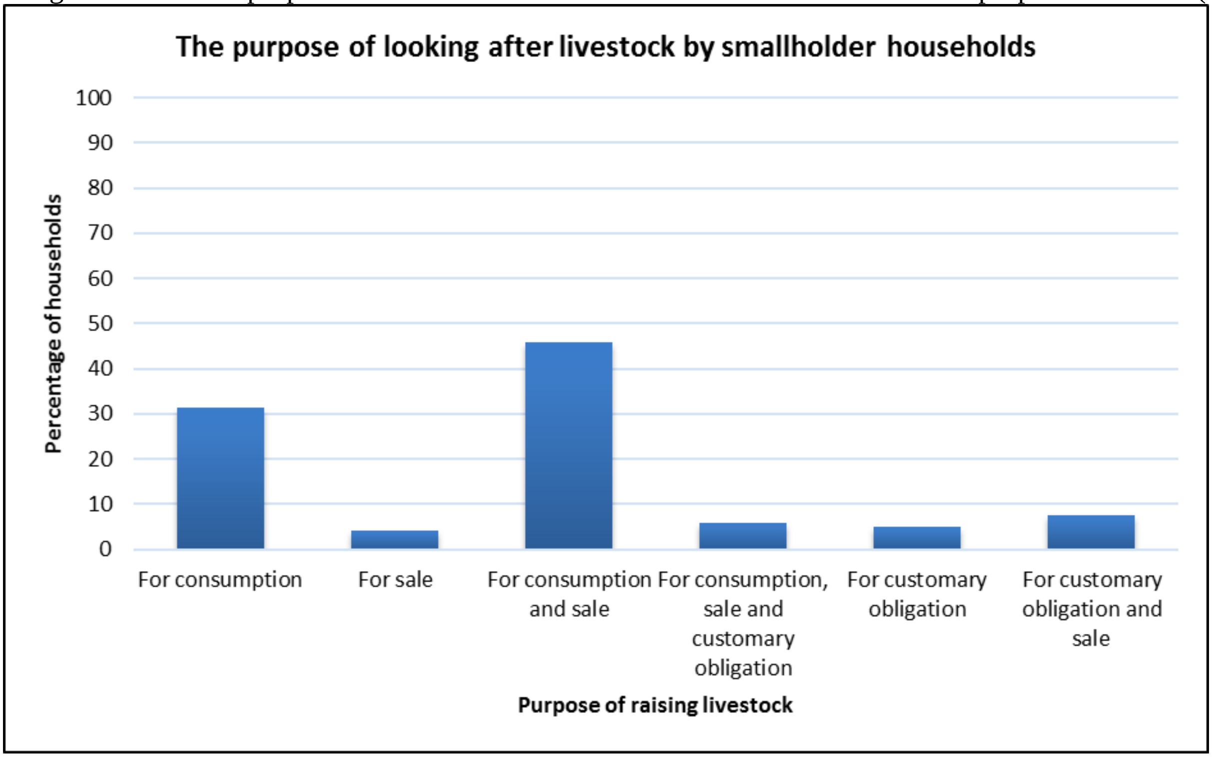

Figure 101).

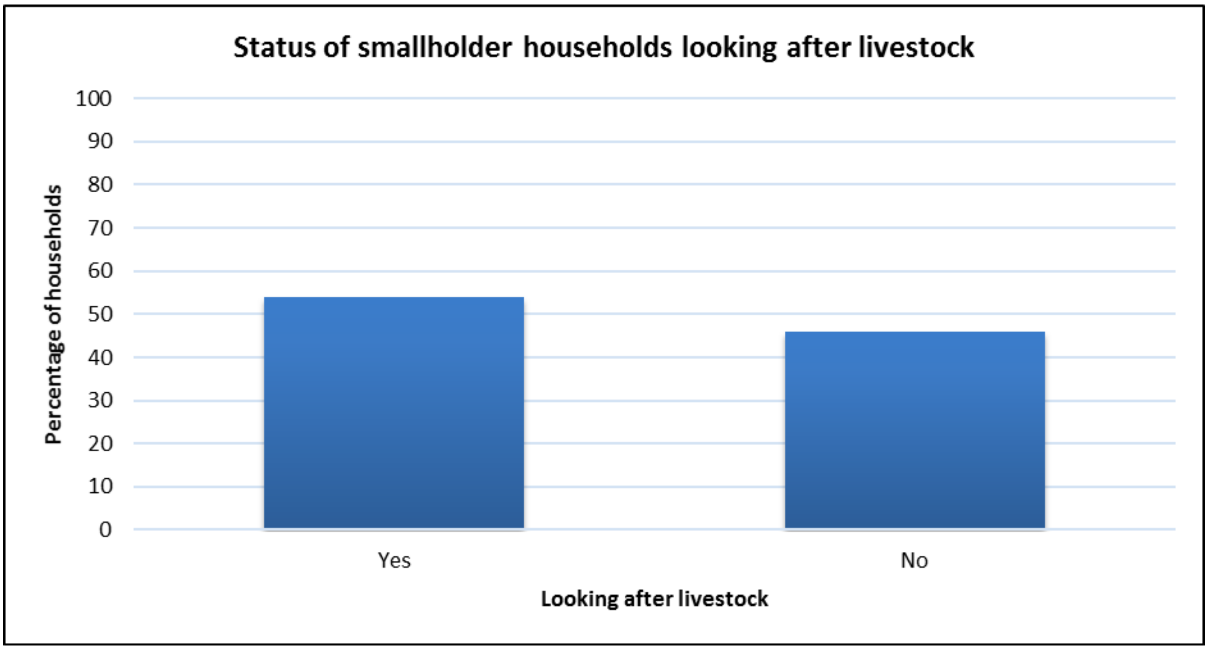

Figure 100. Smallholder households who are either raising or not raising livestock (n=152)

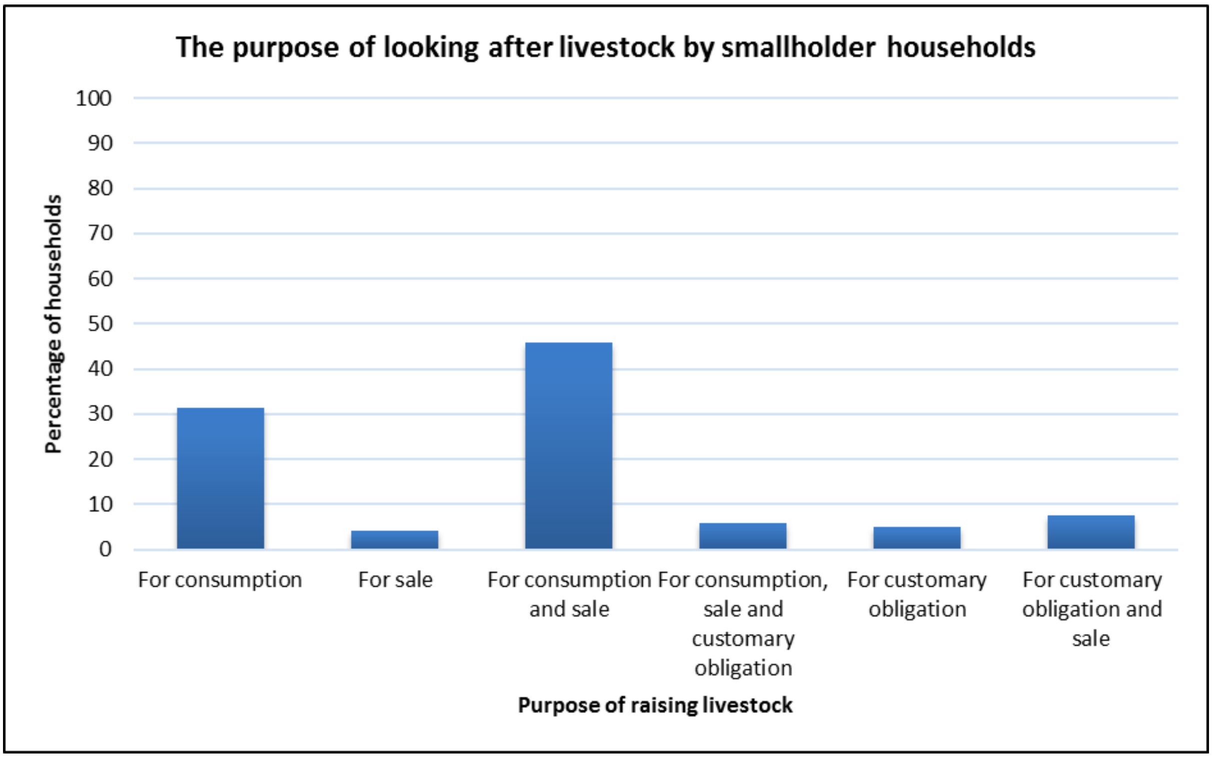

Figure 101. Main purpose of raising livestock by smallholder households (n=118)

Livelihood-income earning source

Garden food crop sales remain the main alternative income source followed by betel-nut sales, piggery, wage employment and fishing (Figure 102). Despite garden food crop being main income source, the frequency and quantity of food crop being sold is on average once a week followed by 2-3 times a week and once a month (Figure 103).

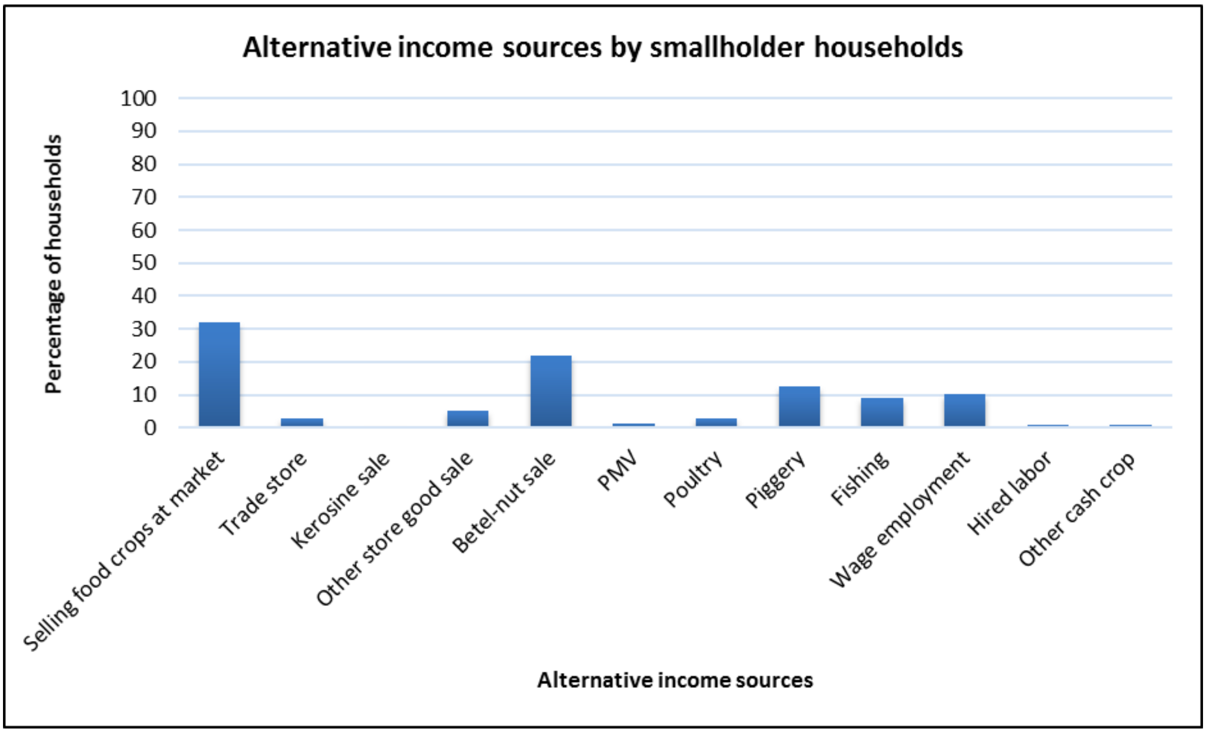

Figure 102. Other avenues of income generation by smallholder households (n=406)

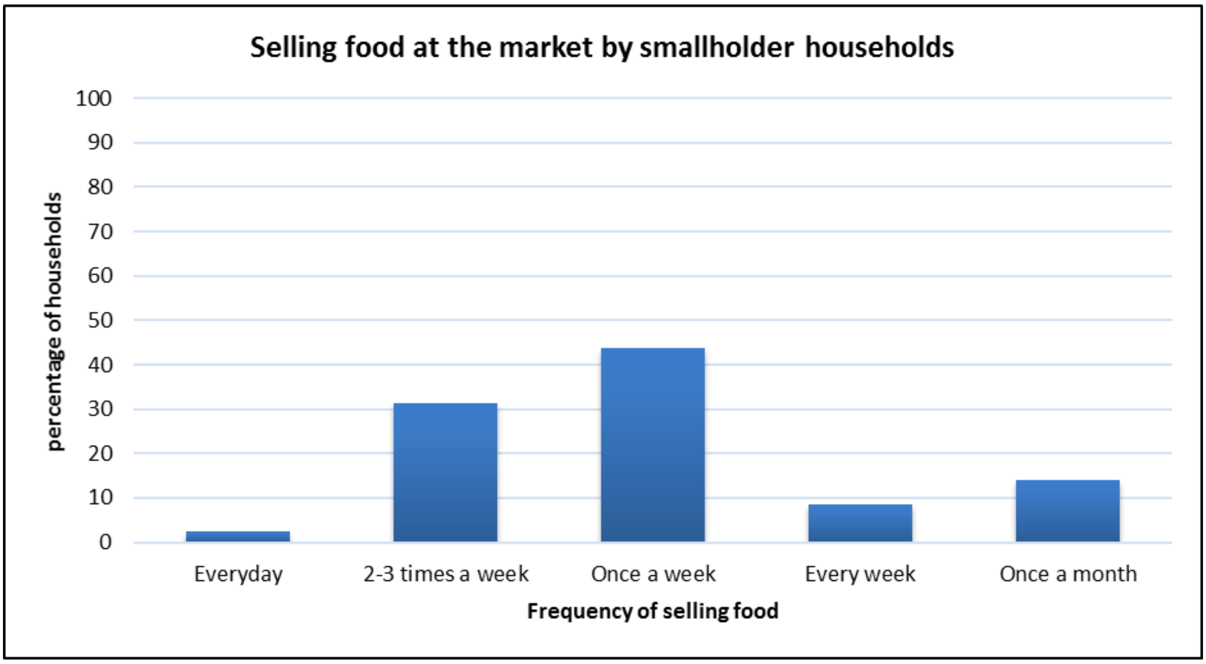

Figure 103. The frequency of selling food crops at the market by smallholder households (n=128)

Labor supply

The common combine harvesting method (Wokbung) is the common harvesting method used by smallholders. The smallholder nucleus family unit are still intact with most smallholder blocks having the original block owners living on the blocks and managing the labor socioeconomic affairs of the block. The less household density and less pressure on income and income distribution also contributed to maintaining this FFB harvesting strategy.

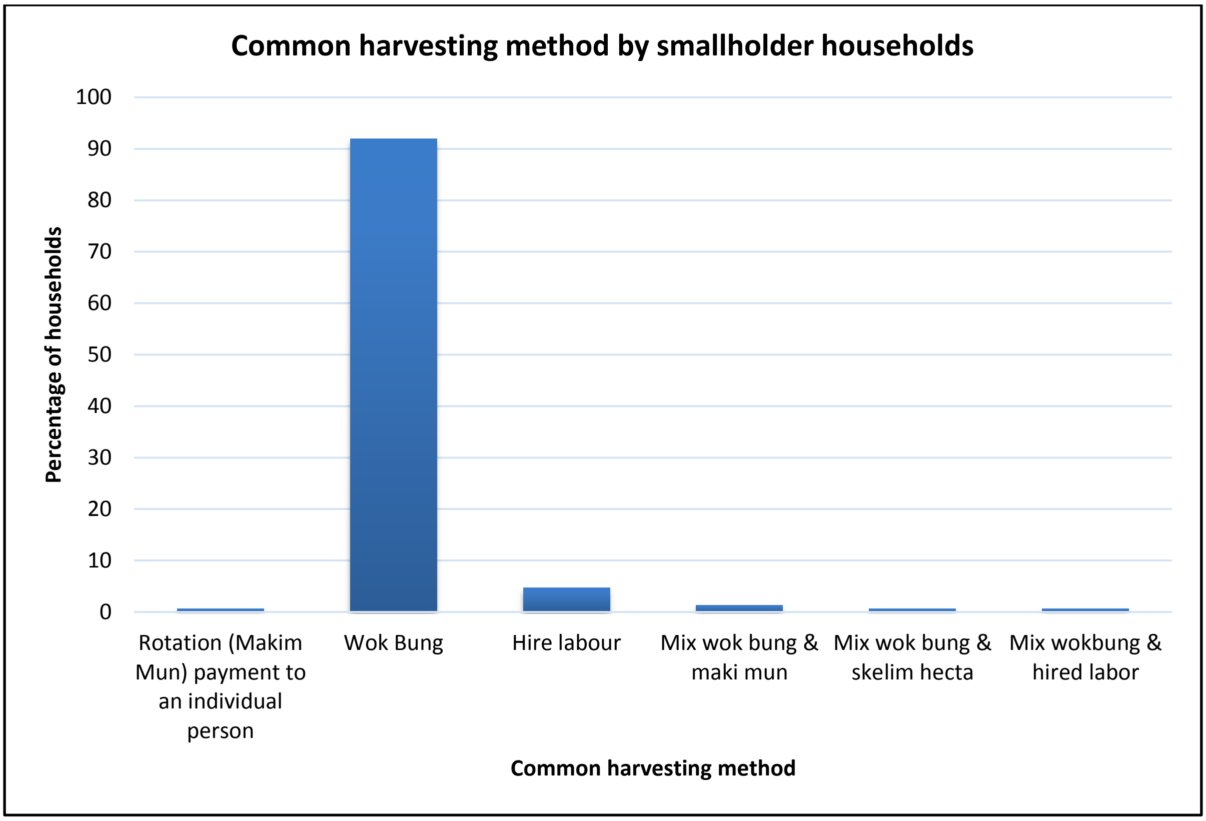

Figure 104. The main harvesting strategies used by smallholder households to earn income (n=149)

Agronomic practices

Approximately 50 percent of the interviewed smallholder households indicated that they did not do FFB harvesting at all or harvested once in the last month. The other 50 percent stated that they harvested their FFB twice in the last month (Figure 105). Those smallholder households that indicated zero or one FFB harvesting and pickup last month were due to mainly low FFB crop. This is because most of the smallholder blocks still have over-aged standing palms whilst some recently replanted their blocks and their seedlings are still in immature phases (Figure 106). Some either face tools shortage or road access problems (Figure 106).

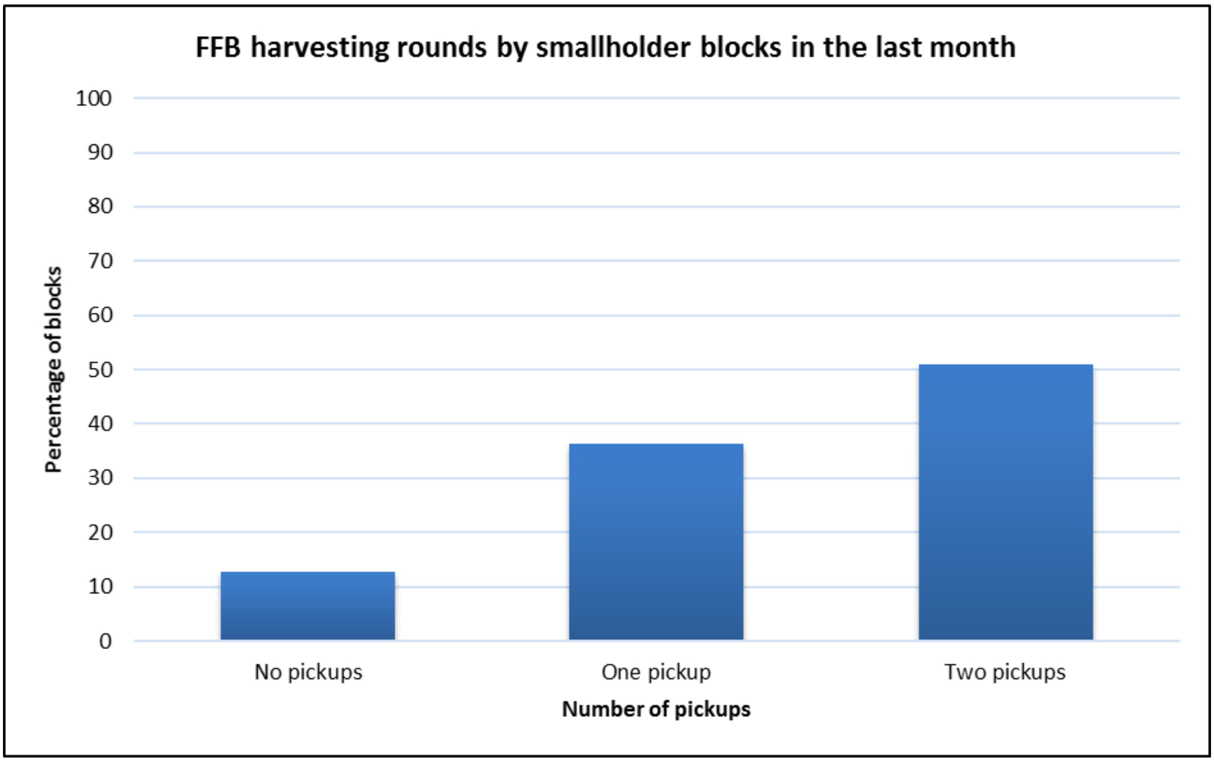

Figure 105. The frequency of harvesting FFB by smallholder households in the last month (n=149)

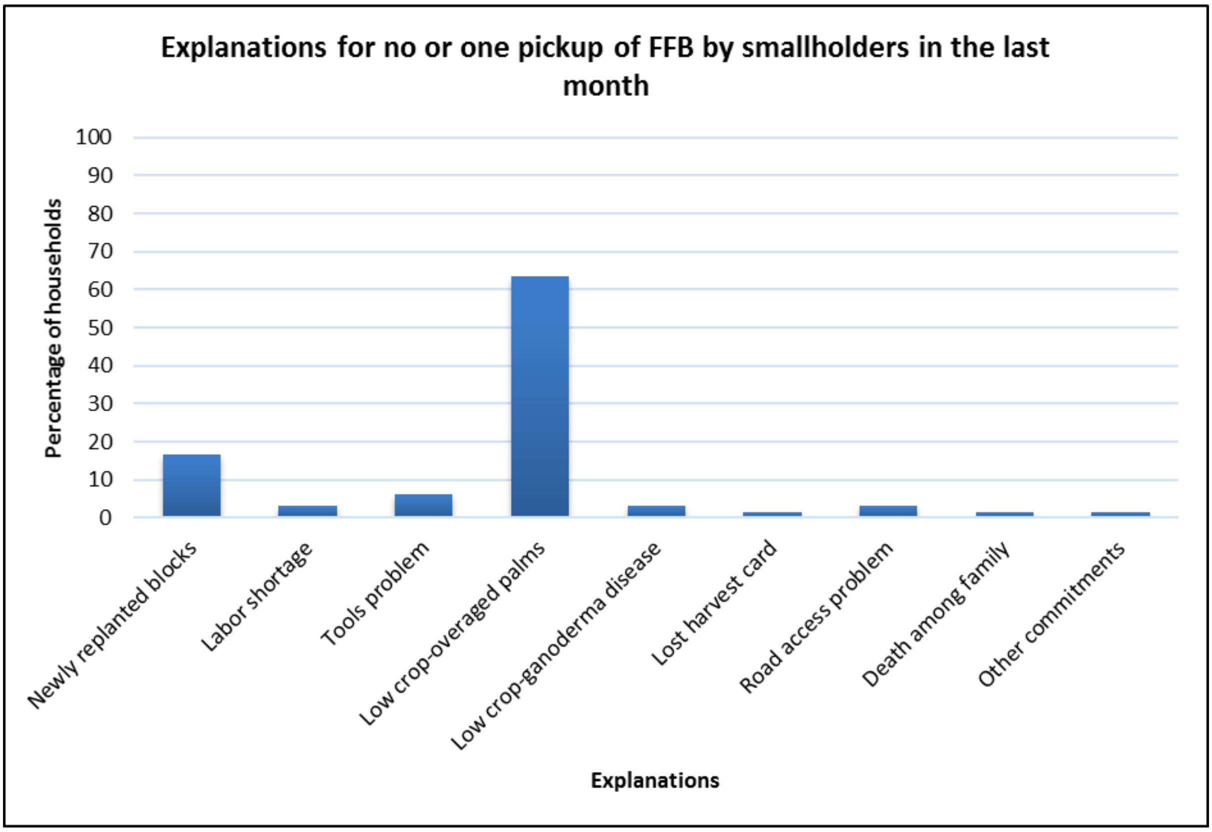

Figure 106. The explanations why there was no or only one harvesting done in the last month by smallholder households (n=66)

E.6.8.5. *Conclusion*

The study of the smallholders in Milne Bay brought forward the socioeconomic baseline statuses of smallholder households. The study showed that the socioeconomic statuses of the smallholder livelihood are still in good health. However, there are emerging problems that the industry should prioritized and develop strategies to address these issues. These issues include over-aged standing palms causing low FFB production and decreased yield per hectare. The decline in smallholder oil palm planting, as less land area were developed under smallholder scheme since the initially planting in the mid-1980s. The study indicated that most smallholder household gardens were cultivated on customary land which will result in future land pressures.

Therefore, the above identified issues are related to pressure on customary land. There is an urgent need to conduct further studies on customary land use rights into landowners and migrants occupying customary land for oil palm and other livelihood developments.

E.7. DONOR FUNDED AND SPECIAL PROJECTS

E.7.9. Examining land tenure and income security among oil palm land-poor migrant farmers of West New Britain

(Emmanuel Germis – MPhil Thesis Summary)

E.7.9.1. *Summary*

The "purchase" of customary land by migrants to pursue livelihoods in the oil palm frontier of West New Britain (WNB) in Papua New Guinea (PNG) is increasing rapidly. Yet evidence suggests that land laws governing the leasing and transacting of customary land in PNG are lacking thereby causing uncertainty for both migrant farmers and customary landowners. Previous research has reported that migrant farmers have more secure livelihoods if the rules governing land tenure are predictable. Therefore, current and future land access through formal and informal land rights has implications for a secure and sustainable farming system.

This thesis examines the "purchase" of customary land at two villages in WNB: Morokea and Gaungo villages. Migrants acquiring customary land for livelihood investment purposes have very diverse characteristics and use a range of ways to negotiate access to customary land. The primary decision to "purchase" customary land is often decided at the family level, with the family head's decision influenced by other family members as well as relatives and friends. The decision making comes into play when migrants themselves are in search of land or vice versa, individual or group of landowners in search of buyers to purchase parcels of their land. Some migrants use their former work and other business experiences to provide public goods and services to the host landowner communities, thereby increasing their value and 'acceptability' to their hosts. Early migrant growers in Morokea were accepted into the landowning clan as clan members by their landowner 'brothers' through a traditional socially embedded process. More recently, migrants have had to pay for land rights and while this represents the increasing commercialisation of land transactions, there are still opportunities for migrants to become clan members.

The research shows that over the last 30 years there has been a steady process of increasing formalisation and documentation of land access arrangements by migrants in Gaungo and Morokea. Despite increasing formalisation of land access arrangements, the maintenance of social relationships and meeting socio-cultural obligations remain essential for migrants wishing to maintain land tenure security. The long-term relationship between customary landowners and migrants is based on mutual trust and respect. The increased demand for customary land over the last three decades has shifted from a general focus on oil palm development to securing land and resettlement opportunities for migrant families. The long-term cultivation of oil palm and resettlement of migrant households has displaced

the traditional notion of land "gifting" as a temporary arrangement, to a formal long-term arrangement of land "gifting".

This research contributes towards strengthening land tenure arrangements between migrants and customary landowners and contributes to the customary land reform program in PNG.

E.7.9.2. *Methodology*

The methodology section of the thesis gave background to the study sites and research approaches used in data collection. It discussed the approaches that were adopted and applied during the research fieldwork and in the process of data analysis. The pragmatic mixed method approach was appropriate for the study.

Study sites

The two study sites are Gaungo and Morokea (Figure 107). These two villages share traditional land boundaries and have a common interest of releasing their customary land to outsiders. The two villages are situated along the north coast of WNB Province bordering Kimbe Bay in the fertile plains of the oil palm farming zone, along the New Britain Highway, ten to fifteen minutes' drive away from Kimbe town, the capital of WNB. These plains stretch from the north coast to the foothills of the Whiteman Ranges that run along the spine of WNB province in an east-west direction separating the north and south inland and coastal areas (Figure 107). Gaungo is on the coastal plain inland along the New Britain Highway and Morokea land is flat with hills scattered from the foothills of the Whiteman ranges to the coast. Both Gaungo and Morokea have similar coastlines with several rivers and creeks cutting through the territory and patches of swamp and mangroves along the brackish waters.

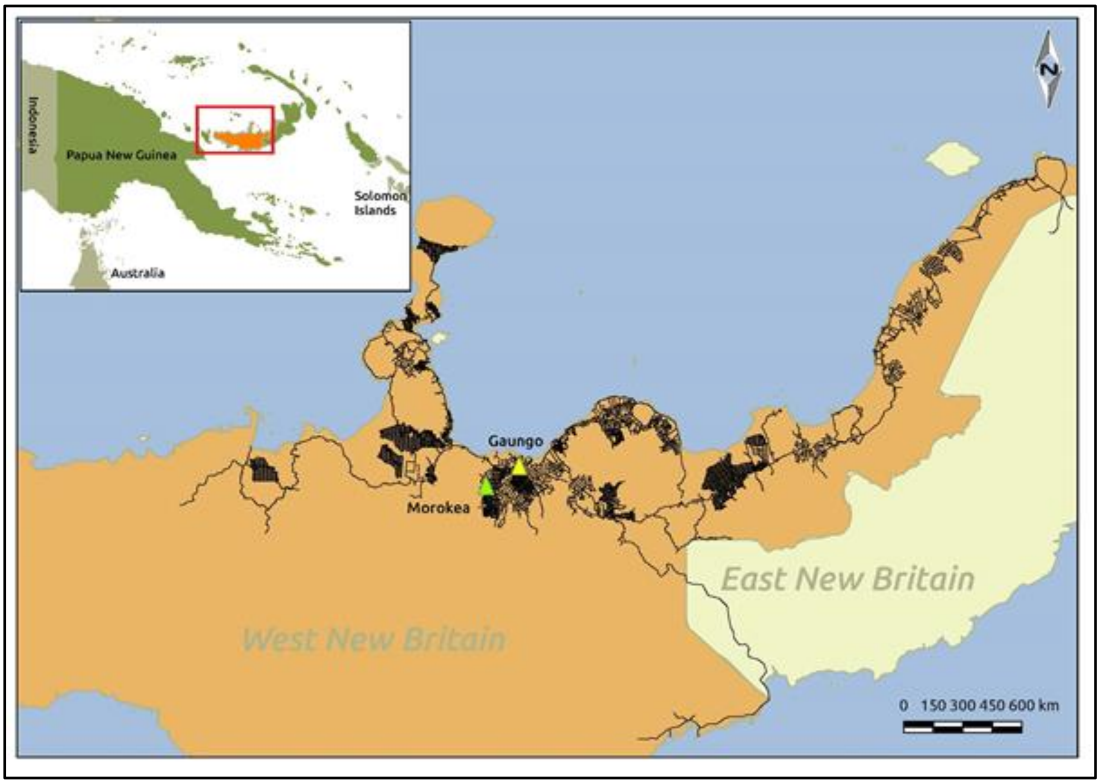

Figure 107. Study sites-Gaungo and Morokea

Research approach

The approach used for the study was pragmatic research using triangulation (Figure 108). The primary and secondary information were both collected using qualitative and quantitative techniques. The primary data collected via household surveys were a mix of qualitative and quantitative data, while those of focus group discussions and direct quotes or texts from individuals (farmers, landowners, OPIC extension officers and smallholder affairs supervisors of NBPOL) were in qualitative form.

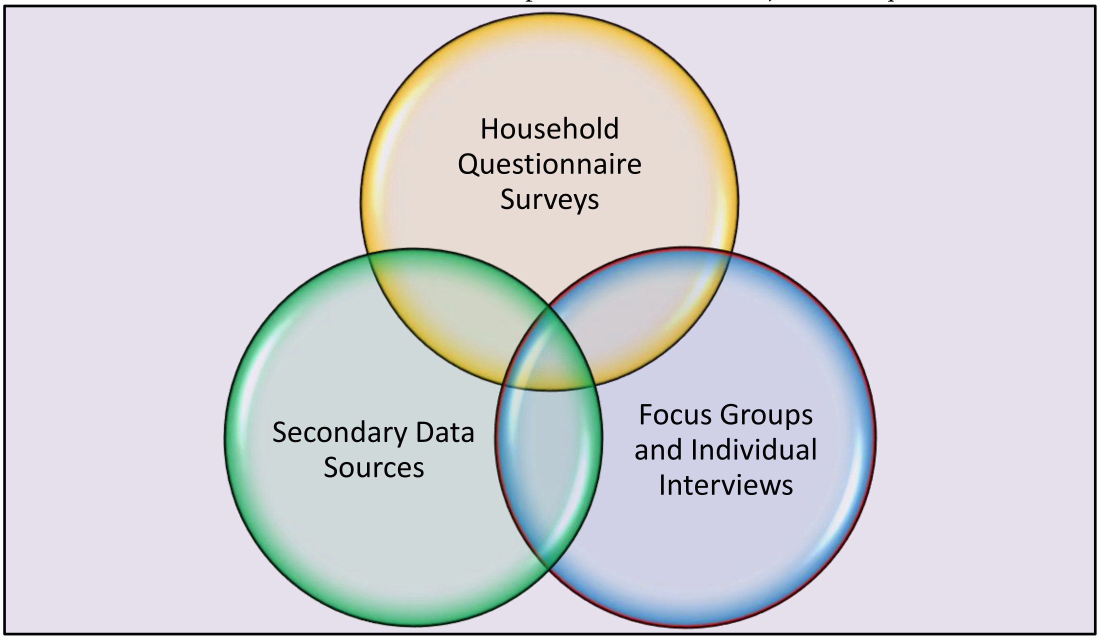

Figure 108.Triangulation research approach

Field data collection techniques

The study involved survey questionnaires, consultations and focus group discussions/meetings, interviews, social mapping of study sites and networking of relationships. Secondary data and reports were also collected. Focus group discussion meetings were held in separate sessions with relevant stakeholders. The date, time and venue for each of the meetings was arranged and each group of stakeholders was transported to the venue of the discussion. The stakeholders involved in the meetings were fourteen landowners from Gaungo and Morokea villages, fifteen extension officers and five field supervisors from the private milling company. Questionnaire surveys and interviews were conducted with sixty-three migrant farmer households. Most households had 2-4 ha with at least two households living on the farm.

Sample size selection

The household questionnaire surveys and interviews consisted of thirty-one households from Gaungo and thirty-two from Morokea. The LPMF farm households were randomly selected and surveyed according to certain selection criteria. The selection/stratification criteria were as follows:

- The period when the land was purchased (1980s–2000s and since 2010).
- Farms with 2 or more hectares with a primary household living on the farm were selected.
- Ethnicity of the farmers
- Location of the farms were considered to make sure different ethnic groups in different locations of the two study sites participated. This was intended to provide a full representation of views from different farmers in the two sites.

A random sampling technique was used for the household interviews, questionnaire surveys and focus groups.

The four discussion meetings with key stakeholders involved landowners from both Gaungo and Morokea villages (fourteen participants), OPIC Kavui, Nahavio and Siki divisions (fifteen participants) and SHA NBPOL (five participants). Fourteen landowners from the two villages were selected for the focus group discussions. The landowners were identified and selected by the OPIC extension officers who have regular contact with them. The selected landowners were individuals representing the major landowning clans and responsible for decision making on land tenure and land 'sales' to outsiders. Moreover, these individuals are mandated to sign CLUA forms and they are members of the community restoration authority in their respective villages. Secondary data were collected from industry stakeholders (OPIC and SHA NBPOL) databases.

E.7.9.3. *Results and Discussion (Summary of thesis chapter)*

Big shift from informal land transactions to a more formalised yet traditional system

This thesis argues that land tenure transactions with 'outsiders' living at Morokea and Gaungo have become much more formal through time but continue to be informal to an extent by traditional principles of land tenure. Partly, this process of customary land formalization was a result of landowning clan groups becoming organized for their Incorporated Land Group (ILG) and customary land registrations and wanting to introduce a more formalized tenure renewal process for outsiders wishing to replant their oil palm after the 25-year cultivation cycle. The thesis shows that customary land tenure arrangements for development are possible in PNG and can be site specific and context based. The thesis also shows the importance of understanding and building on customary land tenure systems that are functioning well on the ground rather than replacing them with unfamiliar models from elsewhere.

Diverse range of ways to access land

This thesis has shown that there are diverse and flexible ways for migrants to access land at Gaungo and Morokea. Outsiders have accessed customary land through pre-established relationships with landowners, some without any prior relationship with landowners, intermarriage with landowners, or used their contacts amongst the migrant community at Gaungo and Morokea to identify opportunities to buy land. Initially, land was accessed by outsiders through 'gifting'. This system was based on friendships, trust and respect between landowners and migrants, whereby informal verbal agreements to transact land with minimal written documentation were sufficient for outsiders to gain access to land. There has been a shift to more emphasis on cash in land transactions over time.

However, traditional principles remain the foundation of these tenure transactions (see below). Land tenure transactions have gone through several stages from these initial informal and verbal land dealings, to more formal documentation of land transactions. Despite the use of some legal documents in the 1990s to facilitate the 'purchase' agreement (for instance, the Statutory Declaration form and the one-page CLUA), disputes over land transactions increased. It became evident that the industry needed to develop a new CLUA document that clearly defined the terms and conditions of the land use agreement and addressed the needs of landowners and migrant farmers. The new four-page CLUA specifies that the land is customary land and will revert to landowners once the migrant's land use rights lapse. Migrants have only user rights to develop oil palm on the land and these user rights do not grant outright ownership over the land. During the land tenure period, landowners should not interfere with the migrants' business developments on the land unless some of the agreed terms and conditions are breached. For example, problems that might lead to the lease being challenged by landowners include incomplete payment for land, accommodating additional households on the block and causing severe law and order problems.

Social relationships remain critical for maintaining land access

The study showed that social relationships remain critical for maintaining land access and tenure security despite the use of the new CLUA (Figure 109). One way in which outsiders maintain good social relationships with landowners is by using their former work experience to create enterprises and provide goods and services in the village. Through such services they maintain their tenure security and improve the livelihoods of the landowners and the farming community more broadly. Developing from an unplanned oil palm scheme, the migrant and landowner community lack basic public service facilities such as health clinics and schools. Some migrants use their former work experiences to provide these services like school classrooms built on their oil palm blocks to cater for local schoolchildren, small health aid-posts to treat common illnesses and community policing to enforce law and order in the community.

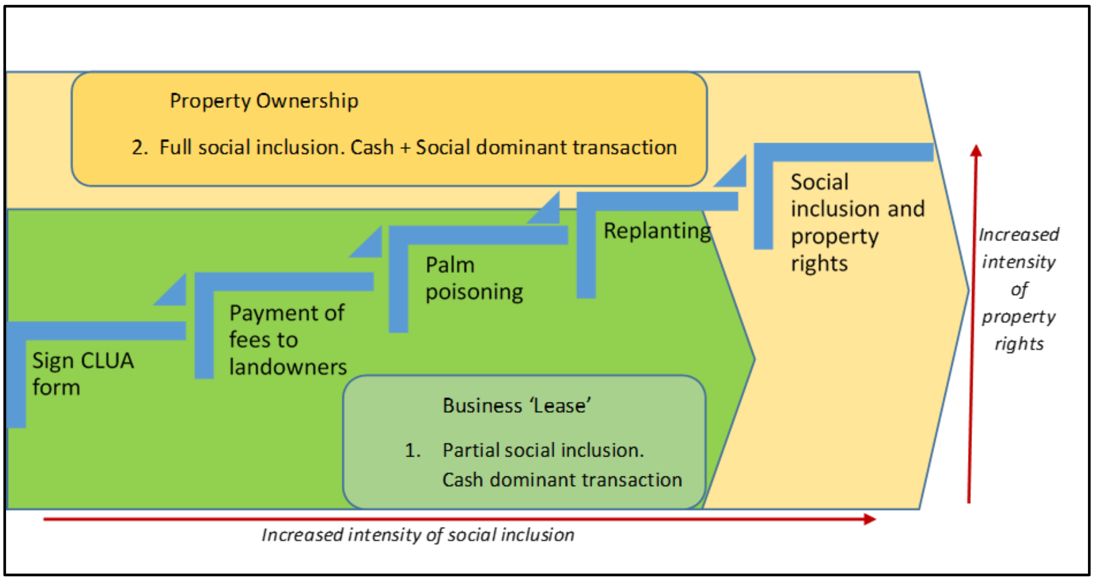

Figure 109. Formalisation of cash and social economies

Outsiders with different vocations and backgrounds came from all over WNB and PNG to secure access to customary land for resettlement of their families and to earn a livelihood from oil palm. The main challenge for outsiders has been not only engaging in social obligations to initially secure customary land but to meet these social obligations through time. Outsiders must pursue several social pathways to maintain and enhance their tenure security, especially during the replanting stage of their oil palm when the renewal of the tenure agreement is decided. Some migrants who maintained social relationships with the landowners may be accepted into the landowning clans at the discretion of their landowner 'brothers'. Most migrant farmers, however, will have their tenure renewed as a type of business 'lease' and they will continue to farm. Other migrants might have their land tenure terminated if agreed terms and conditions are breached or any member of their household causes major law and order problems. Cash payments alone are insufficient for maintaining access to land; meeting social obligations to landowner hosts periodically is a crucial part of cementing these transactions and thus tenure rights. Most migrants are aware of their commitments to landowners and they contribute goods and services as well as cash to the Gaungo and Morokea landowner communities in times of need. The customary land access tenure although is formalized yet remains traditional.

Through time two forms of tenure renewal systems emerged: a Business lease/user rights contract where cash is seen as the main form of transaction; and a Property ownership arrangement where cash payments and full social inclusion occur where landowners accept their migrant "brother" into their landowning group. However, some migrants are now reselling their farmland to outsiders because they cannot cope with the stress of continuously maintaining their social obligations with the landowners, or they feel that tenure renewal is likely to be terminated at the replanting stage of their oil palm.

The increased demand for customary land by outsiders and the 'fast cash' needs by some senior desperate clan members initially lead to the direct informal customary land arrangements between migrants and landowners. Over time, migrants and landowners have engaged in processes that were based on their own common interests. Other stakeholders (e.g. OPIC, OPRA, NBPOL) in the smallholder oil palm industry were not initially involved in these land transaction processes but were forced to focus on improving the tenure security of both parties to avoid major land disputes which seemed to be becoming increasingly likely. New information regarding customary land tenure arrangements among landowners and migrants was therefore gathered by OPIC and OPRA to inform and facilitate new land tenure arrangements among landowners and outsiders.

The requirements for sustainable farming practices contribute to the land access formalisation process.

The requirements of RSPO certification have also contributed to the formalisation of land transaction processes. Under RSPO land transactions must be transparent and all transactions documented, and records safely kept. These attempt to ensure land under oil palm development is free from dispute and meets farm establishment requirements. These sustainable standards are a compulsory requirement on the oil palm industry, and migrant farmers and landowners must maintain these on-farm standard practices to comply with the RSPO requirements.

These findings from the study build on previous studies to reach a fuller understanding of customary land transactions in WNB. Such information is relevant to the customary land reform program in PNG and will contribute to the existing literature in the area of study.

An outcome of the land transactions in Morokea and Gaungo has been a shift in how clans arrange land access. Landowners in Morokea and Gaungo and nearly all traditional societies in WNB (except for Talasea area-patrilineal society) have a matrilineal kinship system of land ownership. Landowners, especially at Morokea, adopted the Cognatic kinship system of land ownership. This system of inheritance is common in Western societies but not widespread in PNG. Landowners at Morokea claim that they are the first society to disturb their traditional fabric of matrilineal kinship and accept the Cognatic system. They have taken the Cognatic kinship system mainly to protect their clan land, descent and inheritance. The Cognatic kinship system also assists them to recruit enough people into each kinship lineage to maintain their claim and make their presence felt as landowners against the increasing demands for land by outsiders. The decision to employ this kinship system also became part of their ILG registration. Clan leaders of landowning groups and clans at Morokea decided to allow clan member decision-making to be made at the household level where parents decide for themselves and affiliate their children to either the paternal or maternal lineage.

Finally, the study has contributed insights into customary land tenure systems and how these tenure systems have evolved over the last three decades in the history of oil palm development on customary land by outsiders. It is important that key stakeholders in the industry understand the changes in customary land access and build on it while continuing to monitor and evaluate the formalisation of customary land acquisition. They should also push for the new CLUA document to be recognized as a legal document. It is recommended that the industry must continue to conduct awareness and training on the new CLUA, formulate protocols for proper trusted storage processes and facilities for customary land transaction documents. They must also facilitate and standardize the customary land tenure renewal package for oil palm development.

E.7.9.4. ***Conclusion***

The study contributed to an understanding of the process of formalisation of customary land tenure arrangements in the smallholder oil palm industry. It also contributed to the existing knowledge on customary land tenure in PNG and elsewhere in the Pacific. It identified several areas that require further investigation. There is a need for further research on the role and contribution of CRP/LPF migrant farmers to the oil palm industry in PNG; will they, as a group, provide the labour to scale-up the oil palm industry thereby creating rural employment. A comparative study should be done to evaluate the CRP/LPMF model against other smallholder models in PNG such as LSS and VOP to see which has more potential to contribute to the national economy and employment. The study should also investigate

FFB production potentials and other economic and social aspects of the CRP/LPMF compared with the LSS and VOP schemes.

A follow-on study should be done on how landowners organize themselves to form ILGs and register their customary land for oil palm development and the challenges and difficulties they face throughout the process. It could investigate the costs involved in the processes and how long the processes take to be completed. The study could be an impact assessment of land reform policies on societal changes in the landowners' and the surrounding migrant communities. It could also include awareness of the importance of ILG and customary land registration and the procedures, processes, expertise, costs involved, the different departmental sections of the National Lands and Physical Planning office that the registration document passes through, and the duration and waiting periods for ILG and customary land registration.

Thorough training should be conducted among landowners and migrants on how to address different social and economic issues on case-by-case basis to inform the design of the ILG model used by the landowners that can assist them in their decision-making. If this model is successful, then it can be rolled out to other areas that are interested in registering their ILGs and customary land for smallholder oil palm development.

Further research should be conducted on why some migrants are accepted into their host landowning clans with attendant rights and privileges while other migrants are unacceptable and remain as outsiders. This research might consider differences between the two migrant groups in terms of their socio-economic characteristics, patterns of social engagements with their hosts and oil palm production performance. The study should investigate if those 'socially included' migrant farmers are living a better life then those who are 'socially excluded' in terms of housing and other major assets, standards of block management, oil palm production performance, education and health. This study could be based on case studies in different sites over a period of time.

E.7.10. Female entrepreneurship in West New Britain: Success and constraints experienced by female in male domain

(Merolyn Koia)

E.7.10.1. *Summary*

In our society when women are asked about entering or starting a business. The first foremost response is *"bisnis em samting bilong ol marn"* or business is something that belongs to men or in other words; men perform well in business than women. The second response would be *"nogat moni lo wokim bisnis"* no money to start a business. However, tides are slowly changing, and some women are engaging in business, but the road isn't easy. The challenges faced and experienced by women entering into business are raw and very stressful which many times forced women out or are engulfed with fear even thinking of starting one. Many women have started a small business, but a lot have failed and only a handful have managed to get through tough times and are still successful. How did they do it, well this study researches into what the individual characteristics and other factors associated with their success and what challenges and constraints they faced and how they overcame them to be successful.

E.7.10.2. *Background*

This survey was part of the part of the current ACIAR funded project (ASEM 2014/054 – Identifying opportunities and constraints for rural women's engagement in small-scale agricultural enterprises in PNG). The project investigates the following questions;

a) What factors have enable some rural women to establish and manage successful agribusiness
b) What are the key enabling and constraining factors determining rural women's transition from producers, traders and managers of small scale agricultural enterprises
c) What opportunities exist for local women to be engaged in commercial agribusiness

d) What type of development policy intervention and enabling environment are required to facilitate women's engagement in agribusiness

The research conducted investigation into research question 1- What factors have enable some rural women to establish and manage successful agribusiness and bring to light the individual characteristics and other factors associated with their success in a male domain. Women interviewed were operating small scale to medium business and entrepreneurial high turn over-over business. The businesses included poultry projects, trade stores, PMV, transport services contracted with NBPOL to deliver fertiliser, seedlings etc., hire car services and real estates. The individual characteristic and other factors associated with their success are;

a) Spouse/family support (immediate)
b) Self-confidence – willing to take risks
c) Time management (discipline) combining work with family
d) Self-control – patience "have a listening ear"
e) Trust (employees/spouse)

The challenges and constraints faced by women in business and are grouped as constraints in starting an enterprise/business and constraints in running a business/enterprise.

There are two objectives to this study;

a) To identify individual characteristics and other factors associated with their success as female entrepreneurs.
b) To investigate the challenges and constraints in establishing and running a business and how they overcome these situations

E.7.10.3. *Methodology*

Women operating small scale business were identified from the 2017 survey on evaluating the Mama Lus Frut scheme. From 123 women who were active mama card holder, 33% of these women used their loose fruit income to diversify into operating other income source. Approximately one year later a follow up survey was done to monitor the progress of the 40 women who were operating small scale business. Only 16 (40%) women continued to operate their business. The nature of business includes individual or family run business, mostly retailers – trade stores, baking, sewing and poultry projects. Another 6 women owned medium business and entrepreneurial high turn over-over business in which the nature of business include trade-stores, PMV, transport contracted with NBPOL to deliver fertiliser, seedlings etc. hire car services and real estates. Questionnaires were formulated, and individual women were interviewed.

E.7.10.4. *Results and Discussion*

Both starting and/or maintaining the sustainability of any business is a challenge for anyone who enters this industry and women are no exception. From the 2017 survey on evaluating the mama loose fruit scheme, 33% of women interviewed had diversified to operate small scaled enterprise as an additional income source into the household. A follow up survey was done in 2018 to see if these women were still operating their business and the results showed that only 40% had their business running while 60% of the women's business had failed within 12 months. Despite many challenges' the women still operated their business.

Interestingly women in all levels of business who were successfully operating their business shared similar individual characteristics and other factors associated with their success and they were;

1. *Spouse/family support (immediate)*
   Having a supportive spouse or support from nuclear family unit was repeatedly mentioned by 100% of the women. The support received from their husbands gave this women zeal to do business.

2. *Self-confidence – willing to take risks*

Doing business is a matter of taking risks which many feel vulnerable to starting a business and it fails but self-confidence is another characteristic. This confidence may be naturally, from good or bad experiences in past failed businesses, or being raised in families who owns businesses or having a good education and even work experience.

3. *Time management (discipline) combining work with family*
   The traditional norms in society is women are obliged to household chores and child care which many women are subjected. How-ever some are breaking free and venturing into this profession where women are being disciplined in balancing work and family is a challenge that many of these women face.

4. *Self-control: patience "have a listening ear"*
   Being patient and having control when situations arise was another characteristic. Women mentioned that it was always good to listen first because poor decisions which can be regretful been angry poor decisions can be made for the business which can be regretful.

5. *Trust (employees/spouse)*
   Having trust and confidence in employees, involving them and delegating responsibilities helps employees to understand and be responsible and take ownership in what they do.

There are similarities in struggles and challenges faced by women operating a business whether small-scale business, medium enterprises and entrepreneurial high turn over-over business. The challenges and constraints faced were categorized as constraints in starting an enterprise/business and constraints in running a business/enterprise. The main challenges they faced in **starting** their business were;

1. *Starting capital (lack of capital)*
   Starting capital is usually one the main constraints, women not have enough to start off something or may not know the "know how" to get additional funds from banks or credit institutes to start a business.

2. *Lack of family support (extended families –they seem to relax and become too dependent)*

3. *Work – life and time management*
   The traditional norm in society is that women are home makers, and this is one of the greatest challenges having to balance work and family which women face at the start of business

4. *Fear of failure or success*
   Fear of failure or success is one factor which influences women whether to start a business or not. They fear of what their family members or community with say about them if their business fails or become successful.

5. *Cultural beliefs and obligations*
   Cultural beliefs and customary has so much influence, not in participating the social activities will affect their relationship with the community.

6. *Lack of self-confidence/insecurity*
   Lack of self-confidence causes fear which women tend not venture or explore new opportunities.

The challenges or constraints they face in **running** a business;

1. *Inadequate Finance and working Capital*
   Many small businesses tend to experience inadequate finance and working capital due to the Dinau system which cause business to fail however others have developed strategies such as

operating alternative income generating sources which is used to sustain the main business during short fall.

2. *Lack of Administrative Skills*
The lack of simple administrative skills hinders women from further developing their business activity

3. *Work – Life Balance and Time Management*
Balancing work and with family is a challenge but being disciplined women were able to carry on with their business than being stressed out.

4. *Cultural Beliefs/Obligations*
Some women are able to lay down some rules to which were able to help manage these social obligations or abide to religious beliefs, so it does not put a lot of stress on their business. This involves openly telling they family members or relatives of what is expected of the business

5. *Lack of Training Opportunities*
Lack of training opportunities is a setback for many women who operate small scale businesses as these avenues open doors to when to learn, network which could be of benefit to women.

6. *Lack of markets*
Markets are the driving force for women to continue their business and with the lack of such avenues kills their moral in doing business

E.7.10.5. ***Conclusion***

Women have proven themselves in the male domain despite the many challenges and constraints. These challenges encountered when starting a business included a starting capital (lack of capital), lack of family support, work – life and time management, fear of failure or success, cultural beliefs and obligations lack of self-confidence/insecurity. Challenges in running a business were included having inadequate finance and working capital, lack of administrative skills, work – life balance and time management, cultural beliefs/obligations, lack of training opportunities and lack of markets.

Women developed strategies to overcome these issues in-order to continue to do business and these included having supportive spouse or family, disciplining themselves in balancing work and family, and setting strict guidelines/rules to over-come struggles they face in non-payment of goods credited (Dinau system). Women with the support from their spouse tend to inform relatives of the purpose of the business and set strict guidelines or boundaries of their support to their families before they start their business so that there is better understanding between the business owners and their families/relatives. In the small-scale businesses, some women tend to divert money obtained from other incomes sources into the business in-order to continue to sustain the main business. Doing business in this society is tough and only tough, creative, intelligent women survive.

E.7.11. Eco-zoom stove: Community impact in Hoskins, West New Britain

(Merolyn Koia)

E.7.11.1. ***Summary***

The eco zoom stove is a convenient mode of cooking which improves and transforms lives. The stove is light weight making it potable, the stove uses less fuel, produces less smoke, cooks efficient which cooks faster and saves fuel/fire wood expenses and cook eco-friendly reducing harmful emission into

the atmosphere. These were proven from interviews with those who owned one. The idea was introduced from Africa aimed to combat firewood shortage. Both the residents of smallholder oil palm blocks and NBPOL plantation staff residing in company compounds share a greater concern of firewood shortage. Firewood shortage experienced by residents on blocks that have planted out the full 6 -6.5 hectares to oil palm and for NBPOL plantation staff who travel great distances usually beyond plantation boundaries to search for firewood. More awareness needs to be done to promote the stove.

E.7.11.2. *Background*

The eco zoom stove is an outdoor cooking stove (Picture 1) and the idea was introduced from Africa. It was first in PNG introduced by Care International to women of Nisan Island, Bougainville especially widows from Bougainville conflict. The idea was adopted, and the stove was introduced in Bialla by Hargy Oil Palms (SIPEF) and in Hoskins in early 2017. The stove weights about 8kg and has a **combustion chamber** refractory metal, **insulation**- abrasion resistant, lightweight ceramic, **stovetop-** three prolonged universal cast iron, **stick support** with installation sockets, **body** painted sheet metal with reinforcement door frame, **bottom tile** kiln-fired with metal lining, **handle**s- stainless steel and silicone.

The eco zoom stove being light weight and use less firewood seemed ideal solution to alleviate firewood shortage experienced by residents on oil palm blocks and plantation workers in NBPOL plantations.
The smallholder land settlement scheme (LSS) developed by the colonial administration in 1967-1968 was based on the land holdings of approximately 6-6.5 hectares. It was expected that the 4 hectares would be planted to oil palm, and the remaining area reserved for food gardening. Block-holders acquired 99-year agricultural leases over their blocks (Jonas, 1972; Hulme, 1984).

Fifty (50) years on, population on the LSS schemes has multiplied rapidly. Today, several family units are found to be residing on and sharing the resources on the blocks. These multiple household blocks are often under a great deal of economic pressure as the oil palm income is divided among several households. Economic pressure has many block owners plant the full 6 – 6.5 hectare to oil palm and resulting less or no access to available fire source. In addition, nearby forests and vacant lands are being cleared for gardening for consumption or sale at the markets for extra income.
Likewise, for NBPOL plantation staff who reside in the company compounds. Firewood shortage is evident and plantation staff spend longer hours travelling great distances is search for firewood. These areas are usually beyond plantation boundaries and mostly buffer zones, but buffer zones are now protected by the company to meet RSPO standards.

The aim is to alleviate firewood shortage experienced by residents and for NBPOL staffs residing the company compounds. Therefore, the objectives were;

1. To conduct awareness and promote the eco-zoom stove to both smallholders and NBPOL staffs residing within the company compounds
2. Get feedback from users of the stove.

Picture 1. Eco-zoom stove

E.7.11.3. *Methodology*

A rapid assessment survey was done on the first 20 recipients of the eco zoom stove. Questionnaire was formulated, and the recipients were interviewed in March 2018.

E.7.11.4. *Results and Discussion*

The stoves were introduced in September 2017 with10 stoves donated to the Mama Loose Fruit Executive Group. It was aimed to assist the group to generate additional start-up capital to assist in conducting their programs. The remaining 10 stoves were given as consolation prizes to best Loose Fruit Mama during field days.

Community Impact
Majority of the respondents/recipients lived on LSS blocks (60%) and 20% respectively were residing in the village and town (Table 104). Women on LSS oil palm blocks whole heartedly expressed how convenient and efficient the eco zoom stove had reduced their effort in fuel (firewood) collection. It was a struggle for residents on LSS blocks where the full 6-6.5 hectares is planted to oil palm resulting in no reserve land to gather firewood from. The residents had to travel long distances to search for quality fuel, therefore many have resorted to using oil palm fronds as fuel. Open fire was the common cooking method (Figure 110) with more than 50% of the respondents preferring to cook food over open fire. Another 20% of respondents residing within the vicinity of the town used both open fire and other sources such as electrical appliances for cooking.

NBPOL purchased 1,000 eco zoom stoves which are sold out to the smallholder growers and plantation workers. Table 105 shows awareness done using 3 main avenues; (a) Smallholder Field days, (b) Block demonstrations and (c) NBPOL plantation compound awareness through requests from NBPOL Women Group – Women Empowering Women (WEW). Since its introduction there is growing interest among men, women and youths in Smallholders blocks and NBPOL Plantations. During awareness women said they could carry it to gardens, church events and use at fast food road side markets while men said they could take it for fishing trips and even to gardens. They said it was good for the elderly who depend on their children and grandchildren to supply firewood and could reduce workload and save time.

Transforming lives
According to the manufacturers, the eco-zoom stove would transform life by cooking efficiently (faster and saves fuel/fire wood expenses) and eco-friendly reducing harmful emission into the atmosphere. It also produces less smoke. Interestingly Figure 111, Figure 112 and Figure 113 showed that 100% of the respondents said that the stove produced less smoke, they spent less time in collecting fire wood and used less fire wood to cook, respectively. Other comments included reduction in work as less time

was spent in collecting firewood. The eco-zoom stove is portable and mobile and it's very handy. With the heat confined within the stove, this made cooking easier and faster.

Table 104. Dwellings of Respondents

Dwellings of Respondents	Frequency (%)
Land Settlement Schemes (LSS)	60
Villages	20
Town	20

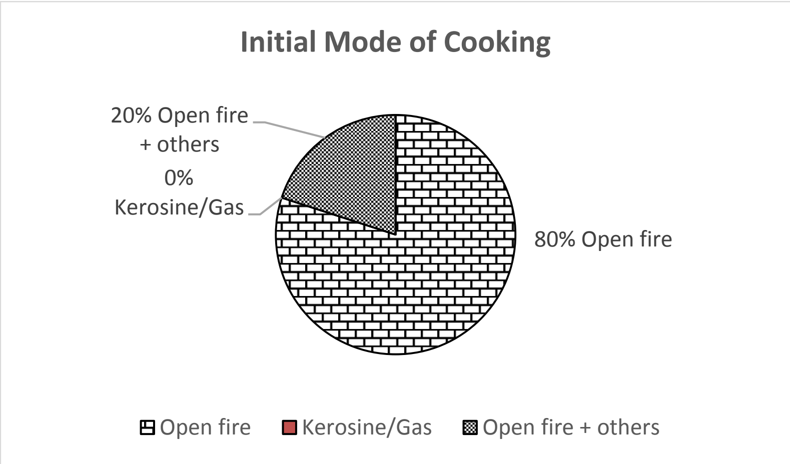

Figure 110. Methods of cooking

Table 105. Awareness registry in 2018

Awareness	Target Group	Total number of awareness
Field Days	Smallholder growers	20
BMP Block Demonstration	Smallholder growers	37
Awareness in NBPOL Plantation (WEW)	Plantation staff	4
		61

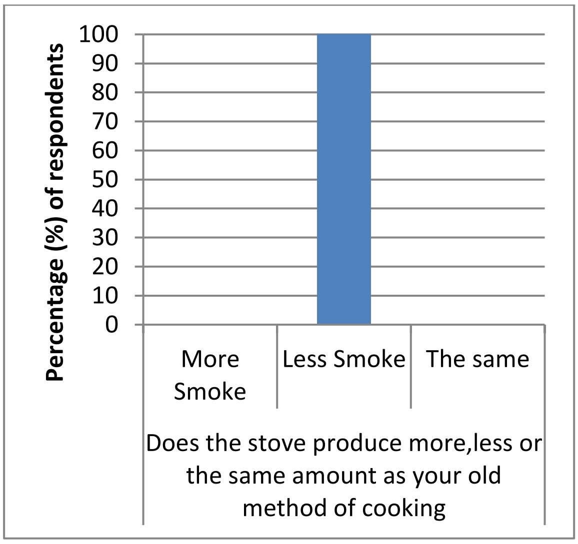

Figure 111. Smoke produced by the eco stove

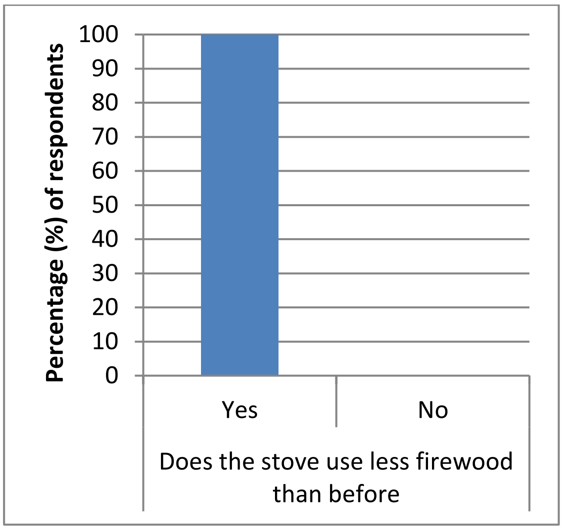

Figure 112. Firewood used to cook

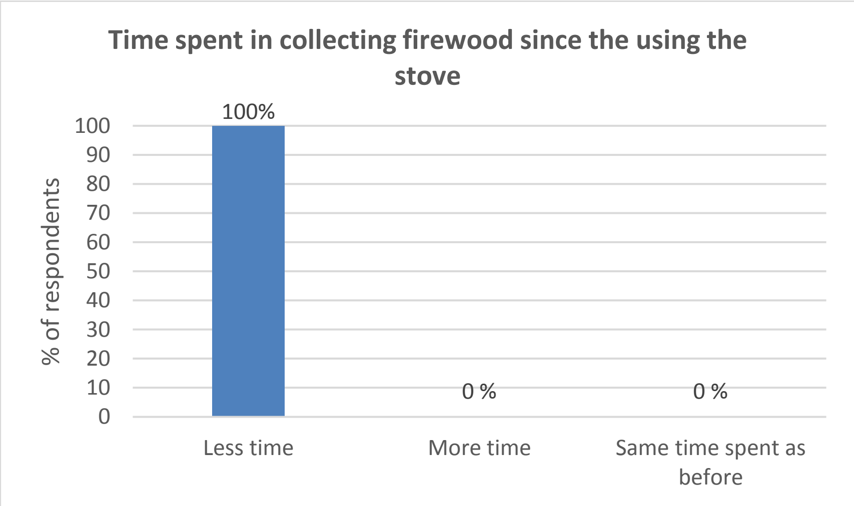

Figure 113. Time spent in collecting firewood after the inception of the stove

E.7.11.5. *Conclusion*

The eco-zoom stove users through the interviews confirmed the stoves to be convenient and efficient mode of cooking. It also provided solution to firewood shortage experienced by smallholder growers who have planted their full 6-6.5 hectares to oil palm and NBPOL plantation staff residing in the company compounds where accessing firewood as fuel for cooking is an issue. More awareness is needed to promote the eco-zoom stove.

E.8. TECHNICAL SERVICES

E.8.12. Field trainings and radio broadcasts

Field training sessions and radio broadcast in 2018 are presented in Table 106. In 2018, all sites increased their training capacity except New Ireland (Poliamba) due to change in staff. The site that improved most in terms of farmer trainings and smallholder engagement was Milne Bay which in the past had the lowest or least farmer engagement records. In Popondetta, PNGOPRA through the its OiC and the Head of SSR in March 2018 took leading role to revive field day training after some 4-5 years of no smallholder training. Since the first two field days facilitated by PNGOPRA, the smallholder department of Higaturu and OPIC Popondetta have now taken charge of training, with participation from other stakeholders like the banks and health authority. Both Hoskins and Bialla projects continued to maintain momentum with the trainings, particularly in the Hoskins project where we are getting well over 200 participants in the field day events.

Apart from the field day events, PNGOPRA through it SSR section continue to carry out block demonstrations in all sites (except New Ireland) to promote BMP and best practices of fertiliser management (4 Fertiliser Rights).

Table 106. Smallholder trainings and radio extension programs conducted in 2018

Project Sites	Activities			
	Field days	Block Demos	Radio Broadcasts	Other trainings
Hoskins (Dami)	21	46	3	2
Bialla	7	23	Nil	1
Popondetta	5	5	Nil	Nil
New Ireland	3		Nil	
Milne Bay	8	16	3	

E.8.13. Stakeholder trainings and presentations

- 16th August 2018 - Investigating Harvesting Frequency in Smallholder Village Oil Palm (VOP) in Bialla, WNB. Presentation for Hargy Oil Palms Management TSD *(Merolyn Koia and Steven Nake)*
- 22nd August 2018 – Foliar nutrient status of smallholders in Popondetta based on 2016 and 2017 leaf sampling analysis. Presentation for OPIC Popondetta, HOP TSD and Smallholders department *(Steven Nake and Richard Dikrey)*
- 24th August 2018 - Foliar nutrient status of smallholders in Milne Bay based on 2016 and 2017 leaf sampling analysis. Presentation for OPIC Milne Bay, MBE TSD and Smallholders department *(Steven Nake, Wawada and Sharon Agovaua)*

E.8.14. Publications

1. Food Security in Papua New Guinea. Technical Note No. 32. The OPRAtive Word.
2. The role of smallholder gardens in maintain food security on the land settlement schemes. Technical Note No. 33. The OPRAtive Word.
3. Changing food production systems amongst smallholders. Technical Note No. 34. The OPRAtive Word.
4. Smallholder food consumption and food security. Technical Note No. 35. The OPRAtive Word.
5. The elusive dream of 'development' on the agricultural land settlement schemes in Papua New Guinea. Book Chapter. Koczberski, G., Curry, G.N. and Nake, S. (2019). In Jones, R. and Diniz, A.M.A. (eds) Twentieth Century Land Settlement Schemes. London and New York, Routledge. pp179-198.
6. Diffusing Risk and Building Resilience through Innovation: Reciprocal Exchange Relationships, Livelihood Vulnerability and Food Security amongst Smallholder Farmers in Papua New Guinea. Published in the Human Ecology Journal on 24th October 2018.

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.